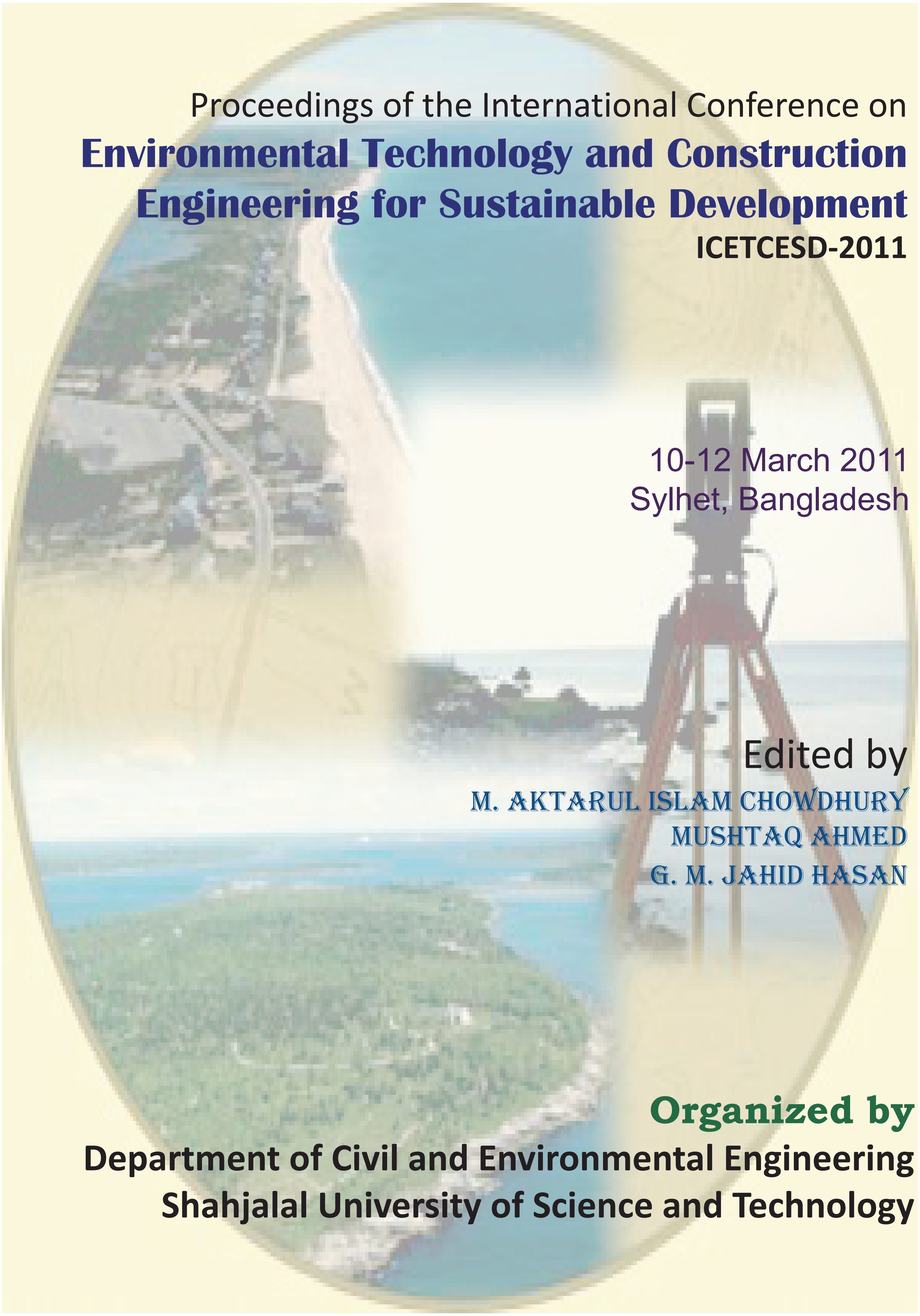

Proceedings of the International Conference on

# Environmental Technology and Construction Engineering for Sustainable Development

**ICETCESD-2011**

10-12 March 2011
Sylhet, Bangladesh

Edited by


M. AKTARUL ISLAM CHOWDHURY
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G. M. JAHID HASAN


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# PREFACE

In a situation of dreadful and deteriorated scenario, natural resources being contaminated, corrupted, distressed, disturbed, disrupted, despoiled, degraded, defamed, deteriorated, polluted, ruined, tarnished and infected by unsystematic, haphazard, inequitable and unwarranted activities of mankind merged with the non-synchronization of the nature, patchy deterioration, unlikely depletion, unmanageable change, non-restricted urbanization, non-conformity of technical progress by leaps and bounds beyond the equilibrium not coping with the as usual natural systems without thinking of the demand of future generation for their existence causes severe environmental dilapidation and culprit pollution by the unplanned urbanization and developing infrastructure in unsustainable way. To the cross-road of the development actions and man-made maneuverings, whole world is triggering such deteriorated tracks continuously. In this context, proper initiatives should be considered to assess the global situation followed by the review of regional and global efforts with the proper recommendations to save the nature, nature entities and natural resources. As the succession of such initiatives, *ICETCESD* 2011, *International Conference on Environmental Technology and Construction Engineering for Sustainable Development* – is organized at Sylhet, Bangladesh for the first time not only in Bangladesh but also in the South Asia Sub-continent of Continental Asia. It will give the opportunities to exchange the views and experiences of the academicians, researchers, engineers, specialists, experts, professionals as well as the learners at international level from home and abroad and to understand the environment technology and construction engineering as a whole essential in the field of infrastructure development leading to sustainable development. It will open the eyes how a system can be made effective within limited resources and constraints leading to sustainable development.

Technical papers and posters were invited from the academicians/ researchers/ professionals/ experts working on environmental technology and construction engineering around the world well before the conference date. About 200 abstracts were received; after review, a total of 118 technical papers and 5 keynote articles were selected for publications in the Conference Proceedings. Academicians, researchers, professionals and other personalities from different countries i.e. Australia, Bangladesh, Canada, India, Nepal, Thailand etc submitted their scientific contributions in this conference. Papers have been lightly edited to homogenize the style and to revise the contents based on reviewers' comments. However, the final responsibility for the contents, quality and the presentation of the papers is held by each individual author. In the proceedings, only the executive summary of the papers are printed and hence published, however, full papers are available in a CD-ROM enclosed with the proceedings.

I would like to acknowledge the great efforts of the authors, who jointly and/or individually contributed by submitting papers. I might appreciate the supports received from the reviewer's who did it perfectly. The contributions of the members of all committee are gratefully acknowledged. Heartiest thanks to Dr. Mushtaq Ahmed and Dr. G. M. Jahid Hasan for putting their excellent joint efforts with me for editing the proceedings including composing the text, figures, tables and photographs, which is indeed a tedious job. Finally, great appreciation is due to the Title Sponsors Seven Circle Cement Ltd., Dhaka; Ratanpur Steel Re-rolling Mills (RSRM) Ltd, Chittagong; and Comprehensive Disaster Management Program (CDMP), Ministry of Food and Disaster Management, Ministry of the Peoples Republic of Bangladesh in association with US Aid, European Commission for financing the major portion of the cost to organize the Conference. Also thanks to other sponsors who financially contributed through the sponsorship in the form of advertisement in the souvenir published on the eve of ICETCESD 2011.

Professor M. Aktarul Islam Chowdhury
*Shahjalal University of Science and Technology, Sylhet*
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# CONSTRUCTION ENGINEERING: LESSONS LEARNED FROM FAILURES

DR. A. M. M. SAFIULLAH
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## INTRODUCTION

The impact of infrastructure development and construction practice is known to be significant on the economy of any country. Construction engineering concerns the planning and management of the construction of structures such as highways, bridges, airports, railroads, buildings, dams, and reservoirs. Construction of such projects requires knowledge of engineering and management principles and business procedures, economics, and human behavior. Construction engineers engage in the design of temporary structures, quality assurance and quality control, building and site layout surveys, on site material testing, concrete mix design, cost estimating, planning and scheduling, safety engineering, materials procurement, and cost engineering and budgeting.

As we can see that construction engineering involves a number areas of expertise including management, it is not possible to touch on all these aspects. Therefore this paper will try to limit its discussion on some failures incidences that has a profound effect on development of good construction practice and sustainability of constructed facilities.

Most of the failures described herein are that of buildings in and around the city of Dhaka and relates to construction of the foundation. However, the lessons learned from these failures can be applied to develop good construction practice within the country.

### Growth of the Dhaka City

The Dhaka city lies on a Pleistocene terrace that runs north to south. Most of the old buildings and residential areas were placed on this soil which is well compacted and have very good bearing capacity. But as the city started growing, houses were build on low lying areas raised by earth fillings that were not well compacted. Many of the builders did not make proper soil investigation for the foundation design or did not follow the guidance given in Bangladesh National Building Code (BNBC). As a result during last decade we have seen a number of building collapses which resulted in loss of life, property and economy.

### Some Building Failures

A building located in newly filled land and built on the slope of the fill in Sabujbag area of Dhaka failed when the second storey was under construction. The rear columns on foundation footings settled and the whole building rotated. The front columns snapped from the footing resulting in collapse of the building (Fig.1). It was learned that no soil investigation was made and no proper engineering design was done for the building.

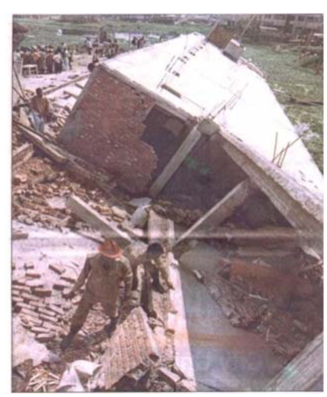

Fig.1.Building Failure at Sabujbagh

In Mirpur an eight storied building tilted to one side after about one year of construction (Fig.2). The building was founded on wooden piles driven in soft and organic soil. Although detail soil conditions and design reports were not available it is apparent that the designer did not take into consideration the possibility of deterioration of wooden pile with time. Also changes in soil properties of organic soil were not considered.

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The building has not been fully abandoned and remains a future threat to stability, overturning and damage to surrounding properties. In Mirpur area a five storied building titled and almost touched the adjacent building. Obviously the differential settlement for the building was not considered in the design. It not known to what extent geotechnical investigation was done for this building.

In Kalabagan a five storied building was constructed over a pond filled with earth.  When the fifth storey was being built the whole building rotated and tilted and collapsed snapping column reinforcements from the footing foundation (Fig.3). Obviously, soil and structural design were not adequately done. No competent engineer was employed by the owner. Builders took an unknown risk by not abiding building Code Provisions.

Fig 2. Eight storied building at Mirpur tilts

Fig.3. Building failure in Kalabagan

Fig 4. Failure of shore piles in Basundhara

One of the greatest building failure tragedy took place in Savar when a nine storied factory building completely collapse at night when workers were working inside. Sixty persons died and about 100 were seriously injured. The whole incidence shocked the nation and the engineers and the civic society were vibrant about more stringent regulatory laws and implementation of quality assurance process for all civil engineering structures. A detail analyses of the failure incidence is presented later in this report.

With Dhaka becoming a mega city with one of the highest density of population we now need to build high-rise structures with basements for car parking. This requires deep ground excavation close to existing structure. The present practice relies on shore piles to resist lateral soil pressure sometimes with a system of struts or without it. Use of diaphragm walling with ground anchoring system is non-existent. Improper design and shoring of the piles have resulted in many failures as shown in Fig. 4. Sometimes this type of failures seriously affect the stability of adjacent structure where detrimental cracks appear that are expensive and difficult to repair.

Fig.5. Tilting of building in Kalabagan

Very recently a seven storied building in Kathalbagan tilted (Fig.5) resulting in collapse of ground floor (soft storey). Tilting resulted damage of columns at supports where it became hinged (Fig.6). Again lack of adequate soil investigation and quality of construction resulted in this failure. It is learned that the building was built over a ditch filled with rubbish and foundation consisted of micro-piles of inadequate length.

Although the failures describe above have been taking place for a long time, no serious attempt is made by the regulating agencies in Bangladesh to effectively control these failures. Also there is lack of knowledge of the architects, engineers and contractors in assessing soil condition and lack of development of an appropriate construction practice by the profession.


Fig.6.Damage of columns at GL

**Failure of Earth Structures**

Meghna-Donahgoda Irrigation Project (MDIP) in Matlab Upazila of Chandpur district is encircled by 60.7 km of flood embankments (completed in 1987) around side of the river Meghna and Donaghoda. After completion of the embankments, severe seepage and boiling was observed along the countryside of the embankment during floods. The embankments were breached during 1987 and 1988 floods causing severe damages. During 1904 flood breach occurred again. Sliding of the slope of the embankments occurred on countryside at about 60 places, seepage problems developed at about 25 km length and boiling occurred at 120 locations. The damages were severe and it remained as a threat to future performance of the embankments during floods.

The remedial measures required extensive in-situ and laboratory soil investigations; an aspect that has been little practiced and developed by our construction industry.

**Assessing Ground Conditions**

From the failures described above it is apparent that a common factor that has led to failure is inability to assess ground conditions for these structures.

There has been a tendency for most building owners and developers not to invest enough money for soil investigation. Also there is no regulation as to the qualification required for a soil investigation firm. This has resulted in low quality of soil investigation reports and inadequate designs with consequent risk in structural stability.

There are several ways geotechnical condition of a site may be evaluated. The simplest way to examine a site is to dig up a trial pit to a suitable depth to reveal soil condition and if necessary to collect undisturbed soil samples for laboratory testing. This is a very effective way of soil exploration but has the disadvantage that this cannot be performed for greater depths to which soil is usually stressed due to foundation load and when the ground water table is near the surface.

The common procedure is to bore a hole and test soil conditions within the hole at several depths or insert a rod and record its resistance as it is pushed down. Table 1 gives a list of common in-situ test used for assessing ground condition.

Table 1 Common in-situ tests

| *Test type* | *Suitable for* | *Not suitable for* |
|---|---|---|
| Standard Penetration Test (SPT) | Sand | Soft to firm clay |
| Dynamic Cone Test | Sand and gravel | Clays |
| Static Cone Test (CPT) | Sand, silt and clay | |
| Field Vane Shear Test | Clay | |
| Pressure meter Test | Soft rock, sand, gravel, and till | Soft sensitive clays |
| Plate Bearing Test and Screw Plate test | Sand and clay | |
| Flat Plate Dilatometer Test | Sand and clay | Gravel |
| Permeability Test | Sand and gravel | |

The most common way to form a borehole is by the 'wash boring' process and the most common in-situ test is the Standard Penetration Test.

It has been observed that in many instances crew performing a boring operation hardly give any attention to the stability of the borehole. Samples collected and situ tests performed in an unstable hole can lead to serious misinterpretation of soil condition. Factors that needs to be checked for a stable borehole includes:

- Hydrostatic condition leading to boiling and other instability;
- Jetting arrangement in chopping bit;
- Adequacy of the size of bailer in uncased holes;
- Rate of cutting.

It is necessary that at all stages of boring and sampling the water level within the hole must be above ground water level. This implies that during withdrawal of tools water level must not fall below ground water level. It is necessary that while using chopping bits the water coming through the drilling pipe should not directly jet on the bottom of the hole which may disturb the soil significantly (see Fig.7). Direct jetting action destroys soil structure and composition and defeats the purpose of soil sampling or in-situ tests (SPT) in the hole. In cohesionless soil and in deep borings it is necessary that side walls of the boreholes are stabilized by some drilling fluid (bentonite slurry).

Fig.7. Deflecting water jet at chopping bit

**Standard Penetration Test (SPT)**

This is the most widely used field test in Bangladesh. The test although named as standard has many non-standard performance conditions. Correct interpretation of soil design parameters from this test depends on a number of factors such as :

- Stable borehole formation;
- No clogging of the vent hole in the SPT spoon sampler;
- Appropriate energy correction for hammer blow on anvil
- Account for individual variation or non-standard performance conditions;
- Appropriate calibration of N-values with angle of internal friction (□);

Presently SPT results provide N values that are corrected for energy and overburden pressure and this corrected N value is correlated to shear parameter □□using correlation developed by Gibbs and Holtz for medium grained soils of US origin. Granulometric properties of Bangladeshi sands are different and there is a need for N-□□□correlation for our soil which is missing.

Some engineers try to correlate N value with undrained shear strength of clay soils. Fig.8 clearly shows that such correlation does not exist in reality and therefore is not recommended for use.

Because of some uncertainties with the interpretations of SPT results it is necessary that while logging geotechnical profile of a soil formation more than one method of in-situ test should be performed. Table 1 lists a number of such in-situ tests. Cone Penetration Test (CPT) is perhaps the more suitable field test than SPT as it can be used for both clayey and sandy soils.

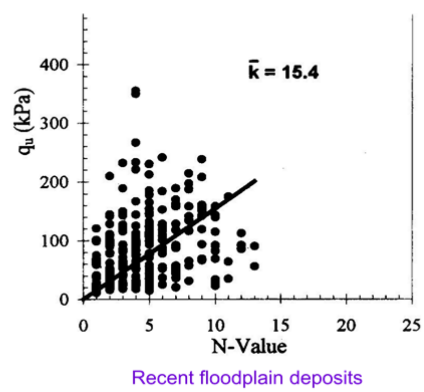

Fig 8. $Q_u$ vs N for cohesive soils

## Soil Sampling

Evaluation of shear strength, compressibility and deformation characteristics of cohesive soils require collection of undisturbed samples for testing in the laboratory. Collecting undisturbed samples requires adequate borehole preparation and careful sampling procedure. Table 2 shows a classification of quality of samples obtained by various processes and type of test that can be performed by each.

Table 2. Classification of soil samples (after Canadian Foundation Engineering Manual, 1985)

| Class of Sample | Quality of sample | Method of sampling | Type of tests that can be performed* |
|---|---|---|---|
| 1 | Undisturbed | Block sample<br>Stationary piston sampler | A,B,C.D.E,F,G,H,I,J,K |
| 2 | Slightly disturbed | Open tube thin walled sampler | A,B,C,D,E,F,G,H,I |
| 3 | Substantially disturbed | Open tube thick walled sampler<br>Split spoon sampler | A,B,C,D,E,G |
| 4 | Disturbed | Random samples collected by auger or in pits | A,B,D,E,G |

A – Stratigraphy B – Stratification C – Organic content D – Grainsize distribution
E – Atterberg limits F – Relative density G – Water content H – Unit weight
I – Permeability J – Compressibility K – Shear strength

It should be noted that the sampling process changes the stress condition of a sample due to drilling, sampling in tube, extruding the sample, trimming the sample and then testing. It is apparent that considerable stress may be released when sample is prepared for testing (i.e. Sample is over-consolidated). Hence, soil test results particularly strength parameters reported should be interpreted considering sample to be over-consolidated at the time of testing.

## Laboratory Tests

There are two types of test performed on soil samples- the index tests on disturbed samples and compressibility and strength tests on undisturbed samples. False and fabricated soil reports are not uncommon. Shown on Fig.9 is a report on grain size distribution curves in which percentage of clay particles are mentioned. It can be observed that there is a clear discrepancy in percentage of clay shown in the graphs and that written in the result box.

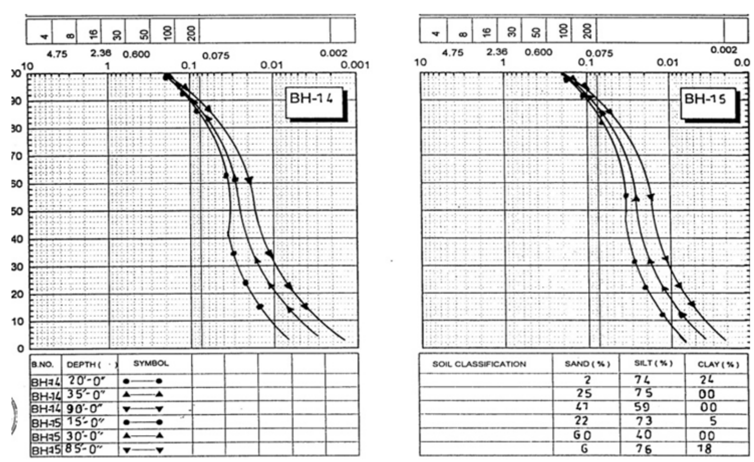


Fig.9. Discrepancy in reporting clay fraction from grain size curve

Laboratory test results should not be taken for granted. Representativeness and process through which sampling has been done must be acceptable before results are used in a design.

## Empirical Relations

Empirical correlations between index properties and compression and strength parameters are commonly used in geotechnical designs. Such relation given in most text books should be verified before use. Shown below are correlations proposed by various authors between compression index ($C_c$ ) and liquid limit (LL), and between $C_c$ /(1+$e_0$) and LL. Here $e_0$ is the initial void ratio of the soil. It can be observed that Cc vs LL correlations for most of the Bangladeshi silty clays do not agree well with those proposed by Skempton (1944), Terzaghi and Peck (1967) and Nishida (1956). Correlation by Serajuddin (1987) and Azzouz et al (1976) give a better fit.

Author studied empirical correlations between $C_c /(1+e_0)$ and LL for nine coastal soils. The result shown in Fig 10 shows reasonably good correlation.

Soil mechanics texts often refers to relation $S_u /p_o' = 0.11+0.0037\ I_p$ , where $S_u$ is the undrained shear strength, $p_o'$ is the overburden pressure and $I_p$ is the plasticity index. It has been found that for our silty clay which has low plasticity index the above relationship does not follow such relation.

Problem with many civil engineering constructions begins immediately after ground breaking. In geotechnical history there has been numerous litigation cases where ground conditions interpreted during design turned out to be different at the time of construction. Often engineers design foundations on assumed soil parameters. False and fabricated soil reports are not uncommon. Whatever may be the reason for variation in soil condition from design assumptions, the result is extra cost or delay in construction, change in design, change in construction operation, or even failure. Good geotechnical engineering practice can limit uncertain soil condition problems.

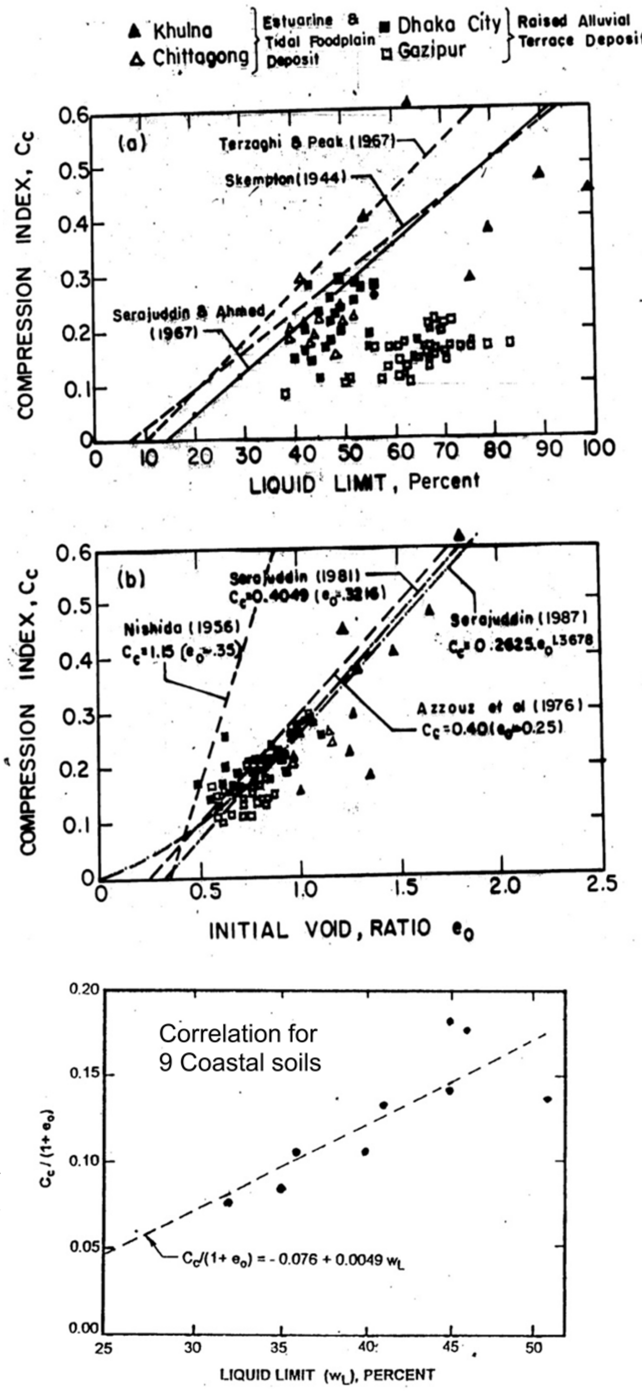


Fig.10. Correlations between $C_c$ and LL

## Bored Pile Construction Practice

A major concern in Bangladesh is the construction of cast-in-situ bored piles. At present there is no Code of Practice in force for this type of construction. This method of pile construction is very popular because piling can be done with very simple tools such as tripod stand, wash boring equipment and tremie pipes. Operations that are critical to safe pile construction are:

- Prevention of hole collapse;
- Maintaining quality of underwater concreting;
- Maintain a clean borehole bottom, and
- Maintaining integrity of the pile shaft.

Prevention of hole collapse requires control of hydrostatic head within the borehole and use of bentonite slurry in adequate mix and density. There are several specifications for slurry to be used in piling work. Table 3 shows a slurry specification given by Federation of Piling Specialists (FPS) for cast-in-place diaphragm walling.

Table 3. Slurry specification for Cast-in-place diaphragm walling (FPS)

| Property | Range of results at $20^0$C | Test method |
|---|---|---|
| Density | Less than 1.10g/ml | Mud density balance |
| Viscosity | 30-90 seconds | Marsh cone method |
| Shear strength (10 min gel strength) | 1.4 – 10 N/m$^2$ | Shear meter |
| pH | 9.5 - 12 | pH indicator |

It is important that we develop slurry specification that is consistent with our soil type and construction practice to provide adequate quality control during construction. Checking integrity of constructed piles is an important condition in the assessment of quality. Such checks are made by pile load test and by use of an integrity tester. During load test it often appears that supports of reference test gauges are placed in a way that these are affected by loading and unloading from load platform invalidating the test results. Interpretation of pile load test results is also very important. Selection of appropriate failure or performance criteria is essential in these interpretations.

**Quality Control in Construction**

Bangladesh National Building Code (BNBC, 1993) provide guidelines for safe construction. The intend of the Code is to ensure Public safety, health and general welfare in so far as they are affected by the construction, alteration, repair, removal, demolition, use or occupancy of buildings, structures or premises, through structural strength, stability, means of egress, safety from fire and other hazards, sanitation, light and ventilation. Any building design and construction undergoes the following stages:

- Soil investigation
- Foundation and superstructure design
- Foundation and superstructure construction
- Installation of utilities and services

At all these stages Building Code should be strictly adhered to. In all the failures reported Building Code has not been followed. Details of construction should be guided by Code of Practice development from good construction practice. Unfortunately no such documents have been developed in Bangladesh in line with our local conditions.

**Collapse of Spectrum Sweater Factory**

One 9-storeyed sweater factory building owned by Spectra Sweaters Ltd., located at Palashbari Village under Savar Thana of Gazipur District, Bangladesh collapsed in the early hours (1.15 am) on April 12, 2005 killing more than 60 and injuring more than 100 workers. The Institution of Engineers Bangladesh formed an investigation committee to investigate the failure incidence.

Investigations revealed that a number of factors were involved in the failure. The observations made after the failure are:

(i) The failure of the building took place in a very short time and without any warning; so, the trapped people didn’t find adequate time to come out.

(ii) The structural frame for the building consisted of flat slabs supported by columns with no beams at any location. Thereby while the columns of the floors collapsed and the heavy slabs fell one over another keeping little gap in between, killed most people trapped inside.

(iii) The roof slabs of the collapsed structure showed that the general motion of the building during collapse was significantly towards the eastward direction. Furthermore, a strong sway of the collapsed roofs of the building was noted towards the northeast direction.

(iv) It was observed after debris clearance that the north-east corner of the ground floor slab had gone down by about 11 feet from the surrounding surface and there was little settlement of rest of the floors or footings (Fig.11). Fig. 12 shows the condition of the north east corner column after excavation.

Fig 11. Settlement of NE corner of GF

Fig 12. Buckling of north-east corner column

After clearing the debris it was observed that none of the pile caps including that of the north east corner column showed any sign of undesirable settlement or failure. Therefore, the assumption that the failure resulted from weak soil condition and foundation failure is discarded. It became apparent that failure was initiated by failure of the column at north-east corner of the building due weak concrete at the base of the column.

A finite element model of the structure was developed in ETABS Version 8, a general purpose finite element analysis and design software. In order to reconstruct the collapse sequence and thereby to narrow down the number of failure hypothesis, the investigation team employed pushover analysis technique and conducted nonlinear analysis. To this end, the primary direction of movement of the collapsed structure as revealed during the first-day field surveys was taken into prime consideration. Thus the investigation committee drew the final failure hypothesis that either the failure of the northeast corner column or its foundation system might have triggered the collapse phenomena. Based on this hypothesis, the support of the northeast corner column was removed from the numerical model to replicate the probable incident. To make the analysis as much closer as possible to the reality, the geometric nonlinearity and large deflection effects were considered in the process of analysis. The pushover analysis conducted this way generated some interesting findings from the developed numerical model and matched with the field survey findings.

Based on analytical findings and field observation, the investigation team was able to derive the following conclusions:

- The failure of the northeast corner column is responsible for triggering the collapse of the structure.
- Upon the triggering, the hinges started to form at slab-column connections at top storey levels pushing the upper floors to fall in a sway motion towards east and northeast direction. A mild sway of the southern side columns to southward direction also took place.
- The collapse of the upper floors caused a tremendous vertical impact on the lower stories, which action caused the lower stories to come down vertically. Falling of the lift core added the final blow.
- Northeast corner bays of the structure collapsed vertically at all floor levels.

Some serious construction problem was observed in the northeast corner column of the building, which made it clear how the collapse of the whole building was initiated. Fig. 11 shows the failed condition of this column above pile cap. It was clear from the excavated portion of the pile cap that the position of the cap was intact. For about 2 feet of the column above pile cap, the column reinforcement buckled and twisted. The concrete at this portion was very weak and contained clay and other deleterious particles. The concrete was so soft that aggregates would easily be pulled out with bare finger. This suggests that although sufficient care was taken in casting the pile cap, the column at this portion was perhaps cast under water that contained significant mud and other loose materials and remained weak. There were twelve 25 mm diameter high yield reinforcement bars that perhaps carried the load of the building but due to sustained creeping these ultimately buckled as seen in the photograph that lead to the collapse of the whole building.

It's evident from the circumstances that the standard civil engineering procedure hasn't been followed in this building. Although there had been some flaw in the design consideration of the building, but it is the careless supervision of the construction at column base level that had initiated the catastrophic failure.

**Hyatt Regency Hotel Disaster**

In July 17, 1981, two suspended walkways within the atrium overlooking Hyatt Regency Hotel in Kansas City, Mo., collapsed (Fig.13). One hundred fourteen people were killed and 200 injured. It was one of the most devastating structural collapse ever to take place in the United States. Law suits resulting from the accident amounted to more than $3 billion.

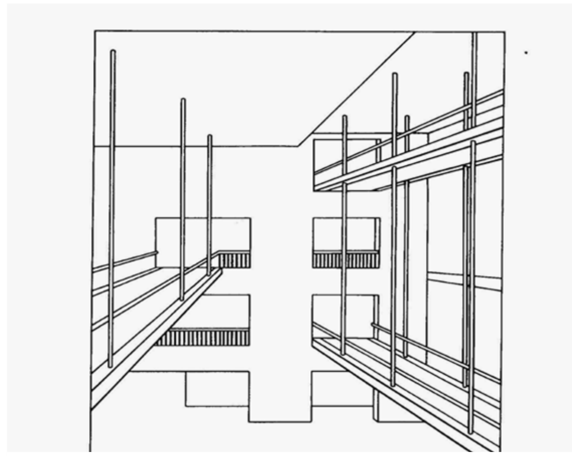

Fig 13. Walkways in atrium of Hyatt Regency Hotel

Construction of the Hyatt Regency hotel began in spring, 1978. The architect's initial conceptual layout for the atrium walkways showed that the second and fourth floor walkways were to be suspended one under the other from six continuous steel rods, 1-1/2 inch in diameter, anchored in the ceiling. The third floor walkway was to be located east of the second and fourth walkways and suspended from six such rods, also anchored in the ceiling.

Drawings showed that the lateral structural support for the second, third and fourth walkways was to be box beam members each comprised of two channels. On the second and fourth floor walkways, the steel rods ran from ceiling down to and through the fourth floor box beams, then continued through the second floor box beams, where the rods terminated.

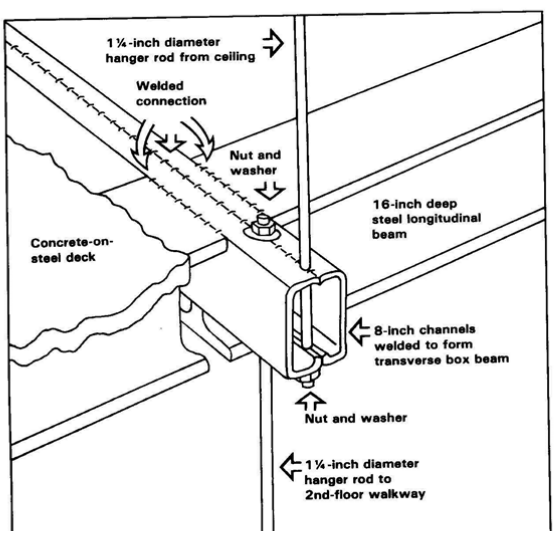


Fig.14. Typical fourth floor Box Beam-Hanger Rod Connection

The structural drawings are somewhat ambiguous with respect to whether the rod was to be continuous between the second and fourth floor box beams.

The fabricator determined to split the rod between second and fourth floor (Fig.14). The engineer although aware of the change gave assurance that it was acceptable. None from the consulting firm checked the critical connection though it differed from the original design concept. The change to a two-rod system doubled the load on that connection. No calculation were ever performed by the engineers to determine the structural strength or adequacy of the box beam connection as shown in the drawing. During the law suit, the Judge found the rods and the box beam hanger rod connection of each three walkways did not meet the design specification of the Kansas City Building Code. The cause of the walkway collapse was the failure of fourth floor box beam hanger rod connections.

**Failure of Roof of Press Gallery of Bangabandhu Stadium**


Fig 15. Far view of Press Gallery of Bangabandhu stadium

The Bangabandhu Stadium was renovated and a Press Gallery was added on the western part of the stadium. The roof of the gallery was made of concrete slab with inverted beams suspended by steel wires as shown in the photograph (Fig.15). Rain water falling on the roof would collect in space between beams and drain out through a small pipe running vertically down. During a heavy rainfall the drainage pipe got clogged due to polythene bags, waste papers and dirt collected on the roof. Water ponded up in space between wire holding the weight of the roof snapped. The whole roof collapsed as it was not designed to take full load of water trapped in between the beams. The failure demonstrated that attention to minor details like drainage and possibility of clogging can bring catastrophic failures in a structure.

**Enhancing Life of Structure through Renovation**

Bangabandhu Stadium built around early nineteen fifties used brick aggregates for most concreting works. As brick aggregates are prone to large absorption of water, the reinforcement in places of the stadium corroded. Due to corrosion of reinforced steel the stability of these structures were at stake. A remediation work was successfully undertaken to renovate the structure which added to the longevity of the structure. During the renovation many innovative solutions were taken up which serve as lessons for such construction work in Bangladesh.

**Effect of earthquake on structures**

As Bangladesh is prone to earthquake all constructions should be designed for earthquake forces relevant to the particular zone. Old building not designed for earthquake should be retrofitted to withstand earthquake forces.

## CONCLUSIONS

A number of recent failures of buildings and engineering structures in Bangladesh have demonstrated that most of these failures occurred because:

- Geotechnical and ground conditions are ignored or not properly done; a review of these aspects have been provided in the paper;
- Construction quality control in relation to material use and construction procedure is lacking;
- Attention to joint details are not given;
- Absence of government regulatory control over building and other structural construction;
- Lack of training of the construction workers;
- Lack of infrastructure for monitoring construction works;
- Lack of research institutions dealing with building failures;
- Not following National Building Code (BNBC, 1993).

In order to prevent engineering failures, a separate institute for construction engineering (perhaps under an engineering university) should be setup that should have a wing dealing with “Forensic Engineering”. The recommendations of forensic engineers should be well published and included in the Building Codes and also lead to development of series of Code of Practice or good construction practices.

# ENVIRONMENTAL TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

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## INTRODUCTION

Environment is the physicochemical, biological and social surroundings of human-beings. The word environment is derived from an old French word 'environ' meaning 'encircle' The human beings right from the time of birth are encircled or surrounded by people, animals, plants, air, water land, soil, sunlight and other physical objects. Environment as a productive system provides basic supports that are required for flourishing all forms of lives, materials that are harvested, energy that is harnessed, services for transportation and recreation and aesthetics for spiritual renewal. Science and technology have made human the most powerful among all species on earth to control, modify and use earth's resources and make alteration of the natural environment. Environment as a resilient system is capable to withstand some degree of stresses associated with human activities and natural phenomena like draught, floods, storms, volcanoes etc. Environment as a sensitive system also responds to anthropogenic and natural changes. The environment inherited from the past is subjected to some degree of transformation in the present and passed on to future generation. Environmental technology is the practical application of this scientific knowledge for the protection and conservation of the environment.

Development is the process of transformation of natural resource endowment of the planet to meet the needs and aspirations of the human population. The most fundamental law governing our planet's finite resources states that matter can neither be created nor destroyed; it can, however be reshaped or transformed to add value. The processes of taming and transformation of natural raw matter into products and services as well as enhancing the growth in quantity and quality of products and services need energy, human endeavor and technology but all these activities have some impact on the environment.

The World Commission on Environment and Development (WCED) known as Brundtland Commission defined Environment as "*where we all live*" and development as "*what we all do*" in attempting to improve our lot within that abode and sustainable development as "*the development that meets the needs of the present without compromising the ability of future generation to meet their own needs*". sustainable development is a process of change in which the exploitation of resources, the direction of investments, and the orientation of technological development and institutional changes are all in harmony and enhance both current and future potential to meet human needs and aspirations. The concept of sustainability of development capsulizes two central thoughts; needs and limitations. Needs may vary from people to people according to the standard and quality of life. The limitations of resources, knowledge, skills and the state of technology and social organization imposes a limit to the environment's ability to meet the present and future needs.

## THE ENVIRONMENT: INTERACTION OF COMPONENTS

The living organisms derive sustenance from non-living resources. Under natural condition plants, microorganisms and animals together with air, water, soil, minerals and solar energy form a harmonious system. The dynamic equilibrium of the system maintained through interactions and interrelationship of the constituents of biotic and abiotic components of the system in the environment is referred to as "*Ecosystem*". Man as a component in the ecosystem is also dependent on nature for all his needs but the process of procuring his escalating demand has put additional stress on the natural system. The people being the most intelligent species in the environment play the most important role in the manipulating and restructuring the natural environment when seen from the perspective of environment as a source of material, energy and services and as a receptor of human impacts. In early time forest products, catching of fish and poaching of wildlife were the means of survival of man on earth. But man's endeavor to satisfy his growing demand to improve his living initiated the

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modification of the natural system through technological innovations. Now man has invaded nature as shown in Fig.1 and introduced modified resources in the environment combining technology with natural physico-chemical and biological system known as development resources.

The complex interactions between earth's living and non-living resources maintain a dynamic balance in the environment. Man is only a component in the subsystem 'animal' in whole system of life but with his ability to dominate and conquer the natural system through science and technology, he has created a transcendental status in the entire system. The invasion of human with science and technology on physico-chemical and biological components of the natural environment has been shown in Figure 1.

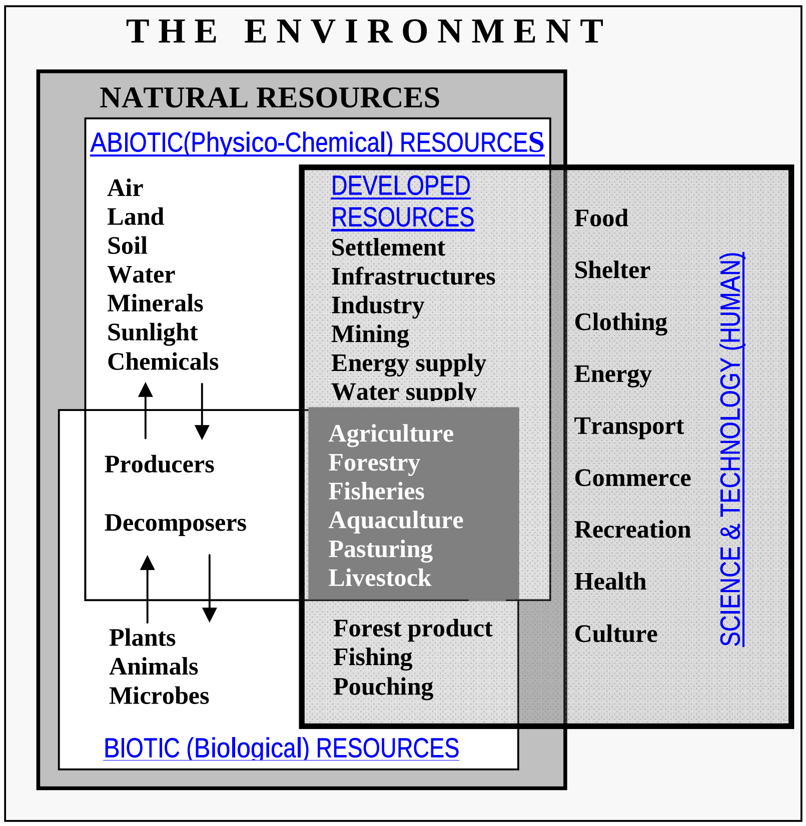


Fig. 1: Human invasion with science and technology on the environment to enhance resources to meet their needs.

All these development activities consume natural resources and interfering with natural environmental resources such as denuding of green cover, cutting of hills, making of tunnels and transportation routes, diversion of water courses, alteration of wetlands and catchment area and discharging of wastes in the environment. Environmental engineers are equipped with the knowledge of understanding the consequences of these massive interactions and adopt protective measures.

## A CONCEPTUAL MODEL AND STRATEGY FOR SUSTAINABLE DEVELOPMENT

The environment with its biotic and abiotic components provides basic resources that support production-consumption activities of population and assimilates the residues during these activities. A conceptual model of sustainable development derived from the definition given by Brundtland has been illustrated in Figure 2 (Ahmed, 2009).

The total resources at time t ($R_t$) consist of renewable resources (RR) and non-renewable resources (NRR). The development efforts representing production, regeneration and value addition using natural resources are supported by science, technological and institutional inputs from the population (Pt). The resources available for

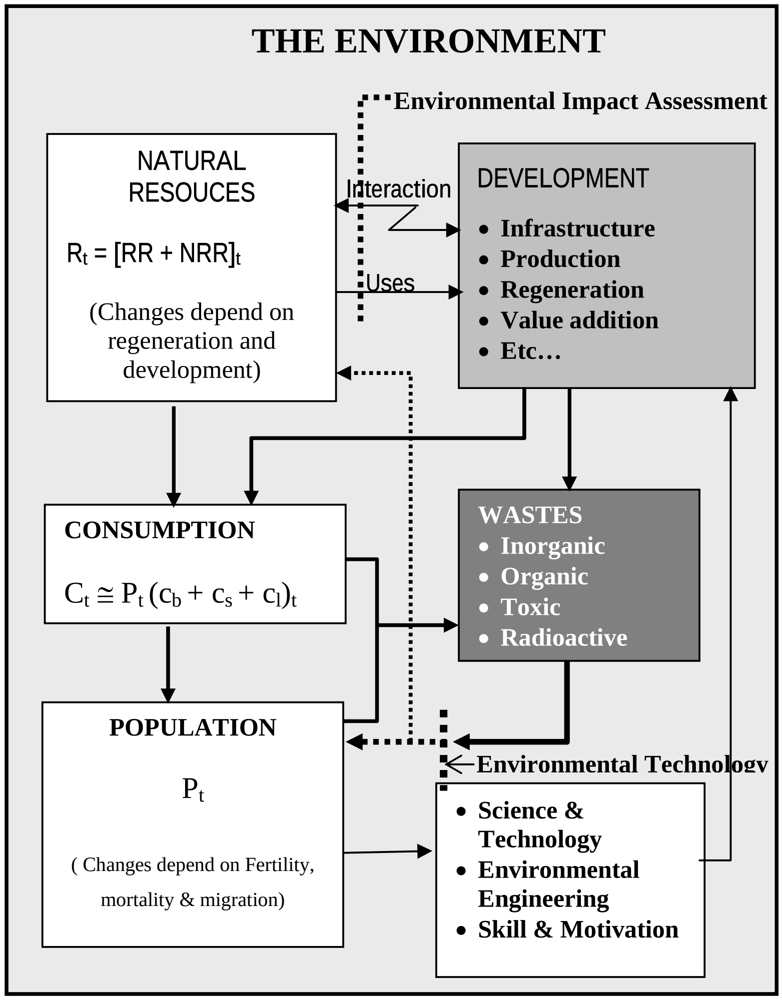


Figure 2: A conceptual model of sustainable development

the consumption ($C_t$) are derived directly from the natural resources and the products from resources development. The resources available for consumption of the population ($P_t$) are to meet their basic demands ($c_b$), secondary demands ($c_s$) and luxury demands ($c_1$) as shown in the equation (1).

$$C_t = P_t [c_b + c_s + c_l]_t \quad \ldots \quad \ldots \quad (1)$$

The basic demands ($c_b$) include foods, water and air to maintain and develop health, minimum clothe to wear and a shelter to live in. The secondary demands ($c_s$) include dresses, transport, house, education, arts, recreation etc, which a man needs to improve his living standard. The luxury demands ($c_1$) are luxury items rooted in one's affinity for such items to raise his status and prestige. The processes of resources development and resources consumption produce wastes to be discharged in the environment. The quantity and pollution potentials of the wastes increase with the increase in development activities and resources consumption. When the pollution load increases beyond the assimilation capacity of the environment, degradation of the quality of the environment takes place, which also affects the natural resources.

If the system at any time t can produce enough resources available for consumption of a small population, a high standard of living is maintained.

But if $C_t < Pt\ cb$

i.e. the resources available for consumption are unable to meet the basic demand, extreme poverty exists. In such cases the people tend to consume the resources base to meet the basic demand causing large-scale degradation and reduction in regeneration capacity of the environment resources.

If $C_t > P_t (c_b + c_s + c_l)_t$

i.e. the resources available for consumption are equal or higher than those required to meet the primary, secondary and territory demands for the population $P_t$ at a time t, prosperity exists.

The present population passes on the environment with its potentials and stresses to the future generation to carryout similar activities. For sustainable development

$$\frac{R_{t+1}}{P_{t+1}} \geq \frac{R_t}{P_t} \quad \text{(for all time t)} \quad \dots \quad \dots \quad (2)$$

$$\frac{C_{t+1}}{P_{t+1}} \geq \frac{C_t}{P_t} \quad \text{( for all time t)} \quad \dots \quad \dots \quad (3)$$

Where, 1 represents a year, a decade or a century ahead in future. These conditions of sustainability mean that per capita resources availability or per capita resources consumption does not deplete over time.

The conditionality may also be expressed as

$$\frac{R_{t+1} - R_t}{R_1} \geq \frac{P_{t+1} - P_t}{P_t} \qquad \text{(for all time t)} \quad \dots \quad (4)$$

This means that the net regeneration and development rate of resources is not less than the growth rate of population.

The sustainability of the development process is greatly dependent on how effectively the Environmental Impact Assessment (EIA) is conducted and adverse impacts are mitigated and the effectiveness of the environmental technology adopted for the management of the wastes generated from the development process.

The guiding strategy to achieve the goal of sustainable development may be summarized as follows:

(1) The population growth must be controlled within carrying capacity to ease the mounting pressure on environment resources.
(2) The environmental impacts of development activities should be assessed and effective environmental protection measures be incorporated to eliminate, reduce and off-set the adverse impacts of development.
(3) The consumption of non-renewable resources should be compensated by the increase in renewable resources or substituted by renewable alternatives.
(4) The consumption of renewable resources should be such that the harvest rate does not exceed the regeneration rate.
(5) The environmentally clean and efficient technology should be adopted for development. Environment friendly activities and products should be promoted.
(6) The wastes are to be considered as unutilized resources. The wastes should be recycled for conservation of resources and protection of the environment.

(7) Waste management must be given priority in the production – consumption processes. The wastes in excess of assimilative capacity must not be discharged in the environment. Interventions in the form of waste treatment and safe disposal must the introduced to prevent degradation of the quality of the environment.

Environmental technologies have leading roles in each of the strategies stated above to achieve sustainable development.

**ROLES OF ENVIRONMENTAL TECHNOLOGY**

**Population Growth and Carrying Capacity**

Population carrying capacity may be defined as the level of population a land area/country can sustain at a given level of technology through the supply of resources for consumption within the supportive capacity of the ecosystem. The growth of all biological species including human population in unlimited resources under favorable environment conditions may be expressed by the equation:

$$\frac{dP}{dt} = rP \qquad \dots \qquad \dots \qquad \dots \qquad (5)$$

Where dP/dt is the rate of growth of population P at time t and r is the growth co- efficient. The growth co-efficient r is dependent on adoption of family planning, aspiration of high living condition, level of education and environment factors. A solution to this equation (5) is given by:

$$P = P_o e^{rt} \qquad \dots \qquad \dots \qquad \dots \qquad (6)$$

In which $P_0$ is the initial population. The equation (6) represents exponential growth observed in some countries adopting no restriction on population growth.

The resources are finite which determine the carrying capacity, K of a system. The growth of population in finite resource system may be expressed by:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right) \qquad \dots \qquad \dots \qquad (7)$$

The solution of equation (6) may be obtained as:

$$P = \frac{K}{1 + \left(\frac{K}{P_0} - 1\right)e^{-rt}} \qquad \dots \qquad \dots \qquad (8)$$

With science and technology, man is able to improve the carrying capacity of the environment to a value K'. This is achieved mainly through resources development, which includes adding value to resources, enhancing the regeneration of renewable resources and exploration and development of hidden resources. The graphical presentation of population growth has been made in Figure 3.

The current trend of world's population growth is to overshoot the carrying capacity but there is limitations imposed by future potential for development and there are risks in attaining population close to maximum carrying capacity. It has been estimated that the world's gross domestic product has increased more than 10 folds during last 50 years (Cunningham and Saigo, 2001). The present global population of nearly 7 billion is estimated to increase to 10 billion in 2030. The earth's total resources with present development potentials can sustain an absolute maximum population of 15-16 billion. But the distribution of resources and population growth is not uniform over earth's surface. In the highly developed countries, the population growth rates is very low where one fifth of earth's population is presently enjoying four fifth of the earth's resources. The population growth rate in the less-developed countries in Asia and Africa is still very high. More that 90 percent of all

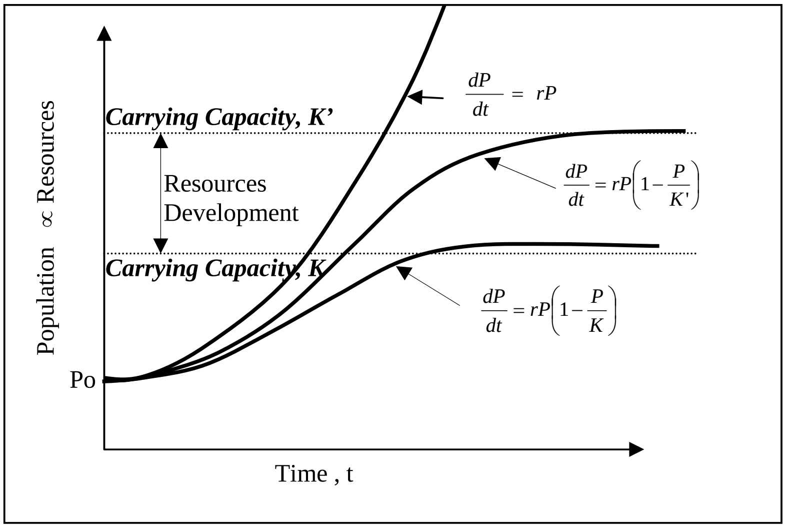


Figure 3: Population growth and carrying capacity

growth in the last century was in less-developed countries. It is expected that the population in less-developed countries will also stabilize in next 50 years.

Man needs natural resources for his living and progress. The population growth is a key factor in the rate of resources consumption and economic development. Human beings in their quest for survival, economic development and enjoyment of the riches of nature must come to term with the reality of resources limitation and the maintenance of the quality of the environment. Technologies play the main role in the development of resources for increased carrying capacity and a population with skill and technology can contribute to environmental sound development.

**Environmental Impact**

All development activities have some impact on the environment and resources. The use of and interaction with natural resources in the development process impose an impact on the resource base. Environmental Impact Assessment (EIA) of development projects by environmental scientist and technologists is required to be conducted for sound and sustainable development. Adoption of environmental mitigation measures and compensation of residual impact by environmental enhancement initiatives are the strategies to achieve sustainable development.

**Resources Consumption**

The strategy of consumption of renewable resources within the regeneration capacity can be achieved by limiting the consumption of resources or by increasing regeneration of renewable resources by use to technology. The first one is impossible to achieve for growing population requiring more resources to meet basic needs and difficult for a population habituated in high quality of life. Hence, increase in the regeneration capacity through application of science and technology is the preferred option. Green revolution in agriculture sector achieved this objective. High yield varieties of crops were developed, the technology of conversion of inert natural nitrogen into fertilizer was acquired, controlled irrigation technologies were developed and many chemicals were formulated to control pests and weeds. Now biotechnology and genetic engineering added a new dimension in further enhancing productivity. The environmental technologies are also to combat the ill-effects caused by such development initiatives. Industrial revolution in developed countries produced enough goods and services for human consumptions and improved quality of life. The environmental engineers took long time to clean the mess caused by industrial revolution by using conventional and new technologies.

Consumption of non-renewable resources leads to scarcity, but scarcity often serve as a catalyst for technological innovation and development:

- Technological innovation can increase efficiency of extraction, processing, use and recovery of materials;
- Technological advancement in exploitation renewable resources as a substitute of non renewable resources such as use of renewable energy instead of fossil fuels.
- Substitution or development of new materials for scarce one
- Discovery of new reserves through better exploration techniques, more investment and exploration in remote areas
- Recycling of materials in resource constraint situation.

**Clean Technology and Waste Management**

All production-consumption processes produce wastes as shown in Fig. 2 that require proper management to protect resource base, health and quality of life. Industrial processes produce huge quantities of industrial wastes that required cleaning. Modern agriculture needs energy, nitrogen, phosphorus, sulfur, irrigation, pesticides and herbicides and each of them have impact on the environment. The additional inputs of energy, nitrogen, phosphorus and sulfur disrupt the natural carbon, nitrogen, phosphorus and sulfur cycles in the environment.

The use of the environment as a sink for wastes generated is a potential threat to sustainable development. Many of the adverse environmental effects of wastes are not confined in a locality rather they spill over geographical boundaries. An industry, for example, may discharge effluent having inorganic, organic and toxic persistent pollutants in water, which will be carried downstream from one locality to the other and from one region to the other which is known as fluvial effect. The inorganic pollutants will disperse, and organic biodegradable pollutants will cause disruption in aquatic system upto a long distance in the downstream. The toxic persistent pollutants will be transported and deposited in other localities/regions and may reach the sea and transported to other countries/continents by water, fish or birds. The emission of pollutants in the air will disperse and fall in the locality but pollutants like oxides of sulfur may cause acid rain the region or far away in other country/continent. The climate change is eminent by the discharge of large quantities of carbon dioxide along with other greenhouse gases. The most alarming threat to the environment is the increase in the discharge of toxic wastes. At present about 190,000 known chemicals have been introduced and additional thousands of chemicals are being formulated each year, many of which are extremely toxic. The long-term effects of many pesticides, drugs, cosmetics and food additives are not yet known.

The environmental costs are sometimes passed on to future generation through over exploitation of resources, and damages to resource bases. This is a kind of environment debts for future generation and is against the principle of intergeneration equity. Sustainable development, theretofore, takes the future into consideration. The underlying premise is to leave future generations a similar or better resource endowment than that the present inherited from their past generation.

Environmental technologies as shown in Fig. 2 can erect most effective intervention to keep the environment clean and productive. Clean and efficient technologies are now available that releases effluent and emission with very low contaminants. Technologies for trapping pollutants from emission as well as cleaning wastewater have improved significantly. Biological treatment processes like high-rate activated sludge, sequential batch reactors, and membrane bio-filtration methods are highly efficient in removing bio-degradable organics present in wastewater. Membrane filtration technologies and electrochemical methods have been made highly efficient in removing organic and inorganic pollutants. Zero discharge technologies, that recycle wastewater and chemicals without discharging anything outside the industrial compound, are now in practice in many countries.

**THE BANGLDESH SITUATION**

Bangladesh faces the most difficult task of balancing between development efforts and sustaining scarce resource base. The most components the environments of Bangladesh are in the state of dynamic changes to sustain its high population growth. The fast growing population is consuming, manipulating, and restructuring the natural environment, which is a source of material, energy and services for sustenance and a receptor of human impact. The country is largely affected by environmental degradation and depletion of its resources. Principal environmental concerns are degradation of land resources, wetlands and coastal environment, fast depletion of forest, declining groundwater table, unplanned urbanization, shrinking bio-diversity, uncontrolled environmental pollution and threats of natural disasters and sea-level rise by global worming.

Agricultural production has increased about three folds in Bangladesh since independence in 1971due to introduction of HYV of crops but this growth is not sustainable. Agriculture is fully dependent on natural gas in Bangladesh which is a non-renewable resource. Gas is used as a fuel and raw material for the production of urea. Gas is the main fuel to generate electricity used for pumping of water for irrigation. Non-availability of this limited resource will bring about a collapse of the agricultural production. A shift toward engineered seeds that produce sterile crop make the farmer more dependent on suppliers of seed. High population pressure has already started affecting the sustainability of agricultural development. Because of intensive use of land, shortage of biomass and increasing use of modern varieties of crops, the cultivated soils are now being depleted of essential nutrients and organic matter content and large areas are now found to be deficient of essential nutrients, particularly sulfur and zinc.

Textile is the highest foreign exchange earning sector in Bangladesh and textile dyeing has been recognized as the highest polluter of the environment as well. The growth of the textile sector without wastewater treatment facilities has become the cause of acute pollution of surrounding water bodies and loss of production of agricultural land. Industries contribute to 60 percent of the total pollution of the water bodies. The urban centers in Bangladesh are growing at a rate out pacing the growth of service facilities. Serious problems of environmental degradation are stemming from urbanization. The pollution level in surface water sources in and around major urban centres is about 5-10 times higher than that of the major rivers. Several instances of severe water pollution occurred in the rivers Karnafuli, Surma, Sitalakhya, Buriganga and Balu during lean period of the year. Such industrial and urban development imposing environmental and social costs in the surrounding area cannot be considered as sustainable development. Application of advanced environmental technology can only protect the natural environment of Bangladesh.

## CONCLUDING REMARS

Some of the key aspects of sustainable development include efficient use of energy, switching over to renewable resources and efficient use of resources through innovative process design, waste minimization, reuse of materials and recycle of wastes, clean up of the mess. Hence, sustainable development which attempts to balance environment preservation and economic growth, without destroying the global ecosystem depends a lot on adoption and effective application of environmental technologies. All nations, poor or reach, need to prepare their own long-term sustainable development strategy reflecting their own stage of development and their problems and technological capabilities. Human resource development in developing countries in the field of environmental technology is needed to increase sufficient national capacity and expert professionals to formulate new environmental sound development plans for development and translate the plans into actions. Sustainable development that promises a way to provide decent life for Earth's human inhabitants can only be achieved by judicial application of environment friendly technologies in the development processes.

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# INTREGATED MANAGEMENT OF SOLID WASTE IN BANGLADESH FOR SUSTAINABLE DEVELOPMENT

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## ABSTRACT

It becomes evident that an integrated solid wastes management evolved from the relevant socio-economic settings and technological capabilities is required to face the challenges to create a clean, hygiene and environment-friendly city. The adopted management system must ensure the environmental and financial sustainability to ensure sustainable development. As one of the developing countries, rapid urbanization accumulate people in the urban areas in a steeply increasing rate, which may reach as many as 40% in the year of 2025, resulting the generation of huge amount of solid wastes. The solid wastes remain unmanaged due to inherent constraints and possess severe threat to human health and nature, especially in the developing countries, like Bangladesh. City authorities fail to develop and hence implement an integrated, safe and sustainable. Despite the inherent constraints, the city authority should look for an affordable solutions based on the local experiences and interactive dialogue among the concerned stakeholders. The overall sustainability of the adopted system must be ensured through evaluation and necessary refinement, which eventually contributes in achieving sustainable development of the country.

## INTRODUCTION

Generation of solid waste is an inevitable consequence of production and consumption activities in any society and economy. There is no doubt that the solid waste generation is growing proportionately with the growth of urban population and eventually very high population density in the cities provides an important aspect, which needs to consider for proper planning to handle solid waste issue. This perception is very much relevant to Bangladesh as in the recent years the population in urban areas has increased copiously without any planning and the accomplishment of necessary infrastructures, which in turns smashes the sustainability of urban environment due to inherent constraints to address solid waste issue properly, thus set adverse impacts on the sustainable development of the country.

Rapid urbanization and sustainable economic growth in the recent years result a very high rate of solid waste generation in the cities of Bangladesh. Till 1950s, the level of urbanization and the number population were significantly low, it has increased gradually from 4.33% at 1951 to 5.19% in 1961, of total population living in urban areas. After that the rate of increase of population is very steep, as 8.78% in 1974, 15.54% in 1981, 20.15% in 1991, 23.39% in 2001 (BBS 1997 and 2001). A recent study by World Bank has estimated that about 40% of the total population in Bangladesh will be living in the urban areas by the year of 2025 (World Bank 2000). Six city corporations, 308 municipalities and 210 other urban centers cover the urban population in Bangladesh. The urban population are mostly concentrated in six major cities, namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet, where nearly 13% of the total population and 55 to 60% of the total urban population are living. The increase of urban population and the density have very significant impacts on the waste amount and the overall management policy.

In the urban areas of Bangladesh, the major weakness of the existing waste management system is the collection efficiency, which falls below 50% of total generated wastes. It occurs due to lack of people’s awareness, participation in the process, absence of sustainable system and the overall inefficiency of the organizational efforts of the local city authority (Jhumana et al 2009). As the present environmental degradation in the urban areas cannot be ignored, attention should be given to find out the loopholes of the existing system and the necessary ways should be explored to run it within the existing capabilities of the city authority in particular and

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the community in general to face the challenges under an integrated approach. The relevant stakeholders need to bring closer to act accordingly with respect to the management aspects. The community participation, which is a sociological process, must be ensured conducting proper dialogue and regular communication that will develop their ownership on the system (Bidlingmaier 2009). In this context, the prime task is to ensure the proper functioning of the adopted system at every tier and to minimize the adverse environmental impacts as much as possible to ensure sustainable development. The starting point of this initiative is to identify the weak aspects of the existing system and to make an affordable plan considering the real position of the city authority and the area concerned to introduce the effective measures to develop a sustainable waste management system in the cities of Bangladesh. To materialize the target perfectly, the community participation must be ensured and the levels of awareness and commitment should be raised following sustainable initiatives developed based on the interactive dialogue among the concerned stakeholders. The overall sustainability of the implemented system must be ensured through its evaluation and necessary refinement based on the practical experiences, actual needs and existing socio-economic settings.

## EXISTING MANAGEMENT OF SOLID WASTES IN BANGLADESH

In Bangladesh, solid waste issue is one of the least concerned environmental aspects at the country's highest decision making level. There is no national policy for proper management of solid waste and to minimize the adverse environmental impacts on human health and nature. However, in the recent years, the relevant stakeholders, especially the city dwellers and the local city authority gave attention to solve this issue, which exaggerates due to rapid urbanization. The existing management of solid waste in Bangladesh is very primeval (WasteSafe 2005, Chowdhury 2009). Wastes are collected from generation sources by non-governmental organizations (NGOs), community based organizations (CBOs) and city authority by door-to-door collection system, and most of the cases waste generator dispose it to the nearest community bins/ secondary disposal sites (SDS)/ open land/ road sides/ drains. In Bangladesh, city authority is solely responsible for providing SDS; collect wastes from SDS and transfer for final disposal as per existing City Corporation Act. All the ultimate disposal sites (UDS) of wastes in Bangladesh are uncontrolled crude open dumping site, where even minimum environmental protections are not provided. Composting is one of the common options for treatment and reuse of organic portions of solid waste is done in a very small scale by dwellers, NGOs, private sectors and even city authority. However, major portions of wastes remain unmanaged - throwing them in the adjacent spaces, roadsides and drains etc. A portion of clinical/hospital wastes is managed by NGOs/city authority (Alamgir et al. 2008 and Fatima et al. 2010) and the remaining follows the same path of the urban wastes. Figure 1 shows the existing situation of SDS and UDS in a city of Bangladesh. The existing management of urban wastes in the cities of Bangladesh can be characterized as (i) absence of appropriate organizational set-up in the city council and accountability, (ii) significant portions of wastes remain out of any sorts of management, (iii) no special attention to manage hazardous wastes, (iv) recycling, composting and other product oriented management activities are running through informal sectors without any support from government level, and (v) insignificant involvement and participation of local community in the system.

Figure 1. Existing situation of typical SDS

Figure 2. Existing scenario of typical UDS

## CONSTRAINTS OF EXISTING SYSTEM

A typical solid waste management system in a LDC, like Bangladesh displays an array of problems, including low collection coverage and services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin, and the handling and control of informal waste picking or scavenging activities. These public health, environmental and management problems are caused by various factors as discussed in the followings (Alamgir 2009):

***Technical Constraints*****:** In LDCs, generally there is a lack of human resources at both the national and local levels with technical expertise necessary for solid waste management planning and operation. Many officers in-charge of solid waste management, particularly at the local level, have little or no technical background or training in engineering or management. Without adequately trained personnel, a project initiated by external consultants could not be continued, so the development of human resources in the beneficiary country is essential for the sustainability of the collaborative project.

***Financial Constraints*****:** In general, solid waste management is given a very low priority in least developing countries, except perhaps in capital and large cities. As a result, very limited funds are provided to the solid waste management sector by the governments, and the levels of services required for protection of public health and the environment are not attained. The problem is acute due to weak financial basis of local governments. This can be supplemented by the collection of user service charges. However, users' ability to pay for the services is very limited in poorer developing countries, and their willingness to pay for the services which are irregular and ineffective is not high either. An effective strategy for raising funds needs to be searched to ensure its sustainability.

***Institutional Constraints:*** Several agencies at the national level are usually involved at least partially in solid waste management. However, the lack of coordination among the relevant agencies with local authorities often results distraction of needs, duplication of efforts, wasting of resources, and non-sustainability of overall management. Because of a low priority given to the sector, the institutional capacity of local government agencies involved in solid waste management is generally weak, particularly in small cities and towns. Local ordinance/by-laws on solid waste management is not also well developed. These weak local government institutions are not provided with clear mandates and sufficient resources to fulfill the mandates.

***Economic Constraints*****:** Economic and industrial development plays key roles in solid waste management. Obviously, an enhanced economy enables more funds to be allocated for solid waste management, providing a more sustainable financial basis. However, by definition, developing countries have weak economic bases and, hence, insufficient funds for sustainable development of solid waste management systems. Local industry which produces relatively inexpensive solid waste equipment and vehicles will reduce, or in some cases could eliminate totally, the need for importing expensive foreign equipment/vehicles.

***Social Constraints***: The social status of solid waste management workers is generally low, especially in the developing countries, which owes much to a negative perception of people regarding such works. At dump sites, transfer stations, street refuse bins, waste picking or scavenging activities are common scenes in developing countries. People involved in waste management have not been received school education and vocational training to obtain knowledge and skills required for other jobs. They are also affected by limited employment opportunity available in the formal sector. The existence of waste pickers/scavengers creates often an obstacle to the operation of solid waste collection and disposal services. Integrated approach with community participation is required for sustainable development by reducing negative social aspects.

## CHNALLEGES AND THE MEASURES

To overcome the present unpleasant and unhygienic situations in the urban areas of Bangladesh, the existing system should be improved in phases to reach an environmental-friendly condition following the approaches as mentioned in the previous sections. The improvement should be done in such a way, that the sustainability must be ensured and the adopted system should be design considering the capability of the city authority in all the relevant aspects and in accordance the prevailing socio-economic conditions, city dwellers’ perception and the technological capabilities. To ensure the sustainability of the issues to be addressed, performance monitoring and impact assessment are must. The assessment reports should include the suggestion of the approaches needed to implement and/or refine the existing one considering the operational and environmental aspects. However, it is difficult to see how the objectives of environmental sustainability are going to be achieved within the inherent constraints faced by the city authority to improve the existing system as targeted. The major issues to be addressed can be short listed in a tabular in Table 1.

Table 1 Major challenge to run management and operational issues of solid wastes

| **No.** | **Management and Operational Issues** | **Major Challenges for Environmental Sustainability** |
|---|---|---|
| 1 | Source storage | - Stop throw away of wastes by any means.<br>- Separate hazardous wastes.<br>- Special attention for bio-waste<br>- Overcome NIMBY syndrome. |
| 2 | Primary transfer of wastes from source | - Proper collection and transfer of wastes from source.<br>- Transfer of hazardous waste with care.<br>- Ensure separate collection and primary transfer of waste |
| 3 | Situation of on-site storage i.e. SDS | - No scavenging and no littering at SDS.<br>- Stop SDS at the illegal/undesignated places.<br>- Time frame for waste disposal and storage at SDS.<br>- Improvement of SDS & no storage on earthen floor.<br>- Separate handling option for hazardous waste.<br>- Conversion of SDS to Transfer station in phases.<br>- Ensure proper management of SDS. |
| 4 | Collection & Transfer of wastes from SDS | - Ensure regular collection within the fixed time span.<br>- Stop seepage of leachate during transportation.<br>- Covering of transportation vehicles to stop littering.<br>- Avoid waste transportation during rush hour. |
| 5 | Composting technology | - Ensure separate storage of bio-waste at the source.<br>- Stop sorting of partially decomposed wastes.<br>- Make mandatory use protective articles at the plant.<br>- Ensure reasonable wage, job security & healthcare.<br>- Stop direct screening of compost, modify the system.<br>- Stop discharge of leachate without prior treatment.<br>- Private sector should be encouraged.<br>- Government support should be increased. |
| 6 | Recycling industries/ factories | - Stop child labour in the local recycling industry.<br>- Provide health protection articles to the workers.<br>- Install pollution/contamination control devices in phase.<br>- Provide government support for sustainability. |
| 7 | Hospital wastes | - Introduce separate management system.<br>- Provide training to identify infectious waste at source.<br>- Separate hospital wastes at source in different categories.<br>- Collect and transfer hospital waste with proper care.<br>- Process the infectious wastes properly.<br>- Don't allow any recycling of hospital wastes |
| 8 | Ultimate disposal | - Stop illegal dumping of the collected wastes.<br>- Recyclables and Bio-wastes should not go to landfill.<br>- Ensure waste deposition in the designated place only.<br>- Stop scavenging and littering of wastes in the sites. |

| | | |
|---|---|---|
| | | - Develop existing sites to meet environmental provision.<br>- Introduce Sanitary landfill in phases. |
| 9 | Waste management section | - Set-up of Independent waste management division.<br>- Private sector involvements need to increase in phase.<br>- Sustainable coordination with concerned stakeholders.<br>- Updates on environmental sustainability of the system.<br>- Regular updates of information and make it accessible. |
| 10 | Participation of the stakeholders | - Establishment of importance of public participation.<br>- Formation of management committee by local people.<br>- Development of social commitment to the individuals.<br>- Development of environmental knowledge of people.<br>- Formulation of regular basis awareness campaign.<br>- Public voices should be respected by policy makers |

## INTEGRATED AND SUSTAINABLE MANAGEMENT OF SOLID WASTES

Management is a carefully planned, judicious use of available means to achieve the desirable end. In case of waste management an "end" is the removal, collection and disposal of unwanted materials. Integrated and sustainable wastes management is associated with several different functional activities such as waste generation, source separation and storage, on-site handling, collection, transportation, treatment, reuse & recycling and final disposal of waste in a proper way which has no effect on environment. In most of the LDACs, due to severe inherent constraints, inadequate or unavailable solid waste collection and disposal services result in indiscriminate dumping of waste on streets and public areas, clogging of urban drainage systems, contamination of water resources, and proliferation of insects and rodent vectors. The employed system needs intelligent combination of such processes. As the management of vast quantities of wastes generated by urban communities is a very complex process, to run these functional activities properly, technical, environmental, administrative, economic and social problems those prevailed in LDACs due to inherent socio-economic settings must be solved in integrated and sustainable way. However, an effective system for waste management must be both environmentally and economically sustainable, otherwise sustainable development of the country cannot be ensured.

**(a)** ***Environmentally sustainable:*** It must reduce as much as possible the environmental impacts of waste management, including energy consumption, pollution of land, air and water.

**(b)** ***Economically sustainable:*** It must operate at a cost acceptable to the community, which includes private citizens, businesses and government. The costs of operating an effective solid waste system will depend on existing local infrastructure.

From the surveys and consultations in the seven LDACs case study cities, the WasteSafe team (WasteSafe 2005) concluded that there is a compelling need for the more integrated management and safer handling of the generated solid waste. The broad context, on aspects such as financial, technical, human resources, infrastructure, and popular awareness and commitment, is believed to pose similar challenges in all LDAC cities. In the following Figure 3, a generalized flowchart for the integrated management of solid waste, which emphasis the needs to all aspects and systems are presented in Figure 4, based on Visvanathan et al. (2004).

## APPROACH TO IMPLEMENT THE PROPOSED INTEGRATED SYSTEM

Waste management in the narrow sense directs the flows of materials so that their impact on the environment, the depletion of resources, and the resulting costs are minimized. As the solid waste management is very complex in nature due to the involvement of very diversified actors, an integrated and sustainable system needs to practice in a pragmatic way of setting priorities is to minimize the total impact of waste on the environment, i.e. the impacts on water, air, soil have to be minimized as well as the consumption of energy, materials and landfill space. Some objectives appear to be crucial for safe and sustainable waste management:

- *Protection* of health and the environment;
- *Conservation of resources* such as materials, energy, and space;
- *After-care-free waste management*, meaning that neither landfills nor incineration, recycling or other treatments leave problems to be solved by future generations.

Although there are various proposals by different researchers on integrated and sustainable management of solid waste, all agree that there is no single solution for such a complex problem. Rather the various and evolving solutions must be sensitive to local conditions and socio-economic settings, and to locally perceived priorities and needs. Certainly, every city should take maximum benefit from the objective research and experience, which

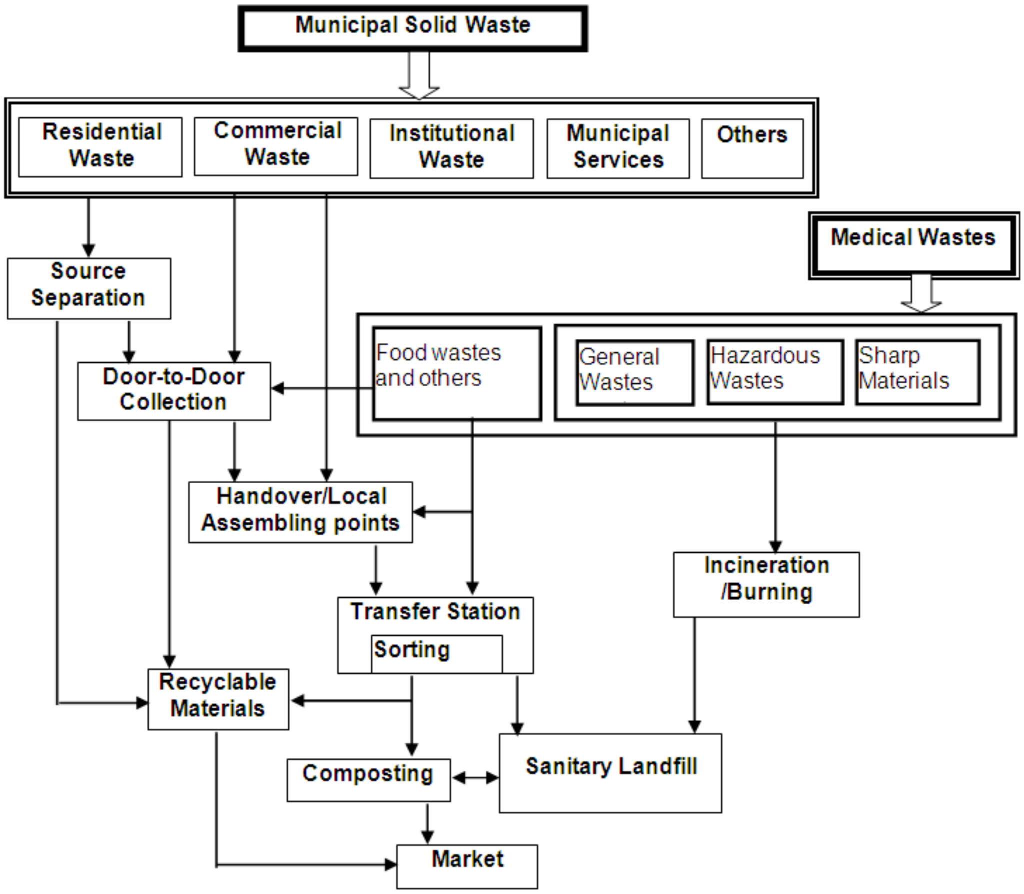


Figure 3: Generalized flowchart for the integrated solid waste management (after WasteSafe 2005)

is available through projects and resources. But the roles and interests of all tiers – such as city dwellers, small businesses, institutions and city authorities - should be considered in their present local context, if they are to be encouraged to work together smoothly and positively.

Thus it was that the WasteSafe approach (WasteSafe 2005) came to focus not upon some ideal system, but on an approach which seeks the improvement of waste management system through (i) a structural dialogue between stakeholders and (ii) about the planning and implementation of change. The dialogue aims to promote desirable checks and balances between the focus and motivation of specific interests through the spreadsheet tools: (i) to promote a device to think the problems systematically and holistically and (ii) to help for setout more selectively a balanced 'business and sustainability' for some proposed intervention action. The common spreadsheet format consists of: (i) Waste system components forming the row headings of the spreadsheet i.e. contain & collect; sort & recover; transfer & treat and dispose & make safe, and (ii) Aspects of evaluation components forming the column headings of the spreadsheet i.e. sources & streams; costs & returns; health & environment and community & structure. The key questions are summarized in the spreadsheet as stated in WasteSafe (2005). The spreadsheet gives an overview of a range of concerns, which need to be addressed together about the closely inter-related issues. The municipality has decided to set up four working groups, corresponding to the four elements – contain & collect, sort & recover, transfer & treat, dispose & make safe. These waste system elements must be synchronized with the following evaluation aspects to ensure balances and sustainability of the system – sources & streams, cost & returns, health & environment and community & structure.

Experiences depict that the existing management system in all the urban areas of Bangladesh are running in an inefficient way with inadequate and inappropriate infrastructures, which cannot be overlooked any more. All of the challenges illustrated in Table 1, cannot be faced properly due to inherent constraints as one the LDACs. However, the pre-designated initiatives should be taken in phases in the line of the system as presented in Figures 4. In this instant, the followings actions can be conducted priority basis:

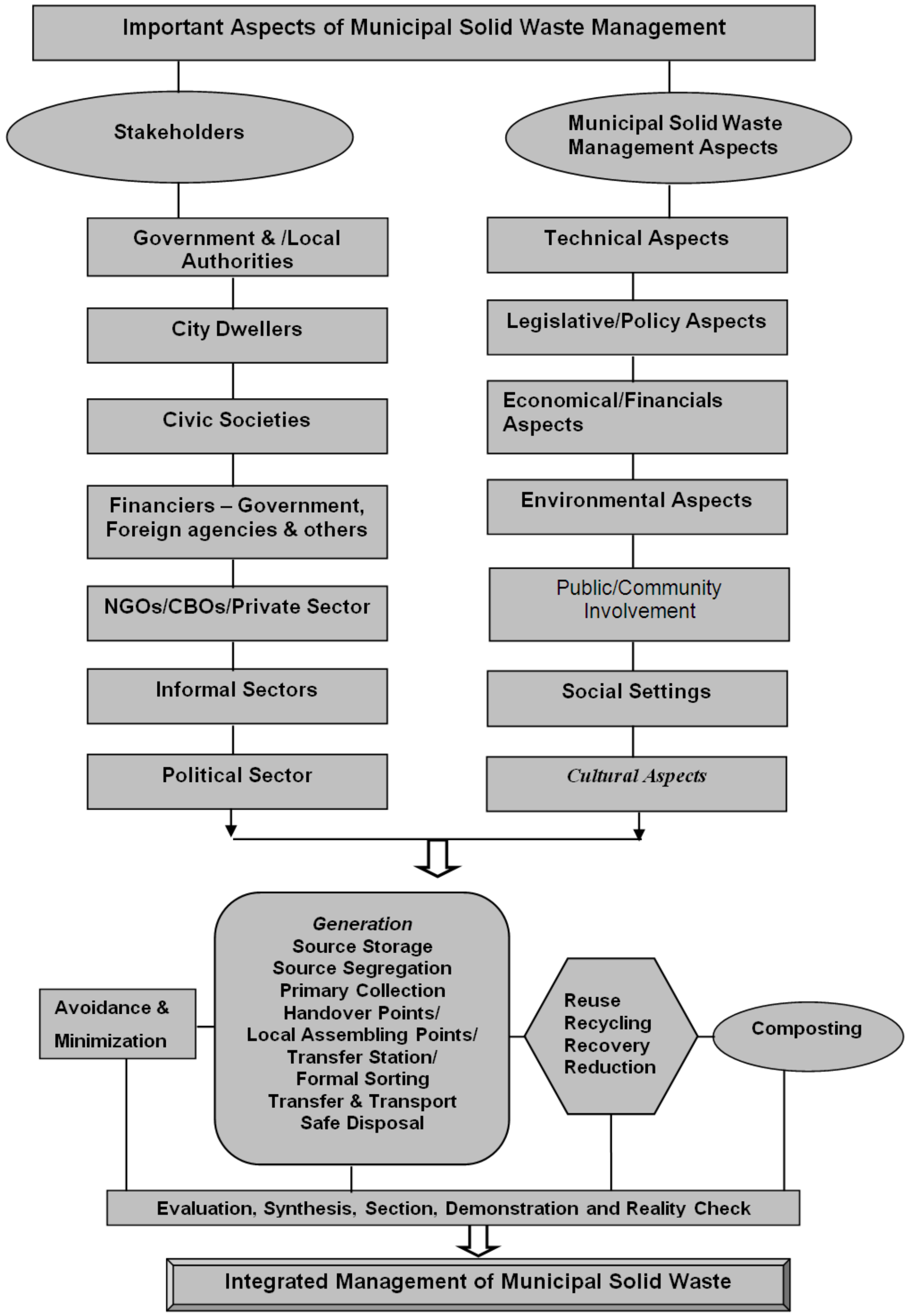


Figure 4: Model of integrated waste management (after WasteSafe 2005)

***Organizational Reforms***

In Bangladesh, city authority is responsible for overall management of solid wastes in urban areas as per the Municipality Act. There is no independent wing with sufficient authority to deal the wastes problems in the municipality. As the proper organizational set-up in the City Corporation and Municipality is one of the pre-conditions to have a sustainable system, the following actions can be taken as a priority basis to this end.

- Set-up of independent waste management division with authority.
- Private sector's involvement need to increase in phases.
- Effective and sustainable coordination with concerned stakeholders.
- Updates on the achievement of environmental sustainability of the system.
- Regular updates of the information and to make them readily accessible.

***Peoples' Awareness Development and Community Participation***

Effective implementation, even a simple system is difficult to achieve if the respective stakeholders, specially the city dwellers do not cooperate and participate in the process. People need to realize the needs and change their minds and habits. Continuous mass awareness campaign should run in this regard through a responsible and public representative body such as city authority (Municipality and City Corporation). Authority should officially involve the people from the relevant stakeholders in this process. Such initiatives have been and are being taken place in different cities of Bangladesh but do not continue due to lack of responsibility, target and planning and as well as financial constraints. Therefore, awareness campaign needs to get institutional shape to run regularly on the target without any interruption till the designated goal has been reached. The major measures to ensure people participation can be listed as:

- Establishment of importance of public participation.
- Formation of management committee involving local people.
- Development of social commitment to the individuals.
- Development of environmental knowledge of people starting from school.
- Formulation of regular basis awareness campaign through effective ways.
- Public voices should be respected by policy makers

***Privatization***

As waste management has become more complex, and expectations for government services have changed, political leaders have searched for different ways to provide public services without straining the capabilities of government. In some cases this has led to treating local government services and departments more like private sector businesses. However, many countries including Asia have already introduced private sectors to provide waste management serves with necessary agreement between the local authority and the company, which have been providing better services with satisfaction and cost effectiveness. This kind of service is also known as private public partnership (PPP) initiatives. Recently, getting positive impression of PPP and also due to the absence of efficient local government system and also to meet local demand, some city corporations in Bangladesh handed over somes areas of the city to such services to private sectors in Dhaka and Khulna through open tender with some specific job such as street sweeping, drain cleaning, door-to-door collection of municipal solid waste and transfer the collected wastes to the designated UDS of city corporation as an experimental basis. It is observed that privatization works well and demand of this kind of services are increasing from other areas of the cities. When privatization is considered, two key issues must be understood:

(a) There is no right answer to solid waste management. Although privatization can be a valuable means of management, it is by no means the only approach available. The decision to privatize depends heavily on the needs of the community, the type of service to be provided, the capabilities and availability of private firms and financial consequences.

(b) Privatization does not eliminate the ultimate responsibility of local government. Although private involvement can help carry out services, the ultimate responsibility for the welfare of the community remains in the hands of the government. Even if the local government develops a relationship in which all management activities are handled privately, it must, at a minimum, ensure that the services are meeting community needs and are cost effective.

**ESTABLISHMENT OF "ENVIRONMENTAL WATCHDOG"**

To ensure the sustainability of the addressed issues, the performance monitoring and impact assessment of the system are must. The assessment reports should include the suggestion of the approaches needed to implement and/or refine the existing one considering the operational and environmental aspects. However, it is difficult to see how the objectives of environmental sustainability are going to be achieved within the inherent constraints faced by the city authority to improve the existing system as targeted. In this context, an independent body other than the directly involved parties such as Waste Management Division and service provider (City Corporation/ Municipality/ NOGs/ CBOs/ Private Sectors) is needed to involve in the process. This body can be designated as *'Environmental Watchdog'*, which may form by the selected and the interested city dwellers from different cornered stakeholders having relevant expertise and/or experiences (Alamgir 2009). The city corporation will provide all the legal and logistical supports. However, the chairman and the members will work voluntarily. As an alternative, the city corporation may select and involve a private enterprise such as an environmental company, who will act as the *'Environmental Watchdog"* for certain period with clearly defined terms and conditions. This body only looks after the environmental assessment at every tier of the existing solid waste management adopted by the city authority. As the accountability and transparency are the two prime aspects to make success of any attempts including environmental sustainability check of the adopted system, this body will also watch whether the information regarding the ongoing activities conducted by the city authority make readily available to the concerned stakeholders. The entrusted body will prepare monthly or quarterly report, which will be an open and free accessible source to all concerned stakeholders including the city dwellers and may be discussed in an open forum. The watchdog also will select the best ward, school, hospital, office, kitchen market, shopping center, etc. for monthly awards and encouragement incentives provided by the city authority. This body should not have any decision taking authority on the solid waste management; however, its works and voices cannot be undermined by the authority. The reports and recommendations provided by the watchdog should be considered as mandatory to discuss in public representatives' meetings of the city authority for necessary observation and considerations.

## CONCLUSION

The existing practice of solid waste management in Bangladesh is far behind the needs in all aspects; as a consequence, the urban environmental sustainability is in large threat. As, in the waste management, there is no single solution, so no need to think about the best solution. To ensure the acceptability of the adopted system by the stakeholders and to ensure environmental sustainability, an integrated system based on the existing practices, local needs, socio-economic settings and technological capabilities, is required to introduce. Local authority has to take lead role to coordinate all the technical, social and political aspects of the adopted system in cooperation of the relevant stakeholders of the area to be addressed. The implementation of system should be done in phases ensuring both the environmental and financial sustainability. Involvement of private sectors and NGOs in the process with strict terms and conditions can improve the situation significantly.

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# GHG EMISSION AND RENEWABLE ENERGY SOURCES FOR SUSTAINABLE DEVELOPMENT IN BANGLADESH

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## SUMMARY

Bangladesh is an energy starving country. The country will be on one of the fast growing power markets with its population and growing energy demand per person, its fast growing urbanization, and its socio-economic development. At present the potential demand of power is 5569 MW and the supply is below 4000 MW. The country is dependent on the imported petroleum that is big burden on the economy. The per capita emission is only 0.2667 tonne per person still much below the world leading countries (19.8 tonne per person for USA). However, Bangladesh is one of the most vulnerable to climate change effect in the world. In this regard, renewable energy resources appear to be the one of the most efficient and effective solution for clean and sustainable energy development in Bangladesh. Biomass is the dominating source of energy in Bangladesh. Biomass energy is used in a very traditional way. Biomass conversion to energy in the form of liquid, gaseous and solid pellet or briquette could be a viable option to reduce the pressure on the conventional fossil fuel. The geographical location of Bangladesh has several advantages for extensive use of grid connected solar electricity and stand alone solar PV system. This article presents a review of the potential and utilization of the renewable energy sources in Bangladesh.

**Key Words:** GHG emission, Per capita carbon dioxide emission, Renewable energy

## 1. INTRODUCTION

Energy is the indicator of economic and social development and improved quality of life. Much of the world's energy currently used is produced from fossil sources and that is used in a way that could not be sustained if the alternative sustainable sources were explored and if the technology were remain constant [1]. Due to the use fossil energy, extra million tons of greenhouse and other gases are increasing substantially to make the earth unstable. Climate change is one of the most difficult challenges facing the world today. Burning fossil fuel such as gas, oil and coal provides about three-fourth of world's energy. When these fuels are burned, they emit greenhouse gases (GHGs) that are now recognized as being responsible for climate change. The primary greenhouse gas emitted through fuel combustion is CO2. Land-use and land-use changes, notably deforestation, also involve emissions of CO2 [2]. Bangladesh has only commercial energy natural gas that mainly supports power generation in the country at present. More than 80% of power generation is dependent on it. As per the forecast of Petrobangla, the total remaining gas reserve (July 2005) of 13.75 Tcf would meet the country's projected energy demand up to 2015. After that, each year, there will be short supply of gas and this would increase to 4421 mmcfd by 2025. This means that to support the projected energy demand, 8.35 Tcf of additional gas would be required. This short supply of gas would have to be managed either by discovery of additional gas field or alternative sources of fuel. Presently known primary commercial energy resource includes natural gas, oil including condensate, coal and hydroelectricity. In the past peat was considered as a source but detail study that exploitation of high quality coal negates its possibility to use it as commercial energy resource. Biomass still plays an important role in country's energy consumption. Till now nuclear energy is not given any serious thought. In 2003, the per capita energy consumption was estimated to be 220 kg of oil equivalent.

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Biomass is the dominant energy source used as a source of thermal energy in domestic, commercial and industrial sectors in Bangladesh. Per capita emission of greenhouse gas for Bangladesh in terms of CO2 equivalent is less than a tonne per year, if traditional biomass burning is excluded. Total greenhouse gas emission of the country was 13.44 million tonne of CO2 equivalent in 1990 [3]. This paper gives an overview of the status of GHG emission and renewable energy worldwide and in Bangladesh.

## 2. GLOBAL GHG EMISSION AND RENEWABLES

### 2.1. GHG Emission

GHG emission is of course the reason why there is a need to avoid producing $CO_2$. The gas like $CO_2$ allows the suns ray in but stop the heat radiation form re-emerging, much as happens with glass in greenhouse. The result is that the greenhouse gas heats up the whole world. However, the extra million tons of $CO_2$ gas we released in the atmosphere seems like to upset the natural balance. World energy-related carbon dioxide emissions grow from 29.7 billion metric tons in 2007 to 33.8 billion metric tons in 2020 and 42.4 billion metric tons in 2035. Table 1 shows world $CO_2$ emission by region. The increasing trend of world emission is more in the developing countries compared to developed country although the per capita emission is much lower in the developing countries. Therefore the developing countries should be more careful to use energy in future for minimizing the global emission. World energy-related carbon dioxide emissions increase by an average of 1.3% year from 2007-2035.

Another indicator of carbon dioxide intensity is emissions per person. Carbon dioxide emissions per person in Organization for Economic Co-operation and Development (OECD) economies are significantly higher than in non-OECD economies (Table 2). China has the highest percentage increase in carbon dioxide emissions per capita of 4.7 tonne per person in 2007 and 9.2 tonne per person in 2035. OECD countries have higher levels of carbon dioxide emissions per capita, in part because of their higher levels of income and fossil fuel use per person. US emissions per capita fall from 19.8 tonne in 2007 to 16.2 tonne in 2035 but remain highest per capita emission in the world. Income per capita is the most important determinant of carbon dioxide emissions per capita, but other factors for example, climate and population density also affect the calculation.

### 2.2 Renewable Energy Sources

World energy use continues to be at the center of the climate change debate due to the anthropogenic emissions of carbon dioxide result primarily from the combustion of fossil fuels. Sustainable energy is only concern of mitigating the anthropogenic emissions. Renewable energy instead of fossil energy is identified is only the sustainable energy to stable future earth. Renewable energy supplies 18% of the world’s primary energy, counting traditional biomass, large hydropower and new renewables such as small hydro, modern biomass, wind solar, geothermal and biofules. Traditional biomass is primary used for cooking in the developing countries and space heating at cold region, represents about 9% and is growing slowly or even declining some regions as biomass energy is used more efficiently or replaced by more modern energy form. Hydropower is the highest installed capacity amounting 980 GW and growing slowing, mainly in developing countries. New renewables are 2% and growing very fast in developed countries and some developing countries. The world’s renewable energy status is shown in Table 3. The fasted growing energy technology in the world has been grid-connected solar PV, with total existing capacity increasing from 0.16 GW at the start of 2000 to 13 GW by the end of 2008. During the same time, other renewable energy technologies grew rapidly as well: wind power, biodiesel, solar hot water/heating, off-grid solar PV, geothermal heat capacity and ethanol.

## 3. ENERGY UTILIZATION AND ENVIRONMENTAL ISSUES IN BANGLADESH

### 3.1. Energy Utilization

Bangladesh is an energy starving country; about 47% of total commercial energy requirement is supplied by imports [7]. The imported petroleum is mainly consumed by the transport sector and agriculture sector (land cultivation and irrigation). A share of imported petroleum is consumed electricity generation. Gas is the biggest share of in total primary energy consumption. About 70% of power generation is dependent on it. As per the forecast of Petrobangla, the total remaining gas reserve (July 2005) of 13.75 tcf would meet the country's projected energy demand upto 2015. The final energy production and consumption scenario of Bangladesh are shown in Table 4 and Table 5.

Table 1: Carbon dioxide emission in the World by region (1990-2035) (Billion tonne)

| Region | History | | Projections | | | | | Average annual percentage change | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2007 | 2015 | 2020 | 2025 | 2030 | 2035 | 1990-2007 | 2007-2035 |
| OECD countries | 11.5 | 13.7 | 13.0 | 13.1 | 13.5 | 13.8 | 14.2 | 1.0 | 0.1 |
| North America | 5.8 | 7.0 | 6.7 | 6.9 | 7.2 | 7.4 | 7.7 | 1.1 | 0.3 |
| Western Europe | 4.2 | 4.4 | 4.1 | 4.0 | 4.0 | 4.1 | 4.1 | 0.3 | -0.2 |
| Asia | 1.6 | 2.3 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 2.1 | 0.2 |
| Non-OECD countries | 10.0 | 16.0 | 18.5 | 20.7 | 23.0 | 25.5 | 28.2 | 2.8 | 2.0 |
| Europe and Eurasia | 4.2 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.2 | -2.2 | 0.3 |
| Asia | 3.7 | 9.4 | 11.2 | 13.0 | 14.9 | 16.9 | 19.0 | 5.7 | 2.5 |
| Middle East | 0.7 | 1.5 | 1.9 | 2.1 | 2.3 | 2.5 | 2.7 | 4.6 | 2.1 |
| Africa | 0.7 | 1.0 | 1.2 | 1.2 | 1.3 | 1.5 | 1.6 | 2.6 | 1.7 |
| Central and South America | 0.7 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 3.1 | 1.4 |
| Total World | 21.5 | 29.7 | 31.5 | 33.8 | 36.5 | 39.3 | 42.4 | 1.9 | 1.3 |

Source: [24]

Table 2: Carbon dioxide emission per capita in the World by region (Tonne per person)

| Region | History | | Projections | | | | | Average annual percentage change | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2007 | 2015 | 2020 | 2025 | 2030 | 2035 | 1990-2007 | 2007-2035 |
| OECD countries | 11.0 | 11.6 | 10.5 | 10.4 | 10.4 | 10.5 | 10.6 | 0.3 | -0.3 |
| North America | 16.0 | 15.8 | 14.1 | 13.8 | 13.7 | 13.6 | 13.5 | -0.1 | -0.6 |
| United States | 20.0 | 19.8 | 17.5 | 17.1 | 16.8 | 16.5 | 16.2 | -0.1 | -0.7 |
| Canada | 17.0 | 17.8 | 15.4 | 14.7 | 14.6 | 14.7 | 14.8 | 0.3 | -0.7 |
| Mexico | 3.6 | 4.1 | 3.9 | 4.2 | 4.5 | 4.9 | 5.5 | 0.8 | 1.0 |
| Western Europe | 8.4 | 8.1 | 7.4 | 7.2 | 7.1 | 7.1 | 7.1 | -0.2 | -0.5 |
| Asia | 8.5 | 11.4 | 10.6 | 10.9 | 11.3 | 11.7 | 12.2 | 1.7 | 0.2 |
| Non-OECD countries | 2.4 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 | 4.0 | 1.3 | 1.1 |
| Europe and Eurasia | 12.3 | 8.5 | 8.5 | 8.7 | 8.9 | 9.3 | 9.8 | -2.1 | 0.5 |
| Asia | 1.3 | 2.7 | 2.9 | 3.2 | 3.6 | 3.9 | 4.3 | 4.2 | 1.7 |
| Middle East | 5.2 | 7.5 | 8.4 | 8.5 | 8.5 | 8.5 | 8.8 | 2.2 | 0.6 |
| Africa | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.1 | 0.1 | 0.1 |
| Central and South America | 1.9 | 2.5 | 2.6 | 2.6 | 2.7 | 2.8 | 2.9 | 1.6 | 0.4 |
| Total World | 4.1 | 4.5 | 4.3 | 4.4 | 4.6 | 4.8 | 5.0 | 0.5 | 0.4 |

Source: [24]

### 3.2. Electricity Generation

The electricity energy is deficit in Bangladesh as per demand. The total installed capacity of electric power is increased from 2350 MW in 1990 to 5823 MW in 2010, with an annual growth rate of 5.17% (Fig. 1). The grid electricity is generated from four main sources: gas 4822 MW, diesel/oil 522 MW, Coal 250 MW and Hydropower 230 MW. The biggest share of electricity comes from gas generation system. The power plants are not operated for maximum output due to the shortage of fuel. The rate of gas production capacity is declining day by day. The country economy situation could not permit to import more petroleum for power generation. The big hydropower plant could not run at full capacity due to declination of water head at lake. However the

Table 3: Renewable energy indicators

| **Indicator** | **Existing capacity at end of 2009** |
|---|---|
| ***Power generation*** | ***Capacity (GW)*** |
| Hydropower | 980 |
| Wind power | 159 |
| Biomass power | 54 |
| Solar PV, grid-connected | 21 |
| Geothermal power | 11 |
| Concentrating solar thermal power (CSP) | 0.6 |
| Ocean (tidal) power | 0.3 |
| ***Hot water/heating*** | ***($GW_{th}$)*** |
| Biomass heating | 270 |
| Solar collectors for hot water/space heating | 180 |
| Geothermal heating | 60 |
| ***Transport*** | ***(Billion liters/year)*** |
| Ethanol production | 76 |
| Biodiesel production | 17 |
| **Rural off-grid energy** | **(Million)** |
| Biomass cooking stoves in use | 570 |
| Household-scale biogas digester in use | 21 |
| Household-scale solar PV system in use | 2.4 |

Source: [4, 5, 6, 25]

Table 4: Final energy production scenario of Bangladesh

| Energy sources | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 |
|---|---|---|---|---|---|---|
| Gas (M.CU.M) | 11087 | 11926 | 12821 | 13783 | 14921 | 15920 |
| Petroleum (‘000’ MT)* | 3311 | 3557 | 3521 | 3762 | 3651 | - |
| Coal (‘000’ MT)* | 620 | 211 | 213 | 0.4 | 0.3 | - |
| Coal production from Barapukuria during 2008-2009 (‘000’ MT) | 109 | | | | | |
| Hydropower (GWH) | 680 | 837 | 803 | 868 | 934 | 950 |

Source: [7] (*Imports)

Table 5: Final energy consumption scenario of Bangladesh

| Energy sources | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 |
|---|---|---|---|---|---|---|
| Gas (M.CU.M) | 10324 | 11346 | 12106 | 12921 | 14020 | 15185 |
| Petroleum (‘000’ MT)* | 3315 | 3399 | 3657 | 3768 | 3782 | - |
| Coal (‘000’ MT)* | 638 | 229 | 261 | 74.4 | - | - |
| Hydropower (GWH) | 680 | 837 | 803 | 868 | 934 | 950 |

Source: [7] (*Imports)

demand of electricity is increasing day by day due to the growth of industry and population. To keep this in mind the alternative and renewable energy sources are coming forward. The off-grid solar PV system is increased remarkably during last few years. Now the capacity of solar PV electric system in the country is 25 MW (Table 6). At present the potential demand of power is 5569 MW, whereas, the supply of power is below 4000 MW. This led the energy starving for the country.

### 3.3. GHG Emission

The per capita $CO_2$ emission of Bangladesh is very low. The $CO_2$ emission is increased from 0.1374 ton/capita in 1990 to 0.2667 ton/capita in 2006 (Fig. 2). This figure is much lower compared developed country like Qatar 56.2 ton/capita and USA 19.0 ton/capita in 2006 [10]. The $CO_2$ emission from different commercial fuel use is estimated as 22.52 million ton ($CO_2$) from gas use and 10.74 from diesel use in 2008. The total $CO_2$ emission estimated is 35.22 million tonne in 2008 and this emission is increased to 36.36 million tonne in 2009 (Table 7). As per the report of MDG, the total $CO_2$ emission is estimated to be 37.82 million tonne in 2006 [11], whereas, the total $CO_2$ emission was estimated to be 13.44 million tonne in 1990 [3] and 14.42 million tonne in 1995 [12].

## 4. RENEWABLE ENERGY IN BANGLADESH

### 4.1 Hydropower

Microhydro and minihydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong Hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. There is one hydro power plant at Kaptai established in the 1960s with installed capacity of 230 MW. The potential of micro hydropower plant sites and capacities are shown in Table 8.

### 4.2 Biomass

Biomass is by far the significant energy source in Bangladesh, approximately accounting for 48% of the country total energy consumption [7]. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse etc. The major industrial biomass is

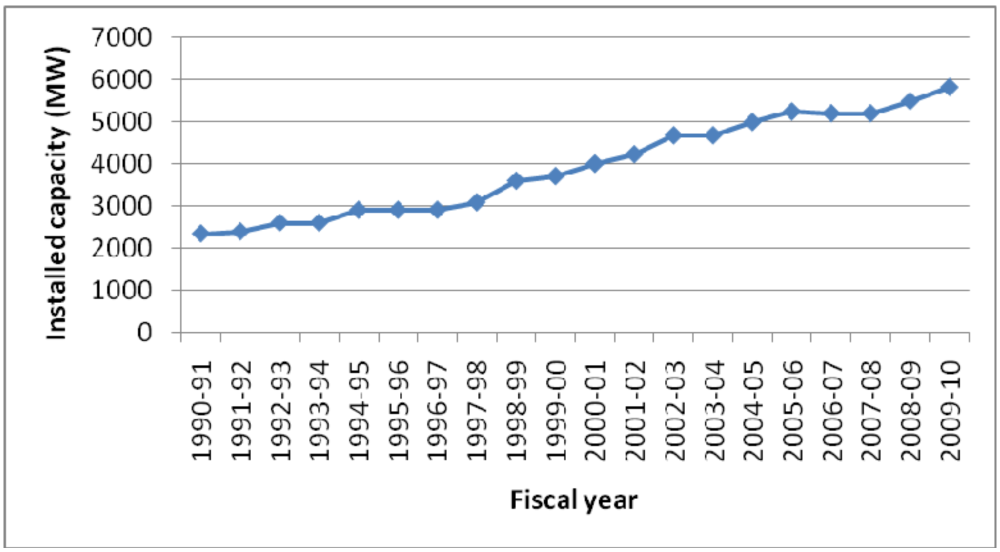


Fig. 1: Electric power capacity development in Bangladesh (Source: [8, 26])

Table 6: Electricity generation from different sources in Bangladesh (2009-2010)

| Fuel type | Installed capacity (MW) | Share in percentage | Generation (GWh/year) | Share in percentage |
|---|---|---|---|---|
| Gas | 4822 | 82.81 | 22661 | 88.44 |
| Diesel | 186 | 3.19 | 520 | 2.03 |
| Coal | 250 | 4.30 | 1030 | 4.02 |
| Furnace Oil | 335 | 5.75 | 996 | 3.89 |
| Hydropower | 230 | 3.95 | 414 | 1.62 |
| Total | 5823 | 100 | 25621 | 100 |
| Off-grid electricity development | | | | |
| Solar PV | 25 | | 36.5 | |
| Wind | 1.9 | | not recorded | |
| Biomass | 250 kW | | not recorded | |

Source: [8, 9, 26]

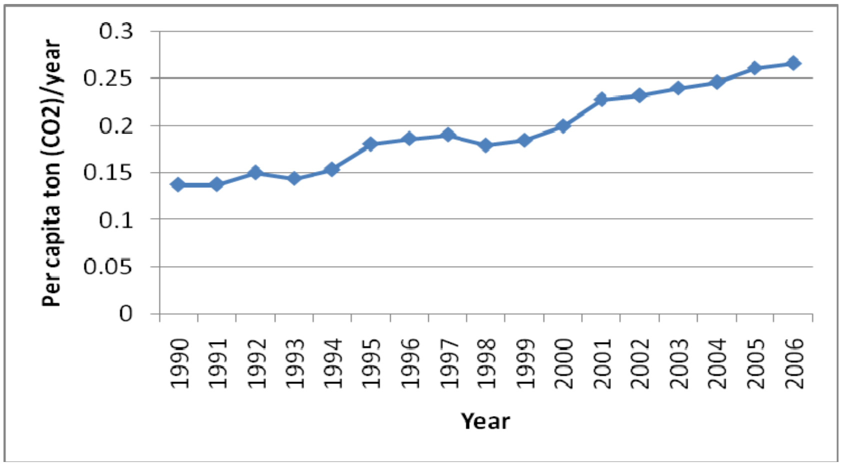


Fig. 2: Per capita CO2 emission in Bangladesh (Source: [11])

Table 7: Direct and indirect greenhouse gas emission from energy sector in Bangladesh

| Fuel type | $CO_2$ emission during 2007-08 (million tonne) | $CO_2$ emission during 2008-09 (million tonne) |
|---|---|---|
| Gas | 22.52 | 23.53 |
| Diesel | 10.74 | 10.96 |
| Furnace oil | 0.97 | 0.89 |
| Coal | 0.99 | 0.98 |
| Total | 35.22 | 36.36 |

Emission factors: Natural gas 51 kg $CO_2$ /GJ for thermal and 0.599 kg $CO_2$/kWh for electricity
Fuel oil: 73 kg $CO_2$/GJ for thermal and 0.893 kg $CO_2$/kWh for electricity
Coal : 88 kg $CO_2$/GJ for thermal and 0.955 kg $CO_2$/kWh for electricity
(Source: [13, 14] for emission factors).

Table 8: Micro hydropower potential in Bangladesh

| Site | Estimated average discharge (liter/s) | Available head (m) | Output power (kW) |
|---|---|---|---|
| Sailopropat Banderban | 100 | 6 | 3 |
| Madhabkundu, Moulovibazar | 150 | 10 | 7.5 |
| Faizlake | 42.5 | 12 | 2.5 |
| Chota Karina chara | 311 | 6 | 9.3 |
| Ringuli chara | 340 | 4.6 | 7.8 |
| Sealock | 1132 | 9 | 51 |
| Longi chara | 425 | 3 | 6.4 |
| Budia chara | 170 | 7.6 | 6.5 |
| Nikhari chara | 480 | 6.8 | 16.3 |
| Madhab chara | 996 | 9.9 | 49 |
| Total | | | 159.30 |

Source: [15]

used in rice processing sector. A huge amount of thermal energy is needed to parboil and dry to process 30 million tonne of rice. Bangladesh produces about 6.62 million tonne of rice husk energy. The biomass energy supply is shown in Table 9. Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh.

Table 9: Estimated biomass energy supply in Bangladesh (Million tonne)

| Fuel type | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 |
|---|---|---|---|---|---|
| Cowdung | 8.2 | 8.2 | 8.2 | 8.3 | 8.4 |
| Jute stick | 2.2 | 2.3 | 2.2 | 2.1 | 2.0 |
| Rice straw | 18.75 | 18.49 | 18.60 | 18.60 | 18.50 |
| Rice husk | 6.4 | 6.5 | 6.6 | 6.5 | 6.5 |
| Bagasse | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 |
| Firewood | 6.2 | 6.4 | 6.6 | 7.2 | 7.8 |
| Twigs & leaves | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 |
| Other wastes | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 |
| Total | 48.95 | 49.29 | 49.80 | 50.50 | 51.20 |

Source: [7]

#### 4.2.1. Rice Husk Energy for Rice Processing

Bangladesh has been producing a significant amount of rice husk food grains for the last four decades as shown in Fig. 3. The rice husk production has been also increased as the rice food grain is produced increasingly for the increased population of the country. The rice husk production increased from 3 million tonnes in 1972 to approximately 9 million tonnes in 2009. The growth rate of rice production was calculated to be 2.35% [7, 28, 29]. This bulk amount of rice husk is used mainly for process energy for rice parboiling. Share of rice husk energy used for rice parboiling is shown in Fig. 4. In Bangladesh, the annual estimated rice husk energy is consumed about 60 million GJ for drying and parboiling of 40 million tonne of paddy in 2010. This amount will increase to 92.5 million GJ in 2030 of rice husk for rice processing in Bangladesh [30]. Therefore biomass from agri-residues is playing a vital role for economic development of Bangladesh. GHG gas emission from rice husk is about 6.5 million tonne in 2010 and this emission will increase to about 11 million tonne in 2030. The GHG emission from rice processing sector is renewed within a short period during next growing season of rice plant ensuring sustainable environment (Fig. 5).

#### 4.2.2. Biomass Briquette

Biomass fuels are using beyond their regenerative limits due to high pressure of population. There is a severe shortage of wood fuel in Bangladesh amounting 2.1 million cubic meters [17]. The estimated total cooking fuel requirement of Bangladesh was about 36.5 million ton [18]. Only 7.5 million ton of wood fuel is available. Bangladesh is facing problem with the deforesting process due to lack of fuel in small cities, public centers, small entrepreneur, tea stall, restaurants and rural areas. To meet this increasing energy demand people collect the wood fuel form the forest. There is only 6% dense forest of total area of Bangladesh. Presently the deforestation rate is 4 hectare per hour [19]. Waste biomass could be a viable alternative option to wood fuel. The main problem of waste biomass is its low bulk density as well as this traditional energy is not in an organized form. Biomass briquetting process can transform this biomass into solid, high bulk density, regular shape which can be easily stored and transported. This briquette fuel is dry woody material and its calorific value range from 14.2 to 17.5 MJ/kg and it is equivalent to “B” grade coal in terms of calorific value [20]. It burns slowly with less smoke than wood fuel. Therefore, there is a potential to replace the wood fuel with this biomass fuel from wastes. Rice husk briquette fuel is very much popular in some area of Bangladesh. The production of rice husk briquette in some areas of the country is shown in Fig. 6. It is reported from the comparison study of performance of the fuel wood and rice husk briquette that one kilogram of rice husk briquette could provide the same service obtained from 1.63 to 1.67 kilogram of fuelwood [18, 21]. At present, about 1.11 million tonne of rice husk is available in Bangladesh for making briquette fuel [23]. From this amount of husk about 1.0 million tonne of briquette fuel could be produced. Annual saving of $CO_2$-equivalent from the use of 1.0 million tonne of rice husk briquette would be 1.82 million tonne of $CO_2$-equivalent from which the country could earn US$21.84 million annually. A case study of Mymensingh showed that $16.42\times10^3$

tonne of $CO_2$-equivalent would be saved by using rice husk briquette fuel instead of wood fuel that is equivalent to US\$197.04×$10^3$ annual worth (Table 10).

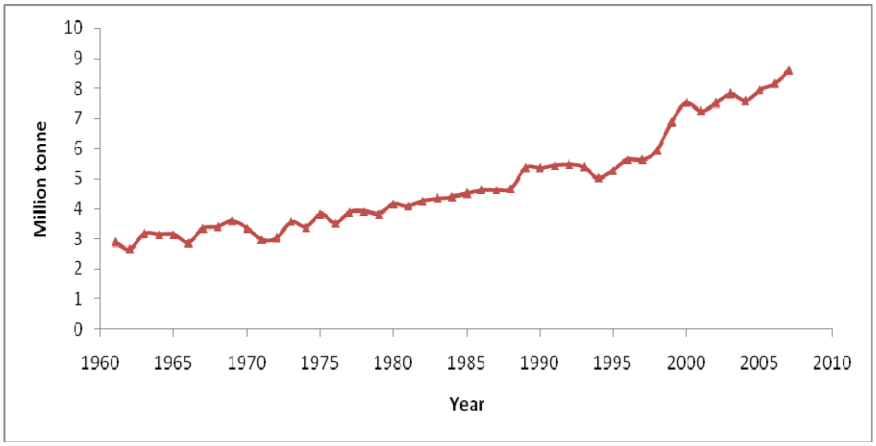


Fig.3: Rice husk production scenario in Bangladesh [7, 28, 29]

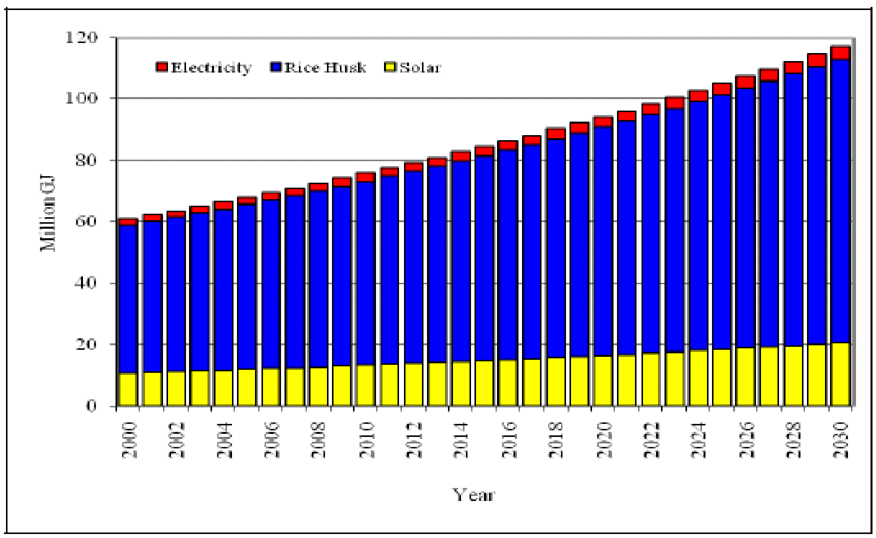


Fig. 4: Biomass energy share for rice processing in Bangladesh [30]

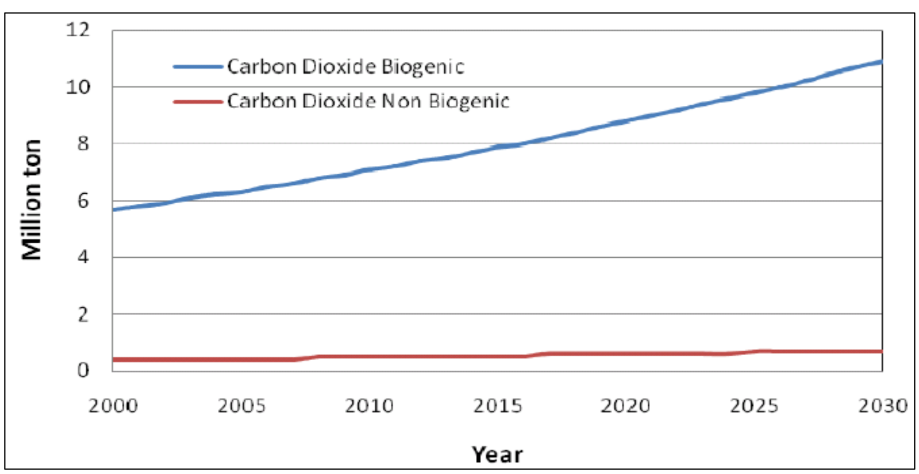


Fig. 5: GHG emission reduction by using biomass energy for rice processing [30]

### 4.3 Solar Energy

Bangladesh is situated between 20.30 and 26.38 degree north latitude and 88.04 and 92.44 degrees eat longitude, is an ideal position for solar energy harnessing. The ranges of solar radiation are between 4 and 6.5 kWh/m$^2$/day (Table 11). The bright sunshine hours varies from 6 to 9 hours/day (Table 12). Solar photovoltaic (PV) systems are in use throughout the country with over 300,000 household-level installations having capacity of about 25 MW (July 2009). So far in Bangladesh the solar electricity being produced from Solar PV panels, which includes, Solar Home System, Centralized (AC) System, Centralized (AC) market electrification, Water pumping, Rural Clinic, Roof top PV mini-grid system, Telecommunications, railway signaling, refrigeration, cyclone shelters etc, ICT training centers, community places etc By the 2012 one million households will be powered form solar PV panel and targeted to produce 50 MW power [9]. Scaling-up of solar PV systems assisted by the development partners are being implemented through the Rural Electrification Board (REB), Local Government Engineering Department (LGED), Bangladesh Power Development Board (BPDB) and other agencies implementing solar energy program. Renewable Energy Research Centre of the University of Dhaka has installed a model 1.1kW grid connected photovoltaic system. There is a strong potential for solar energy within the country. Solar Thermal Power/Concentrating Solar Power (CSP): The technology involves harnessing solar radiation for generation of electricity through a number of steps finally generating mechanical energy to run a generator. This technology needs to be disseminated in the country to supplement the power supply.

### 4.5 Wind Energy

Wind Energy has also made some inroads, but its potential is likely more limited to coastal areas islands with strong wind regimes. Although these coastal settings afford good opportunities for wind powered pumping and electricity generation, the problem of monsoon winds (March to October) exceeding the design parameters of most any wind machine must be addressed. Additional work is needed on technical requirements and opportunities for wind power in monsoonal regions, as extensive wind development has taken place in India (e.g., Tamil Nadu), where conditions similar to Bangladesh can be found. Presently there are 1.9 MW of installed wind turbines operating in Bangladesh, notably at Feni and Kutubdia. The potential sites of wind power and energy output per square meter are shown in Table 13.

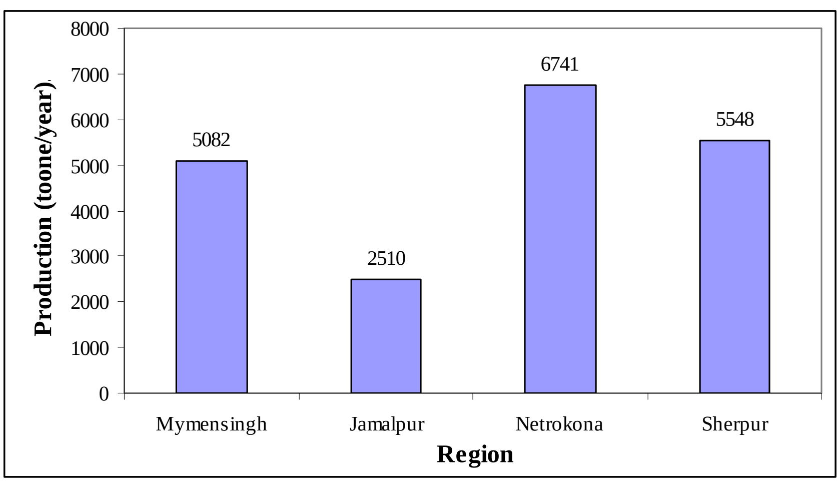


Fig. 6: Production of rice husk briquette fuel in selected areas of Bangladesh [21]

Table 10: Global emission CO2 saving with biomass briquette fuel options over wood fuel in Mymensingh town

| Option | Annual demand $\times 10^6$ | $CO_2$ equivalent $\times 10^3$ ton/annum | Net $CO_2$ saving over wood fuel, $\times 10^3$ ton/annum | Return from $CO_2$ abatement $\times 10^3$ US$/annum |
|---|---|---|---|---|
| Wood fuel | 14.244 kg | 17.370 | - | - |
| **Rice husk briquette fuel** | **9.039 kg** | **0.954** | **16.42** | **197.04** |

Source: [22] [$CO_2$ reduction trade, US$ 12.00/ton]

Table 11: Monthly global solar insolation at different cities of Bangladesh (kWh/m2/day)

| Month | Dhaka | Rajshahi | Sylhet | Bogra | Barishal | Jessore |
|---|---|---|---|---|---|---|
| January | 4.03 | 3.96 | 4.00 | 4.01 | 4.17 | 4.25 |
| February | 4.78 | 4.47 | 4.63 | 4.69 | 4.81 | 4.85 |
| March | 5.33 | 5.88 | 5.20 | 5.68 | 5.30 | 4.50 |
| April | 5.71 | 6.24 | 5.24 | 5.87 | 5.94 | 6.23 |
| May | 5.71 | 6.17 | 5.37 | 6.02 | 5.75 | 6.09 |
| June | 4.80 | 5.25 | 4.53 | 5.26 | 4.39 | 5.12 |
| July | 4.41 | 4.79 | 4.14 | 4.34 | 4.20 | 4.81 |
| August | 4.82 | 5.16 | 4.56 | 4.84 | 4.42 | 4.93 |
| September | 4.41 | 4.96 | 4.07 | 4.67 | 4.48 | 4.57 |
| October | 4.61 | 4.88 | 4.61 | 4.65 | 4.71 | 4.68 |
| November | 4.27 | 4.42 | 4.32 | 4.35 | 4.35 | 4.24 |
| December | 3.92 | 3.82 | 3.85 | 3.87 | 3.95 | 3.97 |
| Average | 4.73 | 5.00 | 4.54 | 4.85 | 4.71 | 4.85 |

Source: [16]

Table 12: Average bright sunshine hours at Dhaka city (average period 1961-1980)

| Month | Daily mean | Maximum | Minimum |
|---|---|---|---|
| January | 8.7 | 9.9 | 7.5 |
| February | 9.1 | 10.7 | 7.5 |
| March | 8.8 | 10.1 | 7.5 |
| April | 8.9 | 10.2 | 7.8 |
| May | 8.2 | 9.7 | 5.7 |
| June | 4.9 | 7.3 | 3.8 |
| July | 5.1 | 6.7 | 2.6 |
| August | 5.8 | 7.1 | 4.1 |
| September | 6.0 | 8.5 | 4.8 |
| October | 7.6 | 9.2 | 6.5 |
| November | 8.6 | 9.9 | 7.0 |
| December | 8.9 | 10.2 | 7.4 |
| Average | 7.55 | 9.13 | 6.03 |

Source: [9]

## 5. MITIGATION OF GHG EMISSION

Renewable energy is the key solution for mitigation of ghg gas emission as well as sustainable development. Bangladesh is now using biomass energy as main source of renewable energy. Biomass consumption in rice processing sector makes a sustainable carbon dioxide cycle. Rice husk briquette fuel is being used as alternative of wood fuel. The replacement of wood fuel by briquette fuel ensures the sustainable growth of forest and enrich carbon sink as well. Use of biomass energy in a efficient way can contribute to mitigate ghg emissions from

Table 13: Wind energy potential at selected sites of Bangladesh

| Station name | Height (m) | Mean velocity (m/s) | Energy density (kW/m$^2$) |
|---|---|---|---|
| Engineering Staff Collenge, Munshiganj | 20 | 3.54 | 0.0588 |
| BIT Campus, Chittagong | 20 | 1.75 | 0.0129 |
| Sitakundu | 20 | 2.30 | 0.0449 |
| Khagrachari | 20 | 1.18 | 0.0140 |
| Kutubdia | 20 | 3.57 | 0.0572 |
| Kuakata | 20 | 4.18 | 0.0901 |
| Pakshey | 20 | 2.77 | 0.0338 |
| Naogaon | 20 | 1.92 | 0.0148 |
| Panchagarh | 20 | 1.44 | 0.0118 |
| Kishoreganj | 20 | 2.24 | 0.0194 |

fossil fuel. Biogas is being used as cooking fuel in rural areas and for producing electricity in a small scale in some rural and peri-urban areas. Solar home system for lighing at night in rural areas is being used and the use of solar photovoltaic is increasing and replaces kerosene fuel. The magnitude of total installation of solar photovoltaic is about 25 mw a remarkable success story of Bangladesh.

## 6. CONCLUSION

At present the potential demand of power is 5569 MW and the supply is below 4000 MW. The country is dependent on the imported petroleum that is big burden on the economy. To meet the extra demand of power people are trying to use the electricity from solar PV, but the country economic situation could not permit for extensive of solar electricity at this moment. The total capacity of solar electricity is 25 MW. The per capita emission is only 0.2667 tonne ($CO_2$) per year that is still much below the world leading countries. However, Bangladesh is one of the most vulnerable countries to climate change effect in the world. In this regard, renewable energy resources appear to be the one of the most efficient and effective solution for clean and sustainable energy development in Bangladesh. Biomass is dominating to meet the rural energy in the country. The geographical location of Bangladesh has several advantages for extensive use of grid connected solar electricity and stand alone solar PV system. This article presents a review of the potential and utilization of the renewable energy sources in Bangladesh.

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# ECO-FRIENDLY ENVIRONMENTAL TECHNOLOGY AND CONSTRUCTION ENGINEERING TO HANDLE THUNDERSLAPS OF CLIMATE CHANGE FOR SUSTAINABLE DEVELOPMENT

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## SUMMARY

Natural resources is being abused by the unfair activities of mankind against the harmony of the nature, uneven deterioration, unthinkable depletion, uncontrollable change, non-restricted urbanization, non-conformity of technical progress by leaps and bounds beyond the equilibrium not coping with the as usual natural processes without thinking of the demand of future generation for their survival causing severe environmental degradation and culprit pollution in soil, water and air media. Such activities cause uncontrollable emission of green house gases GHGs enhancing climate change unpredictably and ultimately causing natural clamities indiscriminately throughout the world leading to the natural imbalance enhancing the collapse of environmental, economic and social structure and sustainability. If the situation goes ahead the global life and environmental biodiversity will be obviously collapsed if proper initiative and adequate actions against GHGs emission and the thunderclaps of the subsequent climate change effects is not taken at the moment. The proper and timely initiatives such as increasing the flexibility of environmental managed systems in the form of eco-friendly environmental technology and construction engineering based on the local situation by allowing incremental adjustments; reversing practices that encourage anti-natural systems, improving social awareness and preparedness, and public education programs should be made as the priority basis for regaining green systems leading to adjustable sustainable development.

**Keywords:** Climate change, GHGs, natural imbance, environmental technology, construction engineering.

## INTRODUCTION

Nothing has been created worthless in the universe in accordance with the Law of Consevation of Mass ‘nothing can be created nor destroyed but conserved’ or according to the Law of Conservation of Energy ‘energy canot be created nor destroyed but transferred from one form to another’ that means everything is univershally conserved as the natural phenomena from the time immemorial. Obviously natural system is always sustainable maintaining univershal equilibrium in all respect with interdependence of one living bodies to another; for instance dependence of men for air to the atmosphere, for water to the water bodies, for food to the crops, fruits, vegetables, fishes, animals, birds etc. Similarly human and animal excreta are the main food components for crops, vegetables, trees etc. excreta and feces supplying the highest nutrients when urine is used mixed with a particular ratio of water. Human and animal faces are again the source of fuel and energy. More recently introduced eco-village concept have shown the feasibility of creating an ongoing earth-keeping process of housing, cultivation, plantation, sanitation, fishing, poultry, animal husbandry and their proper monitoring to use the excreta of one as the source of wealth for other for example the human and animal feces as fertilizer in cultivation as shown in figure 1 to explain waste-resource flow of different component of an Eco-village establishing nothing has been created worthless[1].

Unfortunately due to careless and cautiousless of men, nenatural system is being disturbed, disrupted, despoiled, degraded, defamed, deteriorated, corrupted, polluted, ruined, tarnished and infected for the long time collapsing the sustainability owing to unruly global climate change beimg happened unexpectedly by recent decades since 60s of the last century with rapid industrialization in the developed countries of the first world due to direct emission of green house gases (GHG) derived from carbon and carbon compounds to atmosphere without treatment or lack of adequate treatment that being added by fast industrialization of two new economic giants China and India who are not at all ready to reduce Green house gas emission with greatest GHG emitter the USA as expressed in Cope 09. Kankun Coference on climate change in 2010 also ended in smoke to be consencios by the world countries to lessen the severe climate change effects due to GHGs emission generated not

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arithmetically but geometrically by leading GHGs emitters. Unfortunately such emission increases the global temperature severely leading to climate change that cannot be always adopted by the living organisms especially in the developing countries where adaptation capacity is very poor. Not only the less adopted countries but also developed countries are in the verge of climate change effects that are reflected in the recent unpredicted natural clamities like cyclone, tornado, tsunami, floods, earthquakes, landsliding etc. occurred in the USA, Australia, China and many European countries in the last two or three decades where the general publics were in the brink of crucial situation and harshly affected by the direct and indirect impacts of global climatic change that obviously turned down the sustainability. Direct effects comprise changes in the hygro-thermal stress response of humans, atmospheric pollution, climatology, global energy, water quality and availability, biodiversity i.e. biological processes and ecological systems etc. threatening the habitat; indirect effects include the potential for the spread of vector-borne diseases outside in the current range leading to more illness. It is presumed that climate change will cause sea level rise in a vast low lying areas of the world such as Fiji, Western Samawa, Maldives, and Bangladesh etc. Particularly one-third of Bangladesh can be go down to sea losing a large territory; besides, desertification in the northern and north-western part of the country, tremendous declination in the agricultural and food production affecting food security seriously, natural disaster and hazards such as cyclone, tsunamy, SIDR, drought or heavy rainfall in the uneven seasons, deforestation, dieing of the rivers, streams, canals, and other wetlands, geomorphological change in the subsurface, land pattern, and river beds, wind direction, wind intensity, wind speed, transportation facilities, change in the adaptation of tourism may inflict the greatest damage on the environment and infrastructure, and take the heaviest toll of human life leading to the unfathomable social and economic loss.

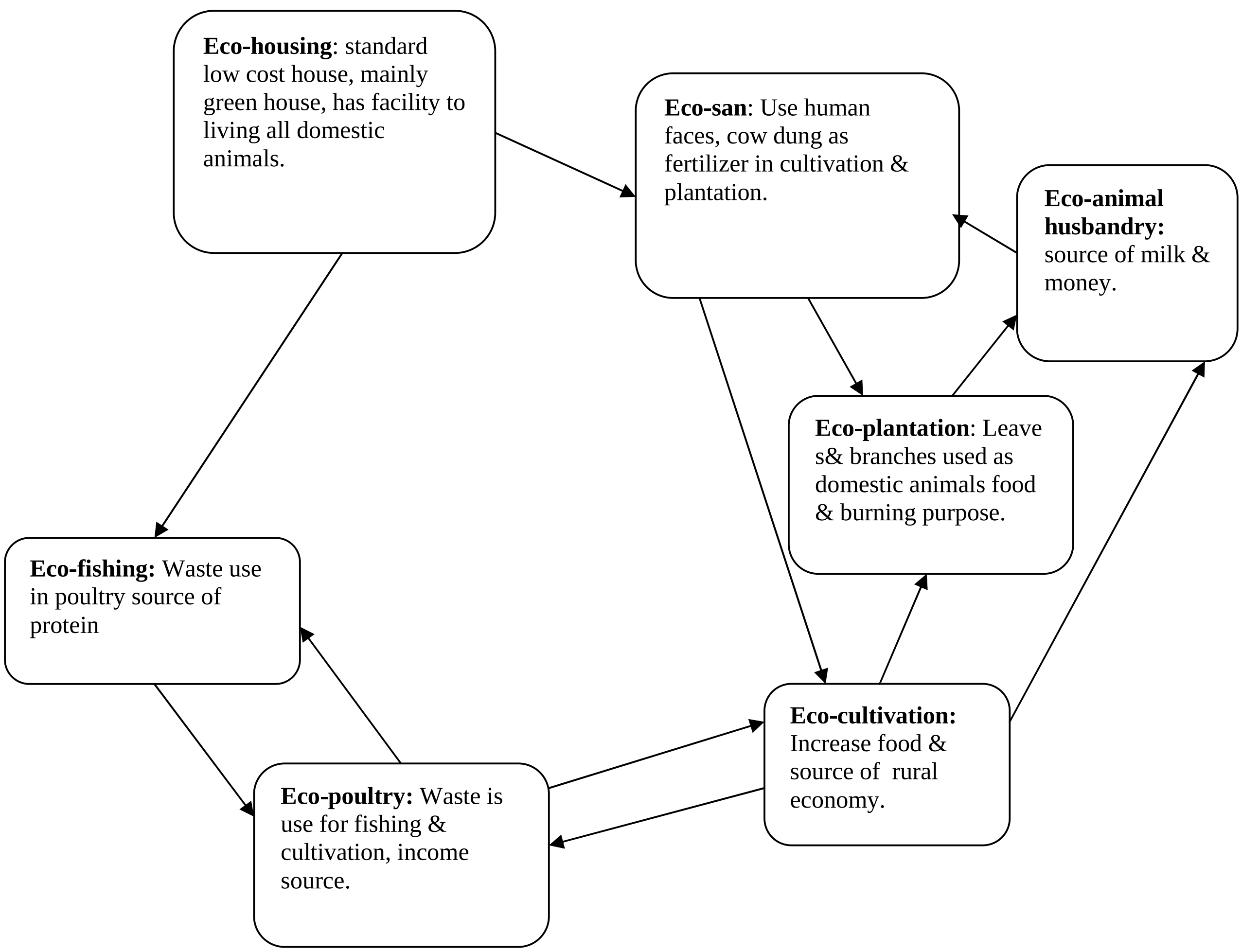


Figure 1: Waste-Resource flow of different component of an Eco-village establishing nothing has been created worthless

## GLOBAL EFFECTS OF CLIMATIC CHANGE THAT CAUSES NATURAL IMBLANCE

Climate change is not only a social, an economic and a political concern but also a humanitarian issue because it will directly affect innocent victims and it is an ecological issue because of our anthropogenic interference with the Earth's atmospheric and oceanic systems. Climate change involves impacts that will have consequences for people who are bystanders to economic affluence and consumption patterns. Extreme climatic events including flooding, sea level rise, storm impacts, drought, heatwaves and wildfires are projected for many regions around the globe[2]. The Nobel-prize winning Intergovernmental Panel on Climate Change (IPCC) noted ahead of the Bali meet that accelerated melting of the Himalayan ice caps and incremental rise in sea levels would likely increase the severity of flooding in the short-term during the rainy season and greatly magnify the impact of tidal storm surges during the cyclone season. The latest UN report on climate change says mankind is "very likely" to be the cause of global warming and predicts a rise in temperature of between 1.8-4$^0$C (3.2-7.2$^0$F) by 2100. It also projected that sea levels were most likely to rise by 28-43cm, and global warming was likely to influence the intensity of tropical storms. Over the last century humans have begun to have a discernible ifluence on the earth's climate, causing it to warm [3,4]. Since the beginning of the industrial age, the concentration of $CO_2$ in the atmosphere has increased from 280 to 350 parts per million[5]. The increase of $CO_2$ in the atmosphere has been more rapid in recent years. The major reason for this increase may be attributable to the extensive use of fossil fuels, such as oil, coal and gas. The destruction of carbon sink by excessive land use and deforestation might be another important cause for the atmospheric $CO_2$ increase over the last 100 years[6]. It has been projected from the historical data and simulation models that the $CO_2$ level in the atmosphere will reach 600 ppm in the last half of this century[7]. The increase of $CO_2$ and several other green house gases such as methane, nitrous oxide, chlorofluorocarbons (CFCs) could cause an increase global temperature of about 4.2°C and possibly a change in precipitation patterns and amounts in some regions[8]. Global warming due to increasing concentrations of green house gases poses a threat to human society by changing the living and working environment to which society has adapted over many generations[9]. Agricultural impacts of climate change could have profound effect in poor and developing countries. Indeed, late heavy rains are often just as disruptive as the late arrival of rain, causing flood damage to established crops at a time when it is too late to replant even to rice having high water requirements which is the principal crop of the Asian humid tropics and the staple food for perhaps 60% of the world's population[10]. The productivity of natural vegetation and, especially, grain yields has increased and will increase considerably in the future due to the increase of carbon[11] and for the use of chemical fertilizer; but it is not universally suited with the climate everywhere. The impact of climatic change on regional ecosystems (particularly forests) could alter the hydrological characteristics of watersheds[12]. The effects of climate change will not be the same everywhere. Warming is predicted to be greatest over land, at high latitudes, at higher elevations, and in winter and early spring. The Intergovernmental Panel on Climate Change[13] projects the following changes in extreme weather events and climate during the 21st century:

**Very Likely (90-99% chance)**

It includes higher maximum temperatures and more hot days over nearly all land areas; higher minimum temperatures, fewer cold days and frost days over nearly all land areas; narrower daily temperature range over most land areas; increase of heat index (a combination of temperature and humidity that measures effects on human comfort) over most land areas; more intense precipitation events in many areas; larger year-to-year variations in precip itation over most areas where an increase in mean precipitation is expected; continued decrease in northern hemisphere snow and ice cover; and continued rise in mean sea level.

**Likely (66-90% chance)**

It includes increased summer drying and risk of drought over most mid- latitude continental interiors; increased risk of drought and floods occurring with El Niño events; increase in tropical cyclone (hurricane) peak wind intensities in some areas; increase in tropical cyclone mean and peak precipitation intensities in some areas.

Many of these trends with deteriorated veffects are observable in 20th century climatic records [13] as discussed below.

***Effects on Water Resources*** includes greater evaporative loss from lakes and reservoirs; greater evaporative loss from soils and plants (evapotranspiration); less runoff and more soil drought for a given amount of precipitation; smaller mountain snowpacks; earlier snowmelt; and reduced groundwater recharge.

***Effects on Transport System*** includes increased traffic on less heated route to avoid heat of extreme heated route; increased maintenance of asphalt surfaces on extreme heated routes due to deformation of the roadway from heat[14]; increased probability of damage to roadways due to increased brush fires in heavily vegetated areas; increased risk of heat stress to maintenance employees; airport delays or accidents due to loss of lift in hot, low density air [14] and/or possible need to reduce aircraft payloads or lengthen runways to compensate for loss of lift; damage or accidents due to warping of rail lines[15]; and blowing dust that would create hazards for travel on roadways, rail lines and airports[15].

***Effects on Natural Systems*** includes cimate change and global warming are expected to impact the distribution and biological characteristics of plants and animals, and affect individuals, species, populations, and ecosystems through altered spatial distribution, population numbers, geographic range, and migration of individual species; growth and physiology of individuals within a population; timing match (i.e., mismatches between climate patterns and a species' life history events); diversity of prey, predators, and competitors within communities; species composition & distribution within ecosystems; migration & movement corridors; exotic & invasive species introductions and distribution; parasite & disease risks; and ecosystem functioning (e.g., nutrient cycling) and structure [16,17, 18].

***Impacts on Ecosystem***

*Aquatic Ecosystems*

Covich et al.[19] report that global warming is expected to reduce montane snowpacks, increase stream temperatures, advance seasonal hydrographs, reduce soil infiltration, and increase evaporation. More rapid runoff and higher peak flows would increase bank erosion and sediment transport, and silt up spawning gravels. Earlier snowmelt and higher temperatures are expected to result in lower summer streamflow[20]. Lower dissolved oxygen and warmer waters will stress many species of fish and invertebrates and increase mortality, particularly in late summer. Spring peak flows during snowmelt are forecast to be lower and earlier. Other effects included: reduced surface water availability, especially during summer months; less water available to sustain aquatic systems; decreases in dissolved oxygen; reductions in streamflow in late summer [20]; less instream habitat for invertebrates and fish; significant changes in species composition and productivity; warming of groundwater and spring- fed streams; and adverse effects on eggs and larvae of fish.

As a result of increased evaporation with increasing air temperature, declines are anticipated in lake levels, water renewal rates, stream flows, the extent of and water levels in wetlands, soil moisture, and groundwater levels [21].

Fish in streams of any country may be particularly vulnerable to local or complete extinction due to global warming [22]. Effects of expected global warming on fish includes increased extinction rates for endemic fish species and isolated local populations in streams; shifts in the distributions of cold-water fish species northward and to higher elevations [19]; increases in warm-water fish species; coldwater fishes to be replaced by warmwater species such as suckers[19]; climate warming favoring non-native species such as brown trout, or rainbow trout at the expense of native species such as cutthroat or bull trout in some habitats within the Rocky Mountain region; fragmentation of remaining coldwater fish populations into isolated, high-elevation enclaves; loss of geographic range in the Rocky Mountains of suitable habitat for trout of 17 to 72% [23]; direct adverse effects on trout reproduction[24]; and reduced recruitment of all fish species[25].

Other changes affecting fish include permanent streams becoming intermittent and shorter flow duration in temporary streams[7], greatly reduced area of wetted channel in ephemeral streams, population declines, loss of habitat, changes in the community, negative effects from changes in water quality, movement within catchments, and crowding of fish in reduced microhabitats.

Effects of global warming on lakes and reservoirs includes insufficient oxygen in deeper, cool water in late summer to support large game fish; reduced potential recreational uses of reservoirs[26]; altered lake stratification by mid to late summer[19]; reduced dissolved oxygen concentration; lowered level of the thermocline; reduction in coldwater habitat[20]; loss of habitat for coldwater fish species in lakes[27]; extinction of endemic fish species already close to their lethal thermal limits; reduced storage of surface flows in reservoirs through the summer and fall; increased evaporative losses; increased potential for production of nuisance algae; declines in water quality; and increasing salinity.

Expected effects of global warming on wetlands include drying trends, changes in structure and functioning, reduced extent of semi-permanent and seasonal wetlands; and gradual replacement of original wetland species species that are typical of drier, transition or upland sites[28].

*Terrestrial Ecosystems*
Changes in terrestrial ecosystems will likely include changes in population density, shifts in range distributions either poleward or upward in elevation, and changes in the timing of life history events such as migration or initiation of breeding. Anticipated effects of climate change on phenology (timing of critical life history events) include earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians and earlier shooting and flowering of plants. Changes in timing of bird migration and plant growth may not be synchronized, resulting in a mismatch in the timing of migratory bird offspring food availability and the timing of chick hatching.

Effects of climate change on plants includes displacement of biome boundaries; migration of the climatic boundaries of biomes northward; native plant migration and adaptation; new combinations of plant species[29]; reduced local biodiversity; increased susceptibility of plant communities to natural and anthropogenic disturbances and eventual reductions in species diversity[30,31,32]; stranding of trees in unsuitable habitat by rapid climate change[33]; changes in ecosystem composition and function[34]; invasion of alien plant species into natural ecosystems; and establishment and growth of new vegetation assemblages[29].

***Other Potential Environmental Quality and Health Issues***
- Extreme storm events (flash floods, tornadoes): Includes direct effects, such as injury and/or death, as well as indirect effects on health from damage to infrastructure (housing, and power, water and sewer systems)[35].
- Water-borne diseases (*E. coli*, *Cryptosporidium*, *Giardia*): May increase if flooding results in damage to sewer or septic systems, or runoff of animal waste into surface waters[35] and shallow ground water.
- Water quality: Drought may increase salinity and concentrations of many natural and man-made contaminants in surface waters[35].
- Tick-borne infectious diseases (e.g., Rocky Mountain spotted fever): These are potentially climate-sensitive, but responses to possible climate change are not well understood.
- Food quality and quantity: Global agricultural productivity may increase in some regions and decrease in others. Significant decreases would threaten nutritional status if costs and/or availability of food were affected[36]. Even if total caloric intake is not affected, reduced availability of certain foods (fresh vegetables, fish) could reduce the nutritional value of diets. Some studies suggest that while increased levels of atmospheric carbon dioxide may increase crop productivity, nutritional quality may be detrimentally affected[37,38].
- Pollen- induced disease (allergic reactions, asthma, sinusitis): These diseases may increase with a longer vegetation growing season, especially if precipitation increases, either in the average or in extreme years[35]. Also, some plants grown at higher atmospheric $CO_2$ concentrations produce much greater amounts of pollen[39].
- Psychological effects: Adverse mental health consequences may result if climate change causes social and economic disruption, and as a result of perceived ecological disruption, frequent severe storms, and disease outbreaks. These effects are poorly understood and have rarely been considered[36].
- Conflict and war: Disruption of agricultural production, water resources, human diseases, and inundation of coastal zones may exacerbate tensions and conflict in areas such as the Middle East, southern Africa, and southern Asia, raising the likelihood of international conflict and war in which the United States may become involved[36].

All such impacts of climate change seriously degrade the global environmental situation especially curving the Pillars of Sustainability as shown in figure 2.

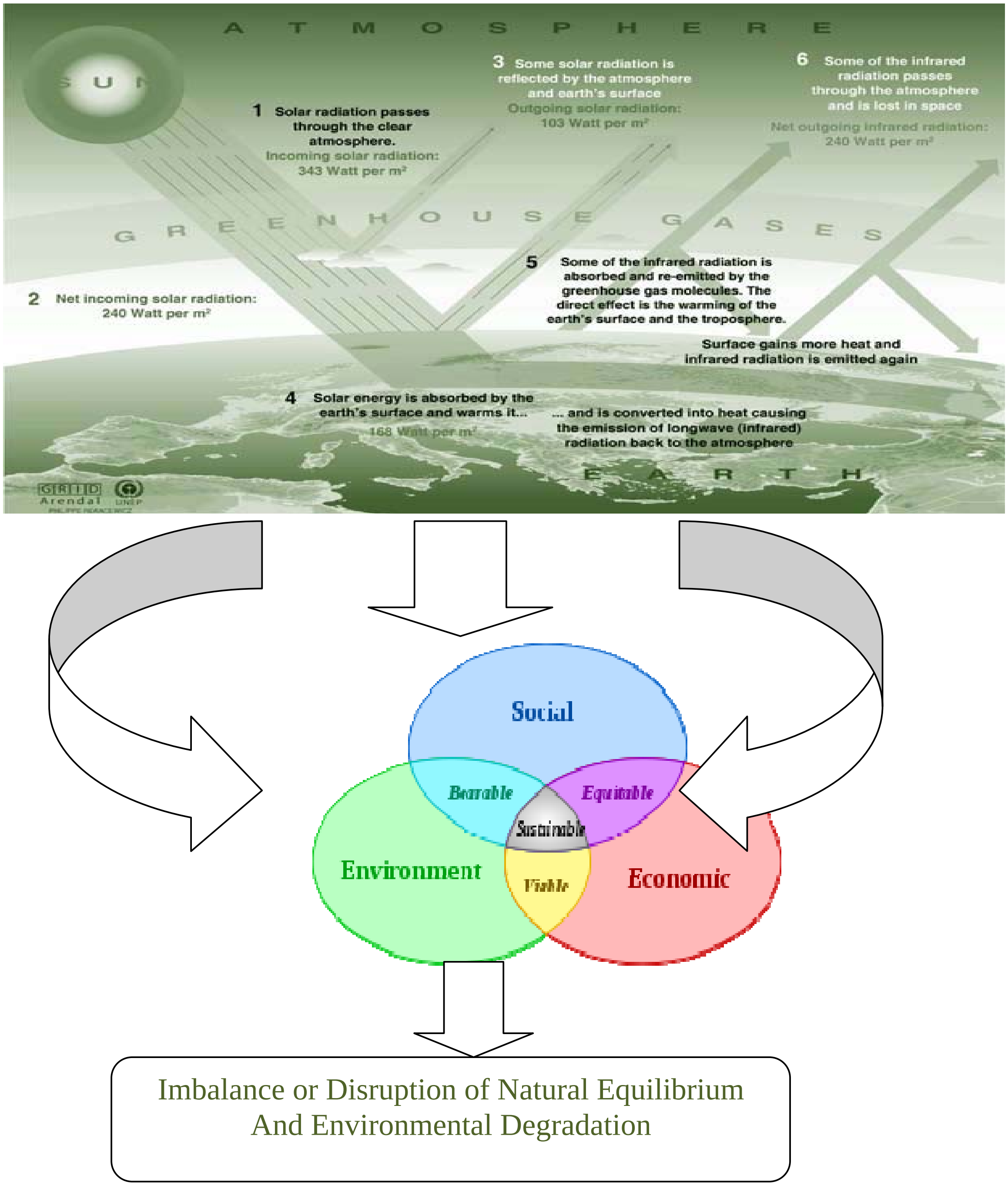


Figure 2: Effects of Climate Change on Three Pillars of Sustainability

**What to Be done to Tackle Imbalance or Disruption of Natural Equilibrium and Environmental Degradation?**

It is the high time to develop eco-friendly technologies in the field of (i) environmental engineering to handle the thunderclaps of climate change and growing environmental degradation caused by unplanned human activities and indiscriminate abuses of natural resources causing imbalance to nature indiscriminate and (ii) construction engineering to construct environment friendly construction materials to reduce GHGs and to use them successfully in practice. This will give an ample scope for saving the environment and minimizing imbalance and disruption of natural equilibrium of the global nature through the mitigation of environmental degradation including reducing and consuming GHGs and adapting to CC threats as shown in figure 3.

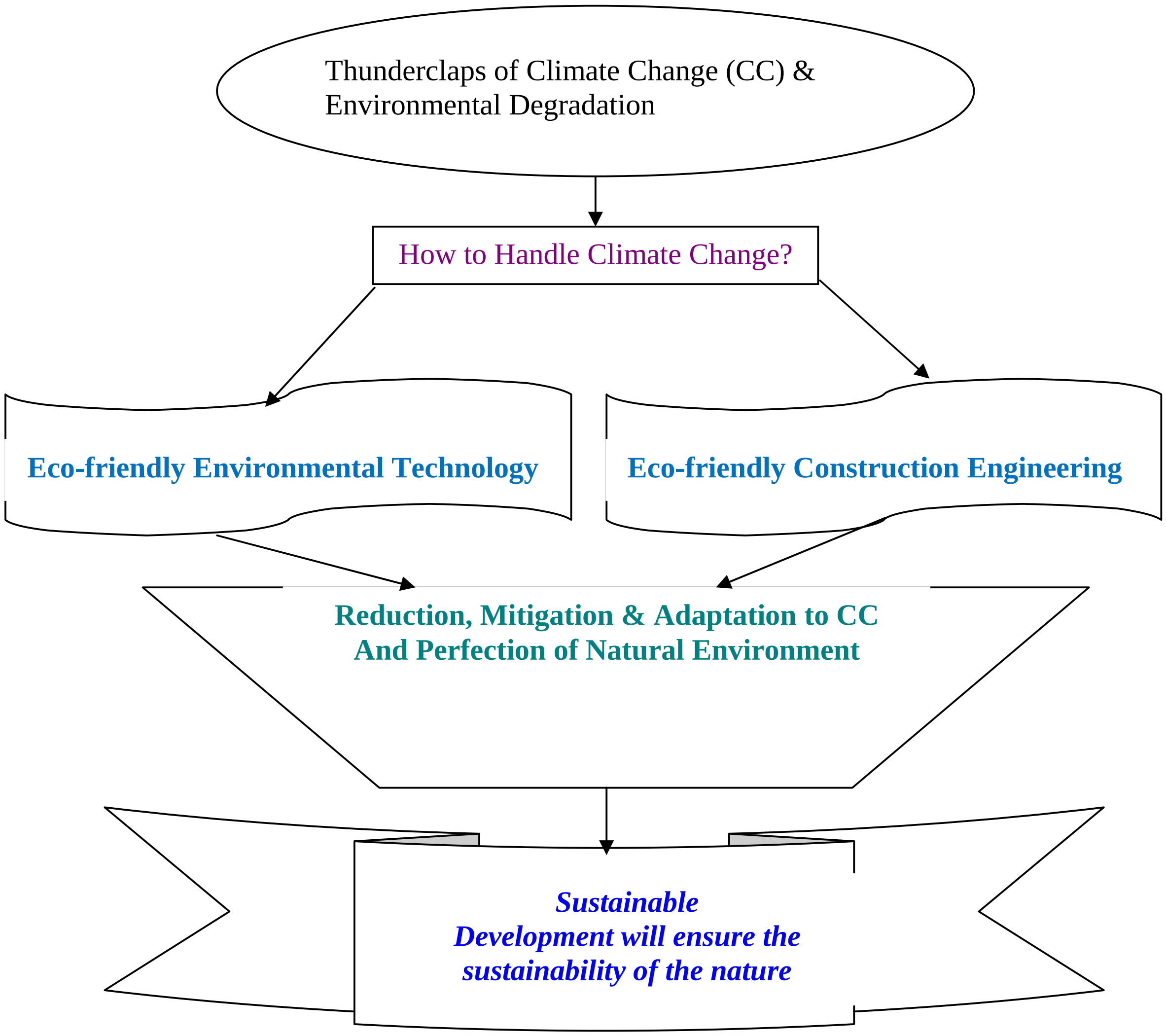


Figure 3: Measures to be taken for tacling CC Effects

**Eco-friendly environmental technology**
Environment friendly ecological technology will be able give the proper guidelines to curve the environmental degradation significantly if used successfully, virtually and efficiently in proper ways in order to curtail green house gas emission especially carbon emission, to control and mitigate the adverse effects of climate change in Bangladesh in the field of

***Eco-agriculture using eco-fertilizers;*** Eco-agriculture will be enhanced by direct use of separated urine mixing with pure water, different types of organic fertilizers, urine supported composts etc. as well as the use of eco-friendly pest control techniques etc. This will save the natural gases for producing chemical fertilizers which can be used for power generation. Mainly eco-agriculture will help to increase the production of the crops per hactre at least double of the current production by chemical fertilizers; also the taste of the vegetables, fruits and other edible foods produced by eco-fertilizers will be improved significantly.

***Eco-industry by installing eco-industrial parks;*** In the first stage eco-industrial parks will be considered for selected type of industries using eco-friendly measures for various industrial operation such as eco-friendly treatment facilities, effective solid waste separation and inventory control at source based on the ecology of industry. Practice of installing eco-friendly industries and eco-industrial parks in both of the private and public sector will reduce the GHGs significantly for better living and amenity.

***Eco-forestry;*** Eco-forestry using environment friendly forestry techniques avoiding alien (foreign) species emphasizing on the development of high yield native species derived from the research finding of eco-forestry under the sub project will increase forest-share to the country. In the long run, increased forest zone, protected forest zone, restricted forest belt will consume GHGs significantly. Besides, long term forest conservation and ecological forest development will develop timber and furniture industry in the planned way that will earn foreign currency for Bangladesh. Side by side ***Eco- tree plantation and socio-ecological forestry will*** ensure efficient participation of people from all walk of life of the society in tree plantation and forestry that will enhance the socio-economic status of the general publics.,

***Eco-tourism;*** Eco-tourism guidelines developed under the sub-project will provide the appropriate guidelines for managing vast wetlands, hills and forest whatever be the mangrove or aquatic as well as developing eco-park, eco-garden, zoos/mini zoos etc. in the environment friendly way throughout the country that will open the new door to earn plenty of foreign like currencies from tourism.

***Ecological solid waste management;*** Ecological solid waste management utilizing environment friendly source separation, Rs, animal feeding, vermiculture etc. instead of incineration and GHG emitting treatment system will improve the solid waste management status significantly leading to zero waste as much as possible.

***Ecological sanitation;*** Ecological human waste management using ecological sanitation through separation of urine from feces installing eco-toilets will curtail the waste load as well as find out a means for using eco-fertilizers, bio-gas, bio-electricity etc.

***Eco-friendly marketing;*** Eco-friendly marketing will provide the guidelines for eco-friendly marketing and marketing facilities in the green way to preserve foods and food materials.

Eco-friendly environmental technology can be effectively used for the development of Bangladesh in the field of agriculture, industry, urbanization, transport, fishery, animal husbandry, live-stock, poultry, forestry, tourism, river and lake water management, waste water management, solid waste management, human waste management, industrial effluent management, ecological water conservation, minimizing green house gas emission especially carbon emission etc., to increase food and crop production, to protect bio-diversity and to ensure sustainability. Planned and broad based application of eco-friendly environmental technology can conserve the natural systems at the urban areas (eco-model-town) to save the valuable water resources, to re-use the waste and refuse whatever be the liquid or solid in the cyclic process of closing the loop in sanitation and overall management in stead of disposal of linear concept leading to zero waste, to reduce the emission of green house gases especially carbon emission, to consume green house gases and to prevent sea level rise significantly *leading to sustainable development by nature conservation and up-keeping biodiversity.*

**Eco-friendly construction engineering**

Environment friendly construction engineering is essential to provide with appropriate guidelines in the construction arena that was already the point of controversy in countries like Bangladesh especially in Capital City Dhaka and other earthquake prone cities like Chittagong and Sylhet. Planning, design and developing eco-friendly construction engineering with proper guidelines based on the findings of direct or circumlocutory research whatever be the field research or non-field research as well as extensive literature survey to use practically and efficiently in proper ways in order to trim down GHG emission especially carbon emission, to control the effects of climate change that would be effectively used in the field of construction through the use of environment friendly construction materials like

- ***introducing eco-housing (using eco-concrete, eco-cement, eco-brick, eco-paint, eco-beam, eco-column, eco-roof, eco-slab, eco-wall, eco-door/windows etc. for hosing);***
- ***constructing eco-transport way (like railway and waterway);***
- ***constructing eco-toilets/latrines through eco-sanitation,***
- ***eco-cross dams etc.***

will reduce green house gases (GHGs) significantly, develop the measures to reduce, mitigate and adapt climate change problems and ensure sustainable development with engineering and technological techniques.

Developing eco-friendly construction engineering and its use will provide tremendous benefits in the field of construction for instance

- ***Eco-housing;*** Introducing eco-housing for different component of building materials as much as possible will improve the urban environment reducing GHG emission as well as ensure the environment friendly life in the urban agglomerations and peri-urban/semi-urban regions. Eco-housing will also ensure the enough spaces around the house for easy and fresh air circulation, eco-garden, lawn, roads etc.
- ***Eco-transport ;*** Eco-transport system using CNG and bio-fuels instead of diesel, petrol, gasoline, furnace oil, kerosin etc. in motorized vehicles as well as introducing waterway and railway in large scale instead of roads and highways will reduce GHG emissions as well as will make transport system lively and more comfortable.
- ***Eco-toilets/latrines;*** Constructing eco-toilets/latrines through eco-sanitation will improve sanitation aystem as well as add to the lively agricultural system, will supply environment friendly bio-gas, bio-electricity etc.
- ***Eco-cross dams etc*.** The sub-project will give the guidelines to construct eco-friendly cross dam as the best preventive measure against sea level rise due to climate change. Such attempts will open a new door of reclamation of the new lands from the Bay of Bengal too.

**Eco-friendly construction engineering** will reduce the fuel crisis using eco-friendly fuels in transports-vehicles, introducing eco-transport, eco-vehicles etc., using eco-friendly energy sources; constructing eco-friendly waterway and railways; developing eco-friendly fishery, fishery-cum poultry, tourism etc.; introducing eco-friendly sullage management, waste water management, industrial effluent management, solid waste management, leading to zero waste; building eco-friendly houses, eco-village, eco-towns using eco-concrete, eco-brick, eco-cement, eco-paint, eco-beam, eco-roof, eco-walls, eco-roofs, eco-column, eco-slabs, eco-doors, eco-windows, eco-toilets etc. through eco-friendly construction engineering.

## CONCLUSION

Extensive use of such eco-friendly means will ensure pollution free environment reducing, and consuming GHGs and adapting to CC. If the environment friendly construction technologies become popular and cordially accepted by people from all walks of life through proper motivation, creating awareness through mobilization and publicity etc. many national problems like energy crisis, unplanned urban housing, non-environment friendly transport issues etc. will be handled efficiently. Such kind of environment friendly technologies being based on locally available natural means and resources will be most cost effective and cost saving. Ultimately eco-friendly above measures will save the billions of foreign currencies as well as increase the GDP significantly.

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# WATER SENSITIVE URBAN DESIGN IN GOLD COAST AUSTRALIA

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## ABSTRACT

Gold Coast is one of fastest growing areas in Australia and Gold Coast City Council (GCCC) has been experiencing challenges of sustainable urban development over the past several decades. The Water Sensitive Urban Design (WSUD) in overcoming these challenges is something GCCC has been implementing as a statutory requirements since 2006. Strong commitments of the stakeholders, development of guidelines and other tools, training and awareness programmes and ongoing programs enabled GCCC to implement successful WSUD elements in various parts of Gold Coast.

The concept of WSUD has been in practice in GCCC for the past 8 to 10 years to supplement the 'end of pipe' solution in order to provide a holistic approach of integrated stormwater quantity and quality management. WSUD emphasises the benefit of stormwater and waterways as a resource and an asset, rather than the conventional view of stormwater merely as a nuisance. It provides many opportunities to integrate water features in urban design and to enhance the social and environmental amenity of urban developments.

In the early stages of implementation, some developments using the WSUD elements experienced some challenges due to poor integration in urban design, lack of protection during construction of land development and building phases. Therefore, a comprehensive programme was undertaken to overcome challenges in successful implementation of WSUD such as preparation of WSUD guidelines, awareness campaign about design, construction and maintenance of WSUD. GCCC released the WSUD Guidelines in June 2007 to assist the development industry and the council officers to promote a holistic approach in the planning and design of urban development that aims to minimise any adverse impacts on our natural environment and coastal ecosystem.

This paper describes the overview of the WSUD guidelines emphasising the update that have been incorporated based on data from Gold Coast and other similar geographic areas including "Deemed to Comply" solution for stormwater quality management for relatively small scale developments. This paper describes some challenges Council are facing for implementing WSUD concept as well as some possible steps in overcoming the challenges. It also includes some case studies of implemented WSUD in Gold Coast including challenges and performances.

**Keywords:** Urban Planning, Sustainable Development, Stormwater, Water Sensitive Urban Design (WSUD), Water Quality, Planning Scheme and Sustainable Environment.

## 1. INTRODUCTION

Gold Coast is one of the fastest growing regions in Australia. Therefore, the development pressure is paramount which transforms 'green field' lands to urbanised area and consequently puts pressure on pristine eco-system. Over the last decade, there have been increasing number of initiatives to manage the urban water cycle in an ecologically sustainable way. These initiatives are underpinned by sustainability principles of water conservation, waste minimisation and environmental protection. Integration of urban water cycle management with urban planning and design is known as WSUD.

The main purpose of this paper is to highlight how GCCC is currently implementing WSUD practices during the development approval process to protect surrounding environment and fragile coastal ecosystem. This paper covers different tools and policies Council is currently utilising to embrace WSUD practices as one of the major objectives for any development proposal within the Gold Coast

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area. This paper briefly outlines the popular deemed to comply solution which has received wide acceptance by the development industries for small scale developments.

While Council has adopted WSUD practice as Council's policy and developed a strong technical capacity in designing/checking WSUD elements, but Council's asset owners are concerned about long-term maintenance burden for the rate payers. In order to eliminate assets owners' concerns this paper has also highlighted a number of measures that have been initiated to educate and improve their knowledge about how to deal with the long-term maintenance issues and thus achieve benefits of WSUD practices for a sustainable growth of the city.

A number of case studies of implemented WSUD elements are discussed in the context of how some of them are performing successfully and how some others are experiencing or causing some difficulties in terms of performance, maintenance or safety issues. Better understanding of the implemented WSUD system is required, particularly whether the state-of-the-art WSUD technology is satisfying the state and local water quality objectives.

## 2. SUSTAINABLE DEVELOPMENT IN GOLD COAST

Gold Coast is located approximately 70 km south of Brisbane (Figure 1). The Gold Coast is the sixth largest city in Australia and one of the fastest growing regions in Australia. It covers an area of 1400 square kilometres with mountain ranges to the west, major populated areas including numerous waterways mainly adjacent to coastal corridor and an extensive coastline along the eastern boundary.

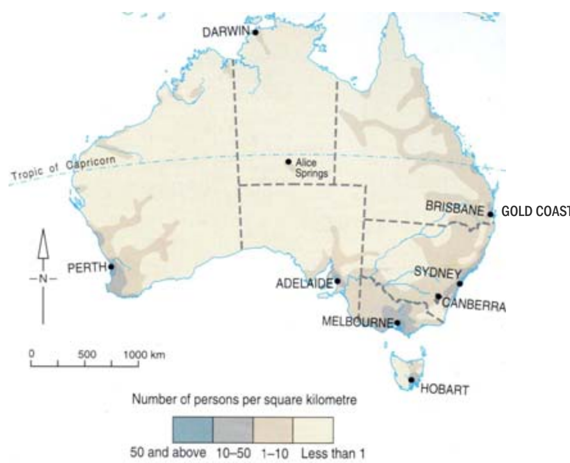

Figure 1: Locality Map and population density

The Gold Coast's current population is just over 0.5 million (Based on projected figures from Australian Bureau of Statistics, Regional Population Growth, Australia, 2006-2007) and is expected to continue to grow by 13,000 to 16,000 people per year. This extensive growth of population is managed through appropriate planning, particularly through a planning scheme. The key challenges for planning in Gold Coast include conservation of natural areas, connecting people and places, provision for economic growth and achieving the right balance between protection of environment and urban development.

Water Sensitive Urban Design (WSUD) is a holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. The key principles of WSUD are to:

- Protect existing natural features and ecological processes;
- Maintain the natural hydrologic behaviour of catchments;
- Protect water quality of surface and ground waters;
- Minimise demand on the reticulated water supply system; and
- Integrate water into landscape to enhance visual, social and ecological values.

Gold Coast City Council (GCCC) has developed a planning framework to implement the WSUD principle. A brief overview of the requirements through planning schemes and guidelines and tools that have been developed to assist the development industry are outlined in this section.

### 2.1. Planning Scheme Requirements

The principle of WSUD is implemented in GCCC as a statutory requirement of the Planning Scheme. The Works for Infrastructure Code in the Planning Scheme seeks to ensure that all works for infrastructure (including stormwater drainage) and the provision of public utilities and services are provided with best management land development practices in accordance with GCCC's Land Development Guidelines, which is the Planning Scheme Policy No. 11.

## 2.2. WSUD Guidelines for Gold Coast

The WSUD Guidelines (GCCC, 2007) is an addendum (Section 13) to the Land Development Guidelines and provide a decision making guide for Best Planning Practices associated with urban development and design including selecting, integrating and locating WSUD elements within a development (i.e. site feasibility). These guidelines also provide advice on Best Management Practices including the planning, conceptual and detailed design of WSUD stormwater systems. The WSUD guidelines are an invaluable resource for those involved in the use of WSUD to mitigate water quality, quantity and ecological impacts of urban development. The structure of the guidelines and broad description of each section are outlined below:

**Section 13.1** (Stormwater Quality Management Guidelines) includes requirements for the preparation of stormwater management plans to satisfy Council's water quality objectives (i.e., pollutants load reductions by 80% for Total Suspended Solid, 60% for Total Phosphorus and 45% for Total Nitrogen).

**Section 13.2** (WSUD Conceptual Design) recommends process for undertaking a conceptual WSUD/Stormwater plan. Includes a step-wise process and detailed considerations for the layout of the development to be water-sensitive and for integration of WSUD elements.

**Sections 13.3 to 13.13** (WSUD Detailed Design) includes detailed design process for a range of common WSUD devices including swales, sedimentation basins, bioretention, wetlands, pre-treatment and plant selection.

### 2.2.1. Deemed to Comply Solutions

Section 13.1 of the WSUD guidelines also includes 'deemed to comply' solutions for small scale developments instead of requiring a detailed stormwater management plan as briefly outlined here:

**Standard residential (attached/detached dwellings):** For site area A < 1000 $m^2$ : Rainwater tank only, but for site area A > 1000, but < 5000 $m^2$ : Rainwater Tank + 2% of Area as bioretention.
**High Rise Residential:** For site area, A < 2500 $m^2$: Rainwater tank using water balance analysis + 2% of Area as bioretention + GPT at basement.
**High Rise Commercial:** For site area A < 2500 $m^2$: Rainwater tank using water balance analysis + 2.5% of Area as bioretention + GPT at basement.
**Industrial:** For site area A < 2500 $m^2$: Rainwater tank using water balance analysis + 2.5% of Area as bioretention.

### 2.2.2. WSUD Standard Technical Drawings

The WSUD Standard Technical Drawings are an addendum to the WSUD Guidelines and includes standard drawings of several WSUD Best Management Practices, including typical cross sections of roads with WSUD, bioretention basins and a wetland riser outlet structure.

## 2.3. MUSIC Modelling Guidelines

A Gold Coast specific guideline for MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software was developed to assist the development industry in assessing the performance of WSUD 'treatment train'. The main purpose of the guidelines was to ensure consultants, developers and Council have a consistent approach to stormwater quality modelling.

## 2.4. Planning, Design, Construction and Maintenance Requirements

The recommended processes for the planning, design, design review, construction and maintenance of 'treatment trains' is described in the WSUD Guidelines. Figure 5-1 of the WSUD Training Awareness

Program (BMT WBM, 2008) provides a flow chart of the above process and shows how the WSUD Guidelines assist in various steps.

### 2.5. WSUD Conditions of Development Approval

Stormwater Management Plan (SWMP) is a mandatory requirement for any development approval within the Gold Coast area, particularly when the area of the land is larger than that specified in the 'deemed to comply' solution category. Any SWMP is to be based on the principles illustrated in Chapter 13.1 of Council's Land Development Guidelines. During development assessment process SWMP is reviewed including any software used to prepare the report (e.g., MUSIC) and conditions of approval are issued to implement and construct all stormwater treatment train based on the approved and/or amended report in accordance with the specifications outlined Council's WSUD Guidelines. Since the long term performance of WSUD elements require regular maintenance, a condition is imposed to lodge a maintenance management plan for WSUD elements. Various conditions including certifications, checklists, monitoring and on-maintenance period are also imposed.

## 3. IMPLEMENTATION AND RISK MANAGEMENT OF WSUD

### 3.1. WSUD Awareness Program

Gold Coast City Council commissioned a specialist consulting company to prepare and deliver an internal training program to generate awareness among various stakeholders in GCCC, to allow GCCC staff to fully understand and successfully implement WSUD and to increase the capacity of selected GCCC officers to carry out further training of GCCC staff. The components of the training program included stakeholders identification, awareness need analysis, design of training materials, delivery training material through workshops and site inspections of various WSUD outcomes.

GCCC has recently upgraded the document control data base system (i-SPOT) which is available to most part of the council including planning engineers, asset owners and the council staff who are responsible for the operation and maintenance of the contributed WSUD devices. Therefore the design drawings and the maintenance management plans for contributed WSUD elements are now readily accessible to all assets owners. Council's inspection section has also taken several checking initiatives in their inspection process to ensure sign off from the consultants during construction phase and as well as certification from the consultants during the assets handover stage about the performance of the WSUD elements.

### 3.2. Risk Management in Planning and Design Phases

WSUD elements have been implemented in Gold Coast for the past 10 years. Some WSUD elements were constructed when the technology was at its infancy. Performance of some systems was not ideal. Some other local government authorities also experienced these difficulties (BCC, 2005). Based on experiences and knowledge of local and interstate, considerable improvements in the design and maintenance aspects of WSUD occurred recently to minimise risks of lack of performance of WSUD elements. Risk management for some typical WSUD elements are briefly discussed below.

#### 3.2.1. Bioretention Basins

A bioretention basin is a soil and plant-based stormwater treatment device, consisting of a porous filter media (e.g., sandy loam) with perforated under-drainage to collect infiltrated stormwater (Figure 2, Source: GCCC, 2007). As the stormwater percolates, pollutants are retained through fine filtration, adsorption and some biological uptake. Bioretention basins often use temporary ponding above the filter media surface to increase the volume of runoff infiltrating through the filter media. These can be installed at

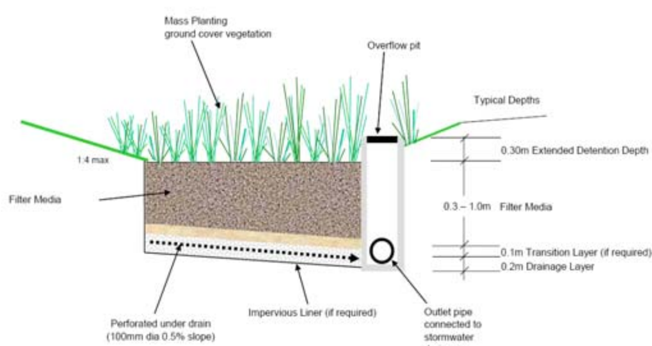

Figure 2: Typical Long Section of Bioretention

various scales (e.g., planter boxes, in streetscapes integrated with traffic calming measures, in suburban parks and retarding basins). While a bioretention basin is a highly effective treatment device, there are some operational risks if not properly designed or regularly maintained as described below:

*High sediment loads:* If the bioretention system is not adequately protected, particularly during subdivision and building works, sediment load will most likely clog the surface of the filter media, impairing the hydraulic conductivity of the media. Design elements to minimise this risk include:

- Ensure pre-treatment devices (e.g., trashrack, sediment fore bays, etc.) are provided;
- Ensure the system is well vegetated with deep/ spreading root systems; and
- Ensure the system is not placed ‘on-line’ until at least 90% lots have buildings.

*Erosion/ Scour:* Maintain velocities low through the system (less than 1.5 m/s during the major storm events), ensuring suitable inlet scour protection and energy dissipation and providing a high flow bypass system for relatively large basin. Geofabric protection of the filter media is recommended to protect the media from erosion particularly during subdivision construction phase. The bioretention device should be located above the flooding extent to prevent the system being washed away.

*Under-Drainage Causing Slow Drainage:* The drainage rate of the filter media can be restricted or ‘choked’ by the under-drains due to high groundwater table, high tailwater level or clogged under-drainage system. Design elements to minimise risk include:

- Under-drainage should be ‘free draining’;
- Ensure capacity of under-drainage greater than max. infiltration rate of filter media; and
- Pipe centrelines should be at no greater than 1.5m apart and have ‘rodding’ points for cleaning.

#### 3.2.2. Swales

Vegetated swales are used to convey stormwater in lieu of or with underground pipe drainage systems to slow stormwater flow-rates and provide for the removal of coarse and medium sediment(Figure 3). They are not usually suitable on very flat surface (<1%) or steep area (>5%) and where the ground water table is very close to the surface. Bioretention system can be incorporated in to swales.

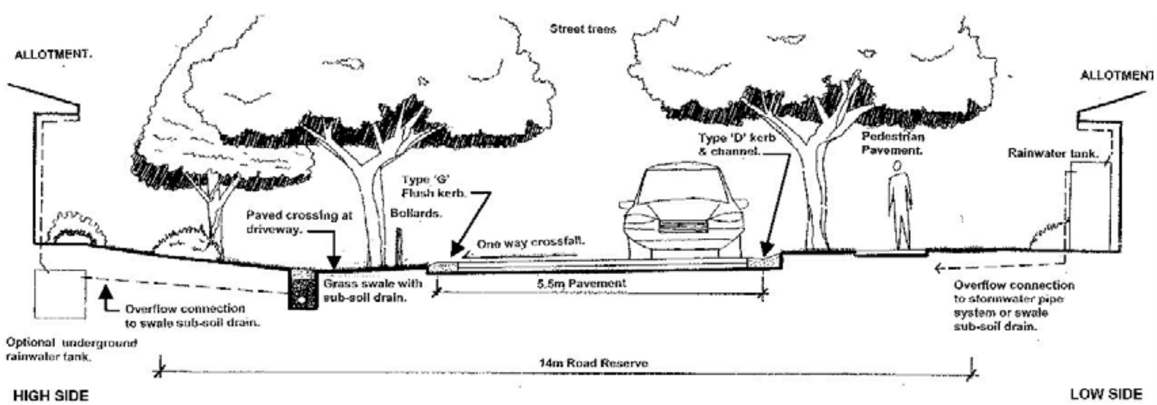


Figure 3: Typical Cross-Section of Grassed Swale (Source: GCCC, 2007)

Some operational risk for swales and design considerations to minimise these risks are outlined below:

*Water-logging:* Ensuring gradients are >1% or use of underflow drains (i.e., bio-swales).

*Sediment accumulation:* Inclusion of minimum 60mm drop off at flush kerb edge.

*Public Safety:* Ensuring flooding safety criteria are satisfied (i.e., depth x velocity $< 0.4\ m^2/s$, maximum flow depth on driveway crossings is 300mm).

*Driveway Cross-Over:* Driveway crossings over a swale can pose several risks including safety concerns with traffic movement adjacent to ‘elevated’ lots, potential blockages and high maintenance requirements. Design considerations to minimise this risk include restricting any swales to the middle/ median of roads where lots are located on both sides of the roadway and maintaining ‘at-grade' crossings with maximum slopes of 1 in 10, and flow depths over crossings not exceeding 300mm.

### 3.2.3. Wetlands

Wetlands are another commonly used stormwater quality improvement devices (SQIDs) provided a suitable area is available either to retrofit an existing development or for a new subdivision. Constructed wetland systems are shallow, extensively vegetated water bodies and typically consist of an inlet zone (sedimentation basin), macrophyte zone, deep water zone and a high flow bypass channel (Figure 4, Source: GCCC, 2007).

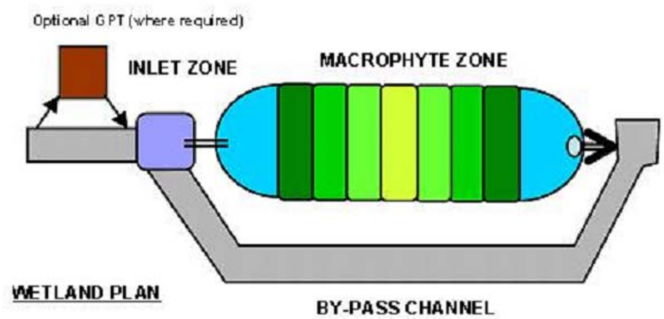


Figure 4: Typical Plan of Various Components of Wetland

Some operational risks associated with wetlands and mitigation measures are described below:

*Public Safety:* Like any permanent or temporary water body, there is a potential for access to open water zones and the inherent risks associated with this. Design elements to minimise this risk include restricting access through planting, permanent barriers (e.g. fencing) or safety benching and maintaining a flat grade (maximum grade of 1V:6H). For any pathway through a wetland, it must be designed with cross drainage and safety consideration.

*Outlet Blockage:* If the riser outlet of a wetland is partially/completely blocked, water levels within wetlands are likely to remain elevated for extended periods of time, which can place enormous stress on wetland vegetation. Some design considerations to minimise this risk include:

- Ensuring the outlet for the macrophyte zone has a maintenance access;
- Some form of debris guard could be installed around the riser outlet or a device can be provided so that water is drawn below the debris level; and
- A simple weir structure with graded rocks.

*Re-Suspension:* High stormwater flow rates can cause re-suspension of sediment that has been captured within the sedimentation basin. Some design considerations to minimise this risk include:

- Allow sufficient sediment storage capacity in sedimentation basin;
- Adequate inlet zone and high-flow bypass channel; and
- Perform re-suspension check calculations as outlined in WSUD Guidelines.

### 3.3. Risk Management During Construction and Establishment Phases

Careful planning and management during the construction and establishment periods are critical for WSUD vegetated stormwater management systems. In addition to the WSUD Guidelines (2007), GCCC has started adopting the Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands (Healthy Waterways, 2009).

### 3.4. Maintenance Phase

Maintenance of the WSUD elements is essential for a long term sustainability of the WSUD system. GCCC requests for management plans for any stormwater treatment system that are incorporated within any developments. Minimum 12 months on-maintenance period is required for any WSUD elements. The required on-maintenance period for bio-retention system and wetland are 24 and 60 months respectively.

## 4. CASE STUDIES IN GOLD COAST

Over the past last decade, a number of new subdivisions in Gold Coast have implemented the state-of-the-art WSUD 'treatment train' incorporating the design considerations discussed in the previous section to minimise risks. The case studies have been categorised in two broad groups, namely about 5 to 10 years ago (early days) and during last 5 years (recent).

### 4.1. Early Days of WSUD (5 to 10 Years Ago)

This was the inception period of WSUD. A number of developments in Gold Coast implemented various aspects of WSUD elements. For example, Pacific Pines, Jacobs Ridge, Upper Coomera.

The 'treatment train' incorporated GPTs for pre-treatment followed by bioretention and/or constructed wetland system for further treatment, particularly to remove nutrients and heavy metals. Swales and bioretention swales were also included either in the median strip or within the road reserve.

**Jacobs Ridge:** The WSUD 'treatment train' for this subdivision incorporated an extensive amount of swales within the road reserve, predominantly on the road verges with one-way cross-falls. Underground drainage system was incorporated within the swales with inlet grated sumps and no Kerb & Channel or road side entry pits in the subdivision (Figure 5). Considering blockage from debris (predominantly from grass clippings), some inlets did not have any gratings but domes for pedestrian safety. Critics opine that the elevated dome structures may pose potential trip hazard for pedestrian. However, in most road reserves, the footpaths are located on the opposite side of the swales. Two way cross-falls with bioretention swales were also part of the WSUD in this subdivision. Dome inlet structure is better option than a grated inlet in the median strip swale due to blockage issue. Generally the property owners maintain the nature strip in road verges, therefore inlet gratings are considered better option than dome structures within road side swales. Community education about potential blockage is required so the property owners do not leave any grass clippings after mowing the nature strip in road verges.

Figure 5: Swales with various inlets

Some of the bioretention basins in this estate were incorporated within parks and detention basins. Event based monitoring at various waterways within this estate and surrounding areas has been carried out since the start of the development of this estate in 2003/04. Early results showed excessive exceedance of water quality objectives (WQOs) for all pollutants, particularly total suspended sediments (TSS). This was attributed to the construction activities, particularly on building sites. Monitoring results after 5 years indicate that pH, electrical conductivity and dissolved oxygen met the WQOs, but TSS, TN and TP still exceeding the WQOs after 5 years of the development though the extent of exceedance is less.

**Gannon Way, Upper Coomera:** A GPT and a bioretention basin were constructed in 2004 for a residential subdivision at this location with 9.5 ha catchment area. A site inspection after 4 years revealed that the GPT was full of sediment and the bioretention basin accumulated a thick layer of sediment. The bioretention basin was located at a low lying area adjacent to a creek. The drainage layer and the invert layer of the outlet structure were low in relation to the water level in the adjacent creek. Therefore, the bioretention suffered from water logging due to poor drainage (Alam & Hossain, 2009). The plants in the basin also showed the sign of water logging (Figure 6a). Sediment was thoroughly removed from the GPT in April 2008, which resulted in reduced influx of sediment to the basin. Stripping of sediment from the basin and replanting have resulted in a healthier basin couple of years later (Figure 6b).

Figure 6: a. Bioretention Water Logged
b. Three Years After Maintenance.

**Pacific Pines:** A series of wetlands was constructed for an early stage of this large residential development. Apart from some difficulties experienced by the inlet zones of these wetlands, the treatment train appear to be well established. The outlet chamber of the inlet zone seem to experience from frequent clogging and result in poor drainage. The pathway through the wetland system also experience constant inundation, which creates hazard for pedestrians due to lack of drainage device across these paths.

A large aquifer storage and recovery (ASR) system with total storage capacity of 15,600 $m^3$ was provided in a later stage of this subdivision not only to achieve management of stormwater quantity and quality, but also to store stormwater in the artificial aquifer for reuse and to use the surface for playing fields (Gilbert & Sutherland, 2006).

## 4.2. Recently Established WSUD (During Last 5 Years)

**Genesis, Coomera:** Genesis is a large scale residential development located at the eastern part of Coomera. WSUD treatment train in this estate consists of swales, GPTs, bioretention swales, rain gardens and constructed wetlands. Some of the elements of Stage 1 stormwater treatment train are shown in Figure 7 (constructed in 2006/07).


Figure 7: WSUD at Genesis; a. Swale, b. Bioretention swale, c. Habitat pond, d. Wetland, e. Spillway

Most of the risk management aspects of design as outlined earlier in this paper were considered in the design and implementation of various WSUD elements. Swales were provided with flush kerb including the required drop off and the trees to prevent vehicle parking. Bioretention swales were provided along the median and the dome inlet structure along the median strip, which is not a pedestrian hazard. The wetland system seems to be well established and the pedestrian crossing is elevated with sufficient drain and handrails. Since the perforated riser seems to get blocked, graded rocks were used over the spillway to maintain sufficient hydraulic retention time for the water quality treatment. However, the above picture (7e) shows that the rocks have been washed away by a series of large storm events, hence the hydraulic retention time would not be adequate. A dedicated high flow bypass system in addition to the above graded rocks may rectify this problem.

Water quality monitoring is being undertaken since the construction of the WSUD elements in Stage 1, mainly at the inlets and outlet of the wetland and also at the downstream end of Stage 1. Turbidity has been found to be consistently high due to construction activities in the catchment, particularly for Stage 3 of Genesis. Alum dosing has been undertaken to alleviate this problem, but further sediment and erosion control (SEC) measures and appropriate application and maintenance of the SEC measures are required. TN and TP concentrations also exceeded the limits in Queensland Water Quality Guidelines, EPA (2006).

**Coomera Waters:** The stormwater management report (Ecological Engineering, 2003) shows a series of treatment train for Stages 12-15 including swales along the road reserve where topography permitted including the proper road side flush kerb, bioretention basins, buffer strips and constructed wetland (Figure 8). The construction of this 'treatment train' started in early 2004. Swales along the major roads have been incorporated without driveway crossing by having a common lane parallel to swales and the driveways off the lane (Figure 8b). Some of the bioretention have turf cover due to an ongoing construction phase and some others have established plants (Figures 8c). Figure 8d shows a high flow bypass adjacent to a wetland.

The geofabric and turf will be removed and replaced with appropriate planting when buildings on more than 90% of lots are completed. Recent visits to this site revealed construction of some swales, buffer strips, constructed wetlands and bioretention in the last several years. It was worth noting that some bioretention basins were implemented on terraced beds due to a relatively steep longitudinal grade of the site. The most components of WSUD appeared to have been established well and the system seems to be functioning as intended although some room for improvements were noticed. For example, some flush kerb did not have arras (60mm drop off at the edge) and the adjacent turf has grown above the edge which resulted in accumulation of sediment along the edge of the flush kerb.


Figure 8:WSUD elements in Coomera Waters; a. Wetland Macrophyte Zone, b. Swales & driveways, c. Bioretention d. High flow bypass of wetland (looking upstream).

Based on various case studies and review of stormwater management plans for various development in Gold Coast, the development at Coomera Waters has implemented one of the most advanced technology of WSUD 'treatment train'. An event based and monthly water quality monitoring has been carried out since 2003 by the developer of Coomera Waters at a number of locations along the receiving waters, i.e., McCoys Creek. Some basic analysis of the concentration based data shows that water quality immediately downstream of Coomera Waters does not appear to have deteriorated as a result of Coomera Waters development (Alam, *et al*, 2008).

A comprehensive monitoring program of the above 'treatment train' was undertaken to assess the effectiveness of the bioretention swale, wetland and bioretention basin (Parker *et al*, 2009). Monitoring devices were installed at the inlets and outlets of the WSUD devices so that the performance of the devices can be assessed in terms of both quantity and quality of stormwater. The results from the monitoring program show that bioretention basin retains a significant portion of stormwater (62%) for small storm events and reduced TSS, TP and TN loads very close to achieving water quality objectives. The concentration of nutrients in outflows from bioretention were higher than that in inflows, mainly due to lack of planting in the newly constructed bioretention. The wetland was found to be the most efficient system in removing TSS(87%) and TN(51%), but not so effective in removing TP(37%). Bioretention swale was effective to meet the water quality objectives.

The retention of stormwater volume by bioretention basin, swale and wetland were 55%, 45% and 5% respectively. These devices (particularly bioretention and wetland) also reduced the stormwater peak flows when no stormwater bypassed the devices, i.e. during relatively small events.

**Broadwater Parklands, Southport:** As part of upgrading an important parkland near a tourist area, GCCC retrofitted a large number of WSUD elements in 2009. A series bioretention basins and a wetland were incorporated within the parkland to treat stormwater from the central commercial area of Southport. These stormwater devices have been integrated well within open space, recreational parks and landscaped features resulting in a high quality parkland with various active and passive recreational facilities. The picture on right shows an integrated wetland including a walkway across the wetland.

## 5. CONCLUSIONS

This paper outlines how Gold Cost City Council has been implementing WSUD for the past ten years mainly through the development assessment process including a number of case studies. Planning framework, WSUD guidelines, various tools including the MUSIC Modelling Guidelines and some practice notes including the 'deemed to comply' solutions have been developed by the council to assist the development industry and council's stakeholders.

GCCC is committed to WSUD practices to enhance and improve our surrounding environment and costal ecosystem. Council has initiated several programs to educate both internal and external stakeholders to overcome any challenges in implementing WSUD practices.

Case studies demonstrate that a significant improvement in design and implementation of WSUD elements have occurred during the past several years. Coomera Waters has implemented one of the most advanced technology of the WSUD 'treatment train'. The monitoring data at Coomera Waters shows that nutrient loads are being reduced due to retention of stormwater by WSUD elements, but the outflow concentration still exceeding the water quality objectives of state and local guidelines. Much work is needed, particularly for the construction and establishment phases of WSUD elements.

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# SEISMIC RISK ANALYSIS OF ELECTRIC POWER SUBSTATIONS

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## ABSTRACT

Electric power substations are very vulnerable to earthquakes. The vulnerability depends on variety of parameters. In this study, a comprehensive procedure for compiling the performance of parameters was developed which enable to estimates seismic risk index of electric power substations. The goals of the study are to improve the assessment of seismic hazard and to investigate the vulnerability of the electric power substations. The critical parameters responsible for vulnerability of substations are identified by statistical analysis of field data. Correlation of different parameters with vulnerability, sensitivity of the weighting factors of critical parameters and sensitivity of seismic exposure levels to seismic risk index are also studied by statistical analysis. Study shows that year of manufacture of equipment, anchoring of heavy equipment, load-bearing system of the building, and control systems are the four most critical parameters for vulnerability.

**Keywords:** Vulnerability, Consequences, Critical Parameters, Seismic Hazard, and Seismic Risk Index

## INTRODUCTION

Considering the electric transmission and distribution network, substations are generally considered most vulnerable to earthquake damage. Past earthquakes around the world showed that high intensity earthquakes can cause severe damage to substations and can result in major service disruptions over large areas. Substations are composed of a variety of components such as: substation building, transformers, circuit breakers, disconnect switches, lightning arresters, current transformers, wave traps, and circuit switchers which are very vulnerable to earthquake ground shaking. The 1994 Northridge earthquake demonstrated that damage to electrical substation components in California also affected power service to British Columbia, Montana, Wyoming, Idaho, Oregon and Washington (Schiff, 1995).

Earthquake damage to substations in Quebec is also likely. Quebec is located in an intraplate region of medium seismicity that can be affected by severe earthquakes. For example, the electric network was affected during the 1988 Saguenay earthquake in Quebec. The damage was related to failure of electrical equipment, cracks in control buildings and false tripping of some relays. It took several hours after the earthquake to restore the power service in Quebec City. Total damage to equipment during the earthquake was estimated at $ 7 Million (Pierre, 1989).

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Considering the potential of earthquake damage to electric power substations, we have recently developed a methodology to evaluate the seismic vulnerability and importance (consequences of failure) of different substations.

**SEISMIC RISK INDEX FOR SUBSTATIONS**

The seismic risk of a substation during an earthquake is calculated as,

Risk = Vulnerability (V) X Consequences (C)

*Vulnerability (V)*

Vulnerability varies from 1 to 10. A value greater than 4 is considered critical. Vulnerability of a substation depends on the following parameters: geology of the site, topography of the site, liquefaction potential, year of manufacture of electrical equipments, sensitivity of equipment to lateral forces, anchoring of heavy equipment, type of foundation for heavy equipment, steel cross bracing, High tension wire layout, year of design of the building, load bearing structure of the building, control systems, stability and operability of emergency generator, redundancy of protection system, and protection and auxiliary relays. Vulnerability of a substation is calculated according to following equation:

$$\text{Vulnerability} = \text{Seismic Exposure} \times \frac{\sum c \times W.F}{\sum W.F}$$

Where,

c = value of each parameter according to different condition

WF = Weighting factor

Each parameter has different weighting factors (WF). Weighting factors were developed by considering:

1) History of damage of power transformers during the Long Beach (1933), San Fernando (1991), Saguenay (1988), Loma Prieta (1989), Northridge (1994), Kobe (1995), Izmit (1999) and Bhuj (2001) earthquakes
2) Overturning of control panel inside the control building
3) Old equipment with ceramic supports not been designed to modern earthquake standards
4) Soft soil amplification during earthquakes

*Consequences of Damage (C)*

The scale for consequences of damage varies from 1 to 10. The value of consequences depends on the strategic importance of the substations. Strategic importance is evaluated by considering the following factors:

1) Impact of loss of the substation on continuity of service
2) The cost of the substation
3) Time required to repair the substation if there is damage
4) Public and employee safety
5) Energy channeled through the substation

The summary of values for all parameters of 133 substations is shown in Table 1.1. The mean value of vulnerability is 4.26, which is more than the critical level 4.0. The mean risk of all 133 substations is 27.75, which is in the range of moderate risk level. The mean values for all parameters are presented in Figure 1.1.

From Figure 1.2 we can see that 40% of the substations are located on compact soils with large particles thicker than 15 meter, or on semi-compact soils with large particles or soft soil with fine particles or soft clay less than 15-meter thick. Next, 17% of the substations are located on semi-compact soils with large particles on soft soil with fine particles thicker than 15 meter. Next, 16.5% of the substations are located on loose to very loose soils with fine particles thicker than 15 meter. The latter type of soil is most at risk during earthquakes. We can also note that 90% of substations lack proper anchoring of equipment. Unanchored equipment is very vulnerable to ground shaking. The structure of the substation building is an important parameter in the risk index. Control panels are located inside the building and damage to the building is likely to result in a power outage. The survey indicates that 52% of the substation buildings are masonry structures. This type of structure is very vulnerable to earthquakes since load bearing walls are unreinforced and made of hollow clay bricks resting on low foundation walls. Only 10% of the buildings are steel structures that are adequately braced and anchored to their foundations. The latter type of building has the highest earthquake resistant capacity.

| **Parameter** | **Mean** | **Minimum** | **Maximum** | **Variance** | **St. Dev.** | **COV** |
|---|---|---|---|---|---|---|
| Geology of the site | 5.25 | 1.00 | 10.00 | 7.24 | 2.69 | 0.51 |
| Topography of the site | 2.03 | 1.00 | 10.00 | 4.49 | 2.12 | 1.04 |
| Liquefaction potential | 2.77 | 1.00 | 10.00 | 6.68 | 2.59 | 0.93 |
| Year of manufacture of equipment | 6.39 | 1.00 | 10.00 | 9.32 | 3.05 | 0.48 |
| Sensitivity to lateral forces | 6.40 | 1.00 | 10.00 | 11.06 | 3.33 | 0.52 |
| Anchoring of heavy equipment | 9.32 | 1.00 | 10.00 | 4.71 | 2.17 | 0.23 |
| Type of foundation for heavy equipment | 2.72 | 1.00 | 10.00 | 5.73 | 2.39 | 0.88 |
| Steel cross bracing | 2.13 | 1.00 | 10.00 | 5.47 | 2.34 | 1.10 |
| High tension wire layout | 3.43 | 1.00 | 10.00 | 7.47 | 2.73 | 0.78 |
| Year of design of the building | 6.17 | 1.00 | 10.00 | 10.25 | 3.20 | 0.52 |
| Load bearing structure of the building | 7.27 | 1.00 | 10.00 | 8.18 | 2.86 | 0.39 |
| Control systems | 7.79 | 1.00 | 10.00 | 9.94 | 3.15 | 0.40 |
| Stability and operability of emergency generator | 1.26 | 1.00 | 10.00 | 2.01 | 1.42 | 1.12 |
| Redundancy of protection systems | 6.27 | 1.00 | 10.00 | 11.99 | 3.46 | 0.55 |
| Protection and auxiliary relays | 5.71 | 1.00 | 10.00 | 7.20 | 2.68 | 0.47 |
| Vulnerability (V) | 4.27 | 1.16 | 7.57 | 1.00 | 1.00 | 0.23 |
| Consequence (C) | 6.48 | 1.00 | 10.00 | 4.33 | 2.08 | 0.32 |
| Risk | 27.76 | 3.11 | 55.59 | 122.99 | 11.09 | 0.40 |

Table1.1: Basic Statistics of All Substation Parameters

Old equipment not designed to current earthquake standards is very vulnerable. Figure 1.3 shows that equipment in 42% of the substations was manufactured between1957 and 1975. In 45% of the substations equipment was made between 1976 and 1986. Equipment was manufactured after 1987 and designed following current earthquake standards in only 13% of the substations. Figure 1.3 shows that 48% of substation buildings were designed during the period from1971to 1985. Only 16% of substation buildings were designed after 1986 using modern earthquake standards. The remaining substation buildings were designed before 1970 without considering earthquake standards and are very vulnerable. In almost 70% of substations, the control panels are not anchored. Anchorage is deficient for 19% of the stations and anchorage is adequate for 11% of the stations.

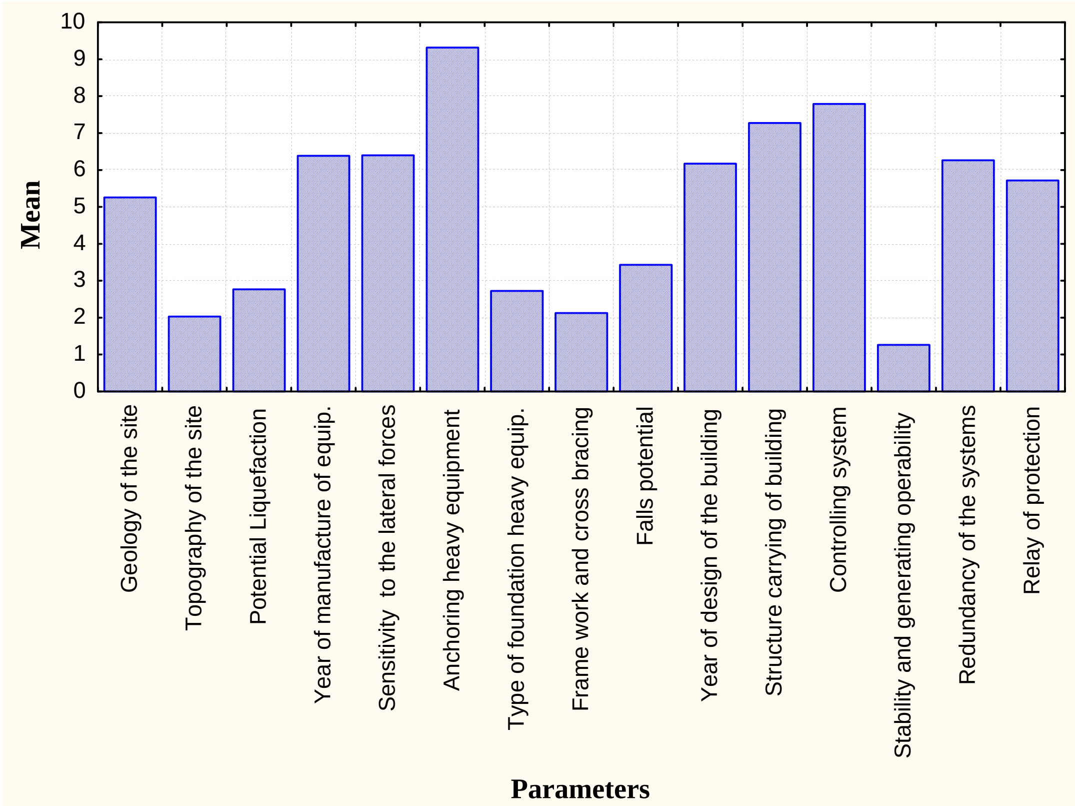


Figure1.1: Mean Dimension of Different Parameters

## CONTRIBUTION OF PARAMETERS TO THE VULNERABILITY INDEX

The relative importance of different parameters to the vulnerability index is presented in Table 1.2. The minimum, mean, and maximum contributions of parameters for the 133 substations to
the vulnerability index are shown in Figure 1.4.

Anchoring of heavy equipment is the most important deficiency for substations. The other important deficiencies are the load bearing structure of the building, year of manufacture of equipment, control systems, geology of the site, year of design of substation building and sensitivity of equipment to lateral forces. Higher voltage substations are more vulnerable due to sensitivity of equipment to lateral forces than the lower voltage substations.

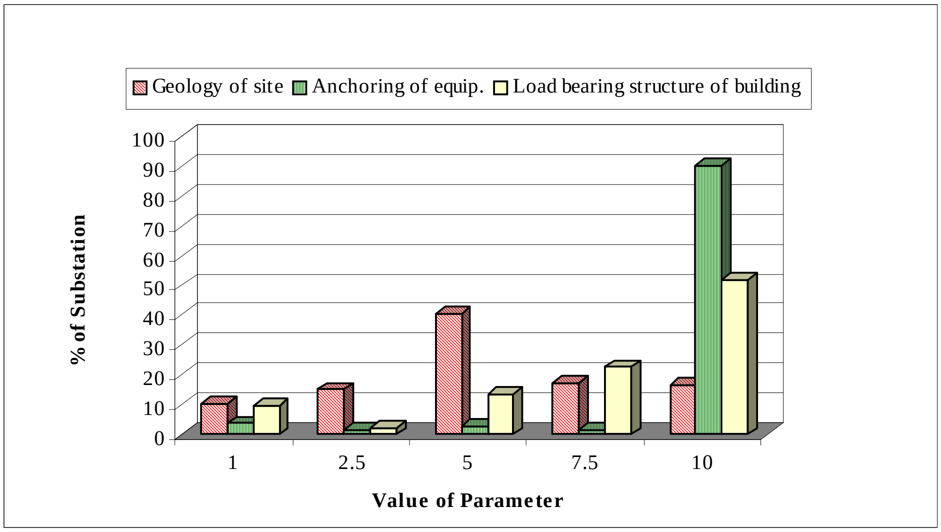


Figure1.2: Histograms of Parameter for Geology of the Site, Anchoring of Equip, and Load Bearing Structure of Building

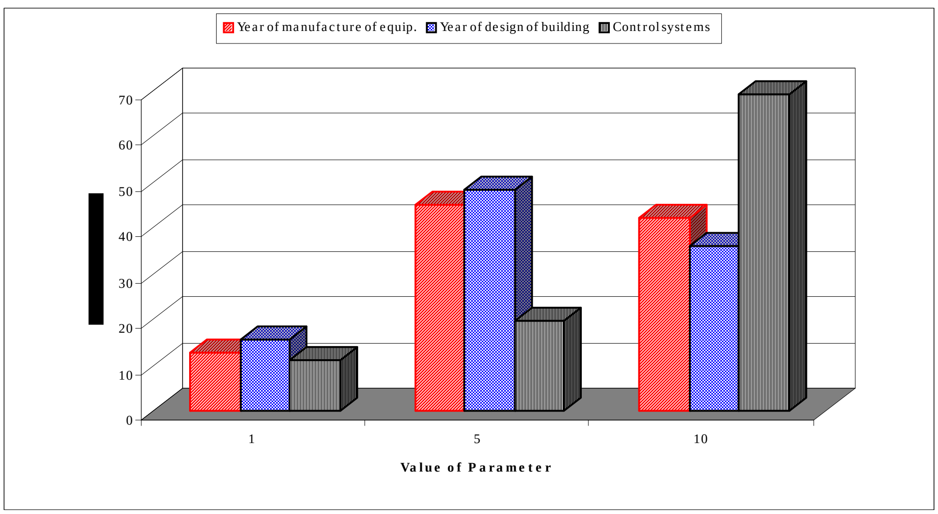


Figure1.3: Histograms of Parameters for Year of manufacture of Equip, Year of Design of Building and Control Systems

## CORRELATION

Table 1.3 lists the correlation between vulnerability with different parameters for substations. Topography, liquefaction potential, sensitivity of equipment to lateral forces, stability and operability of emergency generator, and redundancy of protection systems have low correlations with vulnerability. The load bearing structure of the substation building has the highest correlation with vulnerability. Year of design of the substation-building, year of manufacture of substation equipment and anchoring of substation equipment are all highly correlated with vulnerability.

Using data on vulnerability, consequences and risk for the 133 substations correlations between vulnerability and risk and correlation between consequences and risk were calculated (Figure 1.5 and Figure 1.6). Vulnerability has a correlation of 0.6 with risk and consequences have a correlation of 0.8 with risk. So consequences have a higher linear relationship with risk than vulnerability.

| Parameter | Mean Contribution In (%) | Minimum | Maximum | Variance | St. Dev. | COV |
|---|---|---|---|---|---|---|
| Geology of the site | 8.56 | 1.44 | 23.19 | 19.73 | 4.44 | 0.52 |
| Topography of the site | 1.29 | 0.44 | 10.87 | 2.17 | 1.47 | 1.14 |
| Liquefaction potential | 3.39 | 0.88 | 14.42 | 9.56 | 3.09 | 0.91 |
| Year of manufacture of equipment | 12.32 | 2.09 | 24.04 | 28.02 | 5.29 | 0.43 |
| Sensitivity to lateral forces | 7.90 | 0.93 | 31.25 | 22.66 | 4.76 | 0.60 |
| Anchoring of heavy equipment | 18.87 | 2.68 | 43.29 | 33.38 | 5.78 | 0.31 |
| Type of foundation for heavy equipment | 2.18 | 0.60 | 13.27 | 3.88 | 1.97 | 0.90 |
| Steel cross bracing | 1.64 | 0.61 | 7.19 | 2.40 | 1.55 | 0.94 |
| High tension wire layout | 2.62 | 0.64 | 9.59 | 3.33 | 1.82 | 0.70 |
| Year of design of the building | 8.17 | 1.39 | 14.94 | 12.46 | 3.53 | 0.43 |
| Load bearing structure of the building | 16.98 | 2.73 | 32.17 | 38.85 | 6.23 | 0.37 |
| Control systems | 9.58 | 1.02 | 26.79 | 19.84 | 4.45 | 0.46 |
| Stability and operability of emergency generator | 0.53 | 0.29 | 4.16 | 0.33 | 0.57 | 1.08 |
| Redundancy of protection systems | 2.65 | 0.00 | 8.93 | 3.31 | 1.82 | 0.69 |
| Protection and auxiliary relays | 3.33 | 0.59 | 7.21 | 1.98 | 1.41 | 0.42 |

Table1.2: Statistics of Contribution of Different Parameters to Vulnerability

## DISTRIBUTION ANALYSIS OF VULNERABILITY AND RISK

The Normal distribution of vulnerability for 133 substations is presented in Figure 1.7. The mean value of vulnerability is 4.26 and the standard deviation is 1.0. Using these mean value and standard deviation the probability of vulnerability having any value 0 to 10 can be calculated. The critical value of vulnerability is considered 4.0 and almost 70% substations have the vulnerability greater than the critical value. Cumulative distribution of risk is shown in Figure 1.8. It is observed from Figure 1.8 that 29 substations have negligible or no risk, 86 substations have moderate risk and 18 substations are in the high-risk level.

## CRITICAL PARAMETERS AND HIGH RISK SUBSTATIONS

The four most critical parameters responsible for high vulnerability and high risk are: year of manufacture of equipment, anchoring of heavy equipment, load-bearing structure of the building and control systems (Jaigirdar, 2005). According to analysis 18 electric substations fall in the high-risk category.

## SENSITIVITY OF SEISMIC EXPOSURE

Figure 1.9 explains the variability of substation risk during an earthquake for different seismic exposure levels. 42% of substations are at high-risk when seismic exposure level is 1.0. For seismic exposure 0.7, 12% substations are at high-risk level. 56% substations are at moderate-risk level for seismic exposure 0.55. For seismic exposure 0.55, no one substation exceeds the critical earthquake risk level.

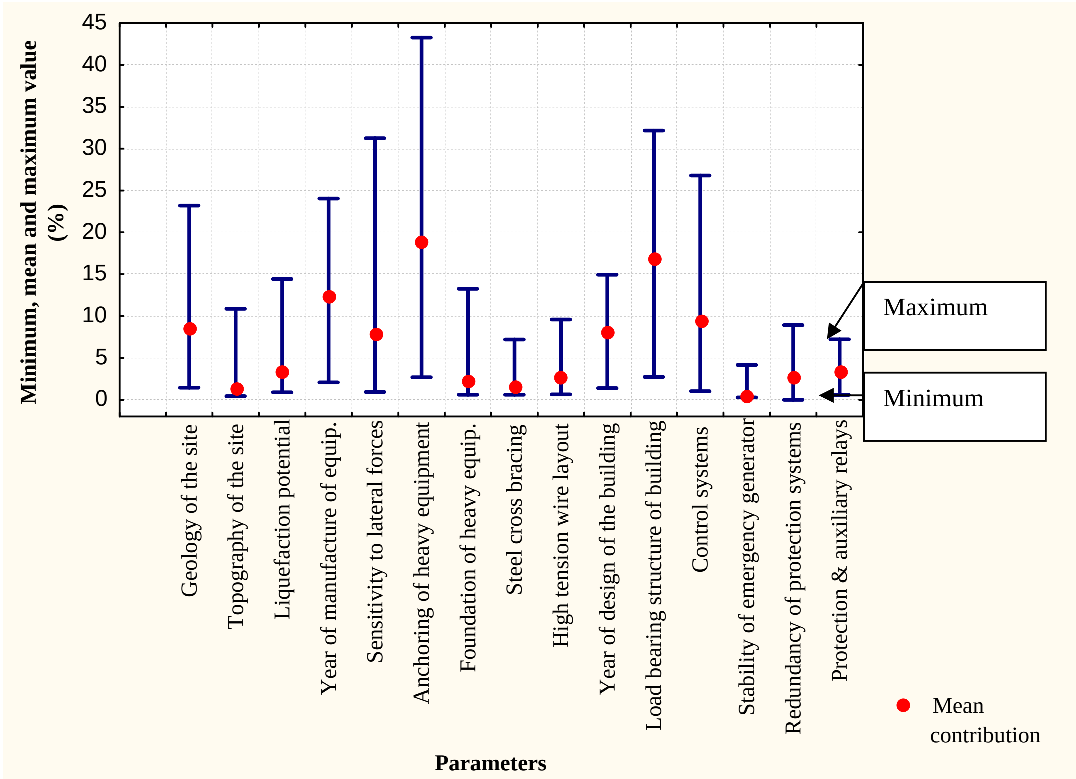


Figure1.4: Contribution (%) of Parameters to Vulnerability Index

| **Parameter** | **Vulnerability (V)** |
| --- | --- |
| Geology of the site | 0.23 |
| Topography of the site | 0.06 |
| Liquefaction potential | 0.02 |
| Year of manufacture of equipment | 0.49 |
| Sensitivity to lateral forces | 0.04 |
| Anchoring of heavy equipment | 0.42 |
| Type of foundation for heavy equipment | 0.13 |
| Steel cross bracing | 0.30 |
| High tension wire layout | 0.31 |
| Year of design of the building | 0.53 |
| Load bearing structure of the building | 0.62 |
| Control systems | 0.20 |
| Stability and operability of emergency generator | -0.03 |
| Redundancy of protection systems | 0.03 |
| Protection and auxiliary relays | 0.32 |

Table1.3: Correlations of Parameters with Vulnerability

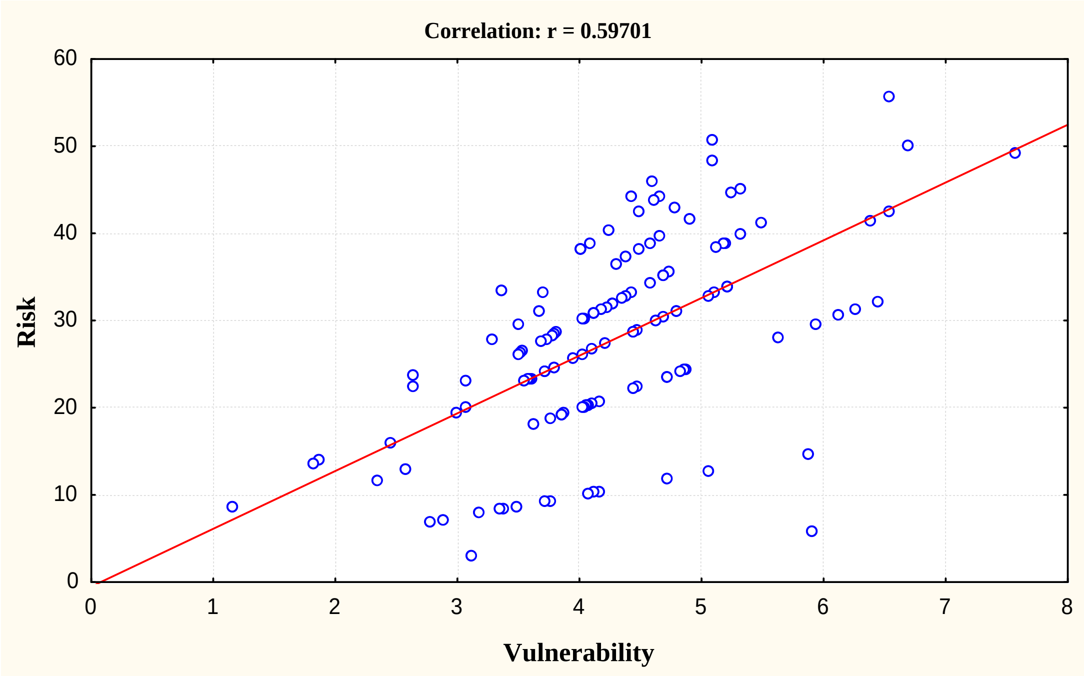


Figure1.5: Correlation of Vulnerability with Risk

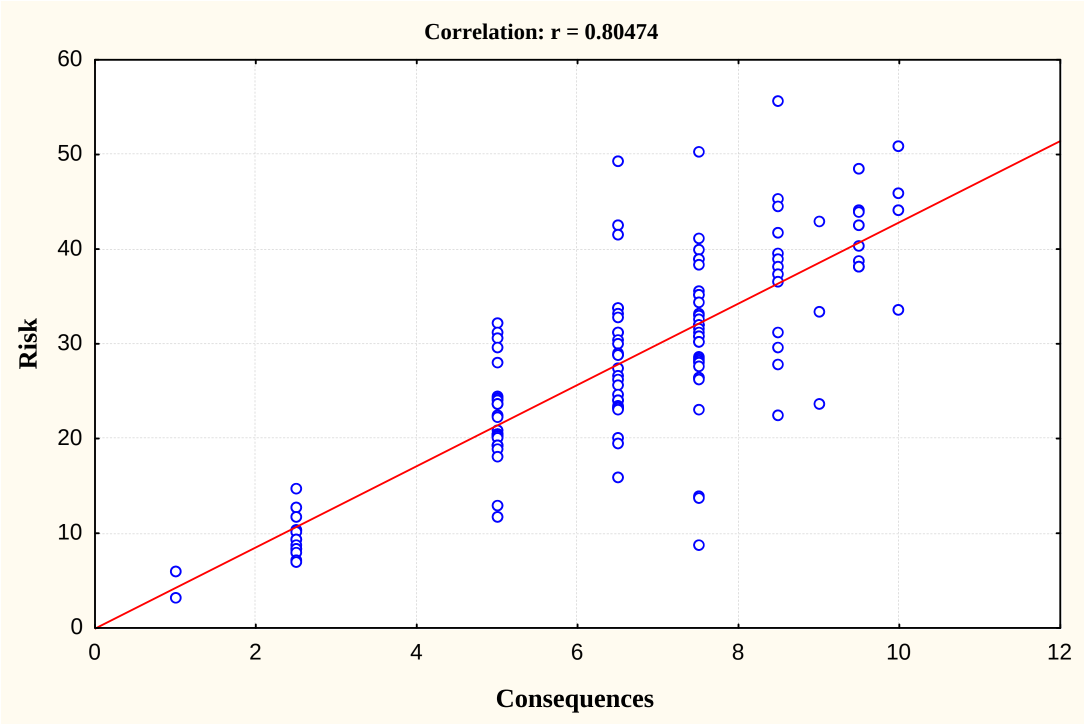


Figure1.6: Correlation of Consequences with Risk

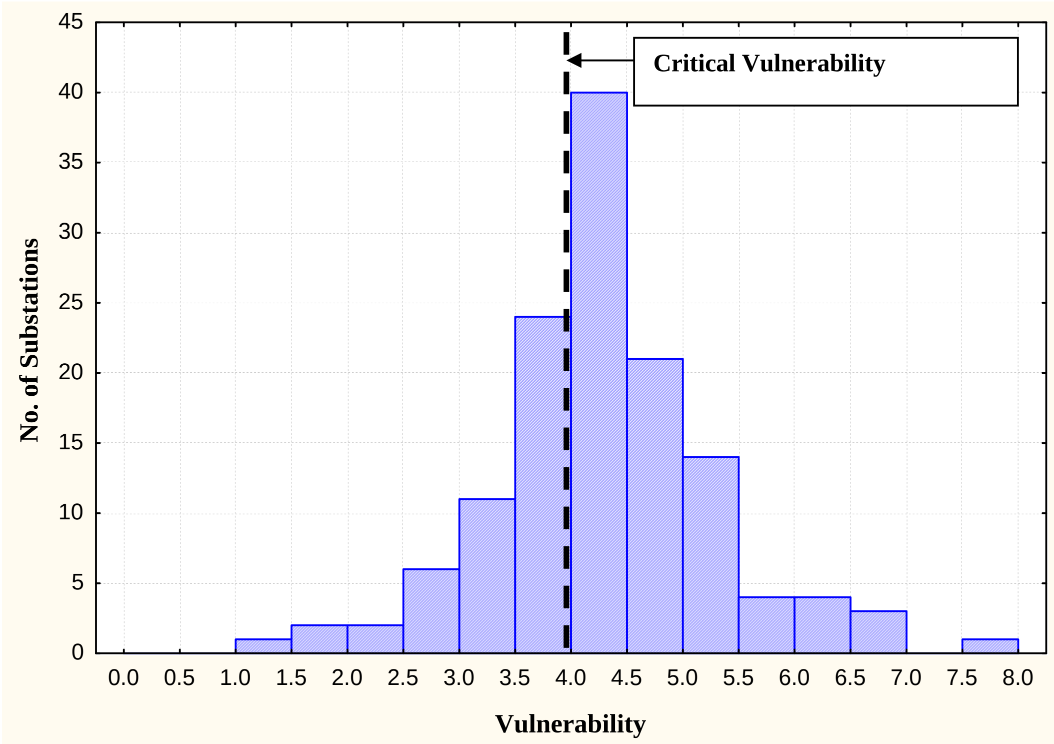


Figure1.7: Probability Density Function of Vulnerability

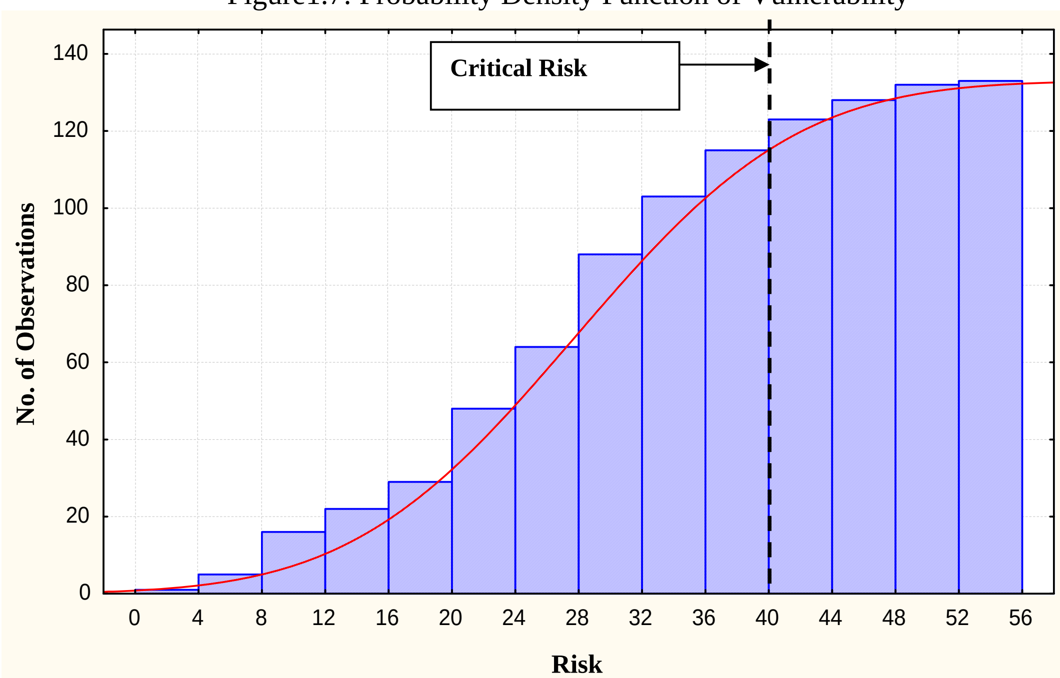


Figure1.8: Cumulative Distribution of Risk of Different Substations

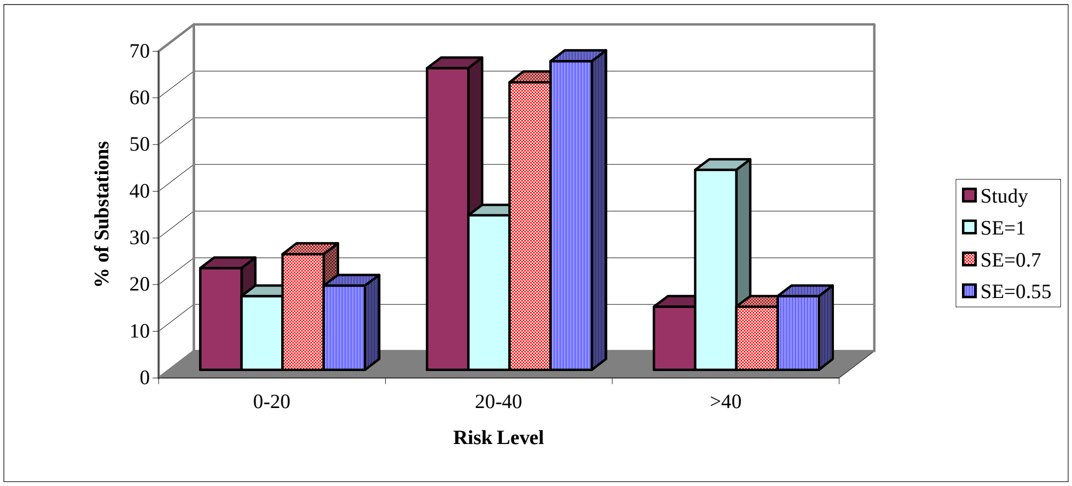


Figure 1.9: Substations at Different Risk Level for Different Seismic Exposure

## CONCLUSION

Statistical analysis of seismic risk on substations was performed using STATISTICA$^R$. The Analysis identified the four most critical parameters responsible for high-risk index of substations: year of manufacture of equipment, anchoring of heavy equipment, load-bearing structure of the building and control systems. The mean value of vulnerability is 4.26, which is more than the critical vulnerability level 4.0. Study shows equipment in 42% substations was manufactured between1957 and 1975. Only 13 % of substations equipment was manufactured after 1987. Data also show that 90% of substations lack proper anchoring of equipment. More than half of substation control buildings are masonry structures. This type of structure is very vulnerable to earthquakes and increases the overall risk level of substations. Only 10% of the buildings are steel structures with adequate bracing and anchoring to their foundations. Analysis shows vulnerability has a correlation of 0.6 with the risk index and consequences have a correlation of 0.8 with the risk index. The sensitivity study shows that the seismic risk index of substations is very sensible to the seismic exposure level. The number of high-risk substations increases significantly when seismic exposure level is set to 1.0.

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# INFLUENCE OF RECYCLED GLASS FIBER GEOMETRY ON PLASTIC SHRINKAGE CRACKING IN CONCRETE

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## ABSTRACT

Plastic Shrinkage cracking can develop in concrete if it exposed to excessive heat and high winds because of high evaporation rates which cause the concrete surface to dry out before it has sets. The resulting evaporation removes the water needed for curing which causes tensile stress in the surface of the concrete. Surface cracking can then occur due to the weak nature of concrete in tension. Currently, various manufactured fibres are used in practice to mitigate plastic shrinkage cracking. Glass fiber using as reinforcement in concrete controls such cracking, but the exact influence of fiber proportion and geometry remains unknown. A test program was carried out to understand the influence of these variables. Four commercially available Recycled Glass fibers were investigated at a low dosage rate 0.05%. For this investigation, a well known technique of plastic shrinkage testing using a fully bonded overlay was employed. In this process, a fiber reinforced concrete overlay is cast on a fully matured sub-base with protuberances and the whole assembly is allowed to dry in an environmental chamber for a day. Cracking in the overlay is monitored and characterized with time. Results indicate that recycled glass fibers in general are effective in controlling plastic shrinkage cracking in concrete even with a very small dosage of 0.05%.It was also found that a shorter fiber is more effective than the longer ones and the presence of fines in the mix dramatically effects on the shrinkage cracking control. Further, combination of different fibers appears to be highly effective in controlling plastic shrinkage cracking.

**Keywords:** Concrete, Fibre Reinforced Concrete, Waste Management, Sustainability, Glass Fibre, Crack of Concrete, Plastic Shrinkage Crack.

## INTRODUCTION

Early-age shrinkage of cement mortar and concrete has posed a major concern for decades especially in applications such as slabs-on-grade, bridge decks, shotcrete tunnel linings, thin repair patches, tilt-up panels, and industrial floors, where the surface area to volume ratio is large. Due to the increased exposed surface area, moisture loss from concrete is rapid, causing excessive volumetric shrinkage. In these applications, the exposed surface area per unit volume of the overlay material is high and the old concrete substrate or the rock surface offers a high degree of restraint. Moisture loss may occur both by evaporation to the atmosphere and absorption by subbase or formwork, especially when concrete is in the plastic state. Although some of the water lost this way is replenished by bleeding, if the surface moisture loss exceeds 0.5 $kg/m^2/h$ as because negative capillary pressures develop in the concrete causing internal compressive strains [1]. Powers (1968) studied that the concrete surface dries when the amount of evaporating water exceeds that of “bleeding”. Plastic horizontal shrinkage is caused by capillary forces due to water menisci on the drying surface [2]. It’s been also found that by delaying the capillary pressure drop associated with plastic shrinkage until after the mortar has begun to set and develop strength significantly reduced the amount of horizontal shrinkage and thus the development

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of shrinkage cracks [3]. If concrete is restrained, these compressive strains may result in tensile stresses far in excess of those needed to cause cracking in young concrete with poorly developed strength. In spite of every effort, plastic shrinkage cracking remains a serious concern. The most effective technique of mitigating plastic shrinkage cracking is by preventing the loss of water from the concrete surface by extended curing. In some instances, however, curing alone is not adequate, and additional measures need to be adopted. Shah et al reported that temperature control, shielding from high winds, reduced use of admixtures that prevent bleeding and the use of shrinkage reducing admixtures. [4]

One highly effective technique of controlling plastic shrinkage cracking is by reinforcing concrete with fibers. It's been already established that randomly distributed fibers which includes steel, polypropylene, glass etc., provide bridging forces across cracks and thus prevents them from growing.[5],[6]. The effects of flax fibres to those of conventional synthetic fibres has also studied and found that a volume fraction of 0.3% flax fibre nearly eliminated shrinkage cracking in plain mortar specimens, and that it performed slightly better than comparable lengths of synthetic fibres of monofilament polypropylene, fibrillated polypropylene, and alkali resistant glass [7]. The properties of recycled carpet fibres in glass concrete was studied and it was found that the fibres increased the fracture toughness and ductility of the concrete, but decreased the compressive strength [8].

Of all fibers used today for this purpose, recycled glass is considered to be the most effective as it is inexpensive, and easy to disperse. However, the exact influence of glass fiber geometry, diameter, length, fibrillations, etc. is not well understood. Banthia and Gupta studied the influence of polypropylene fibre geometry on plastic shrinkage cracking [9]. Their findings indicated that finer fibres are more effective than coarser fibres, longer fibres more effective than a shorter fibre, and that fibre fibrillations appeared to be highly effective at controlling plastic shrinkage cracking.

## RESEARCH SIGNIFICANCE

Plastic shrinkage cracking remains a major concern with many concrete placements. Cracking at early ages can accelerate deterioration, promote steel corrosion and cause significant durability related concerns in the long run. Tones of glass fibres are produced as by-products in the world every year. The addition of recycled glass fibres to reduce plastic shrinkage in concrete can prove to be a positive step towards sustainability. Recycled Glass fiber reinforcement can slow down such cracking but the exact influence of fiber parameters such as diameter, length and deformed geometry are not understood. A test program was conducted in order to understand the influence of such parameters. It is expected that such efforts will allow us to design better fibers for controlling plastic shrinkage cracking in concrete.

Early age crack of concrete has been studied for a long time and there exist several techniques of studying shrinkage induced cracking in cement based materials. Banthia et al developed a technique producing realistic shrinkage conditions [10,11, 12]. In this method, a layer of fresh mortar is placed as an overlay directly on a fully hardened substrate base. This 'substrate base' has protuberances, which increases its roughness and, in turn, imposes a uniform restraint on the overlay. The whole assembly is then subjected to a drying environment to induce cracking in the overlay, which is then characterized using a high magnification microscope.

## EXPERIMENTAL PROGRAM

Substrate bases (Figure 1) having dimensions of 40 x 95 x 325 mm were casted using the mix proportions given in Table 1. For providing additional stiffness two 10 mm diameter rebar were placed as reinforcement in the substrate bases. After casting, the bases were covered using a plastic sheet for a period of 24 h after which they were transferred in a tank with lime-saturated water bath and cured for at least 28 days until used in tests. The substrate concrete had a compressive strength of 80MPa at 28 days when tested in accordance to ASTM C39 [13]. The substrate bases had 18.5 mm semicircular protuberances on the surface and were designed to provide consistent restraint to the overlay placed on top.

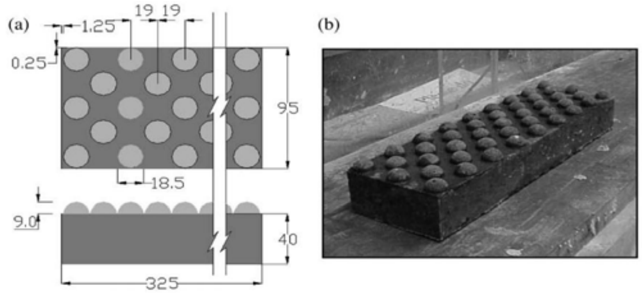


Figure 1: (a) Base dimensions with protuberances. (b) Photograph of the base
Source: Banthia and Gupta

All over the experimental program it ASTM C192/C192M was followed[14]. During testing three identical specimens of the overlay were investigated which were prepared using the following procedure. A fully cured, air-dried substrate base was first placed in the PVC mould measuring 100 x 100 x 375 mm (Figure 2). A 60 mm deep overlay with mixture proportions given in Table 1 was then poured over the substrate base and finished with a trowel. The overlays were either plain or fiber reinforced depending on the material being investigated. The substrate and the overlay 'assembly' was then transferred to an environmental chamber having dimensions 1390X1290X280mm and demolded after two hours depending on the consistency to increase the surface area exposed to drying. The chamber has six rectangular holes in the ends, three of which are located by heaters and three of which allow air to escape. The chamber is equipped with sensors which monitor and regulate both the humidity and temperature of the chamber at -0.70±.09% and 49.6±0.5°C respectively (Figure 3).

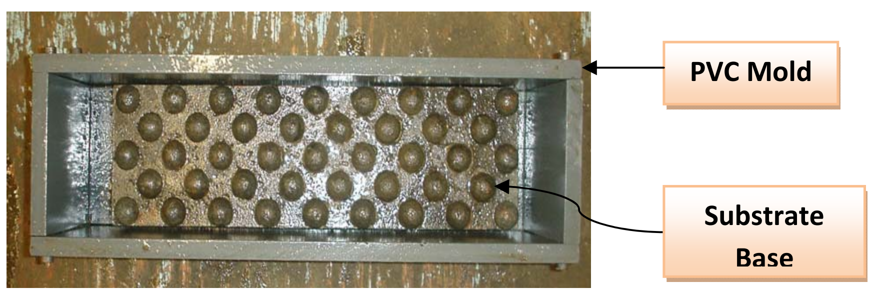


Figure 2: Substrate Ready for overlay.

The specimen remained in the environmental chamber for an additional 18 to 20 hours (for a total of 22 hours in the chamber) after which the crack pattern developed in the overlay was characterized. A typical specimen with cracked overlay is shown in Figure 4. For crack characterization, a high magnification microscope with an accuracy of 0.01 mm was used showing in figure 5. In addition to recording the maximum crack width observed in a given specimen, for each crack, the width was measured at several locations and averaged. These width and length measurements were then used to calculate the total crack area in a specimen.

Figure 3: Photograph of bricks in the environmental chamber

Figure 4: Specimen After Cracking


Figure 5: Crack Measurement Using a Microscope

## RESULT AND DISCUSSION

Four different Recycled Glass fiber mix was investigated. Table 1 summarized the properties of mixes. In Figure 6, representative crack patterns observed for plain and fiber reinforced composites with Fiber M1, M2. M3, M4 are shown. A clear effect of the fiber dosage was observed and the also presence of very few cracks for fiber M4 were noticed.

**Table 1: Recycled Glass fiber properties and dosage**

| Fiber | Fiber Type | Fiber details | Density (Kg/m$^3$) | Dosage investigated |
|---|---|---|---|---|
| M1 | Recycled Glass Fiber | BC long fiber | 2500 | 0.05% |
| M2 | Recycled Glass Fiber | BC short Fiber | 2500 | 0.05% |
| M3 | Recycled Glass Fiber | **Fiber Mix:**<br>50% BC long Fiber<br>50% BC Short Fiber | 2500 | 0.05% |
| M4 | Recycled Glass Fiber | **Fiber Mix:**<br>33% BC Long Fiber<br>33% BC Short Fiber<br>33% BC Fines | 2500 | 0.05% |

In Figure 7, the average crack width was plotted for various individual fibers. In Figure 8, the maximum crack width has been plotted for different fibers. Notice that the effect of fiber reinforcement is apparent in terms of reductions in crack area and maximum crack width. Fiber M4 was seen as more effective than all other Fiber. It was also observed that shorter fiber is more effective than that of longer ones.

Detailed results are summarized in Table 2 in terms of crack area and maximum crack width. The results reported in Table 2 are averages of three specimens for fiber reinforced mixes and five specimens for the control mix without fibers.

Comparison of Fiber Mix M1, M2, M3, and M4 indicates that presence of fines improve the shrinkage cracking capabilities noticeably. This can be explained as a finer fiber would have a larger surface area over which it would bond with the cementitious matrix and thus result in a greater transfer of tensile stress to the fiber. It can be stated that with large surface areas, fibers engage water in the mix and reduce bleeding and segregation. The result is that there is less water available for evaporation and less overall free shrinkage. They also lower the permeability of concrete and thus reduce bleeding of water which improves the resistance to crack growth.

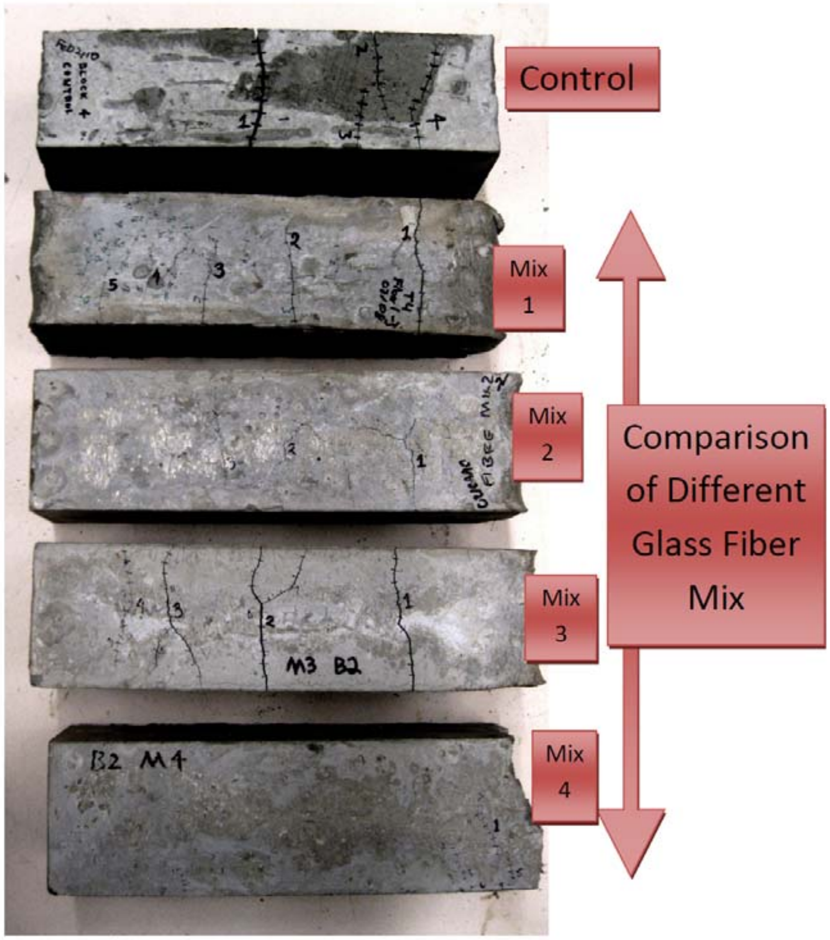


Figure 6: Effect of Different Glass Fiber on Plastic Shrinkage Cracking in comparison to the Control (no Fiber) specimen.

Table 2: Results

| **Fiber Type** | **Crack Area ($mm^2$)** | **Maximum Crack Width (mm)** |
|---|---|---|
| Control (No Fiber) | 94.69 | 2.5 |
| M1 | 66.33 | 1.01 |
| M2 | 5.52 | 0.46 |
| M3 | 30.02 | 0.99 |
| M4 | 1.79 | 0.38 |

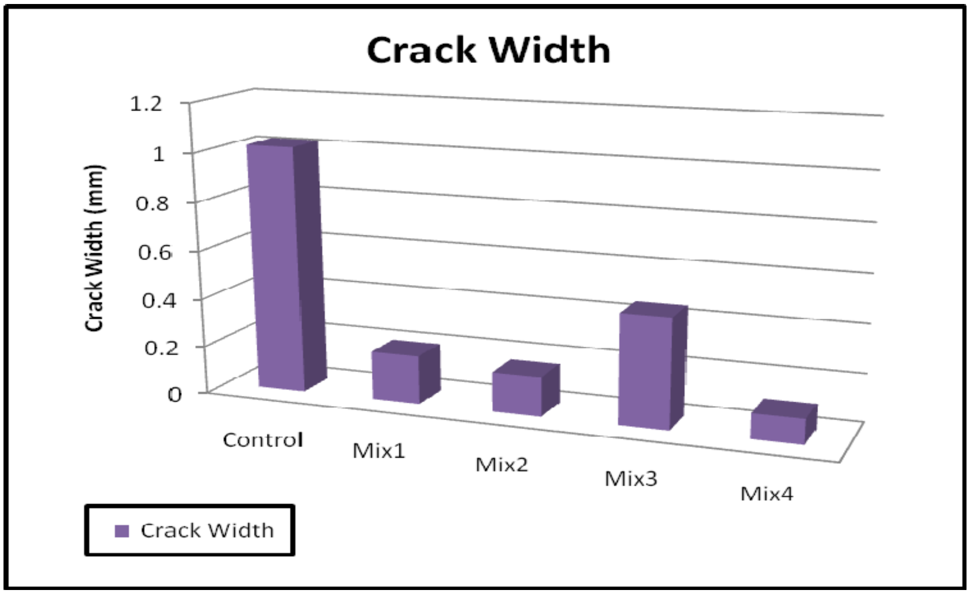


Fig 7: Comparison of Crack width for different Glass fiber

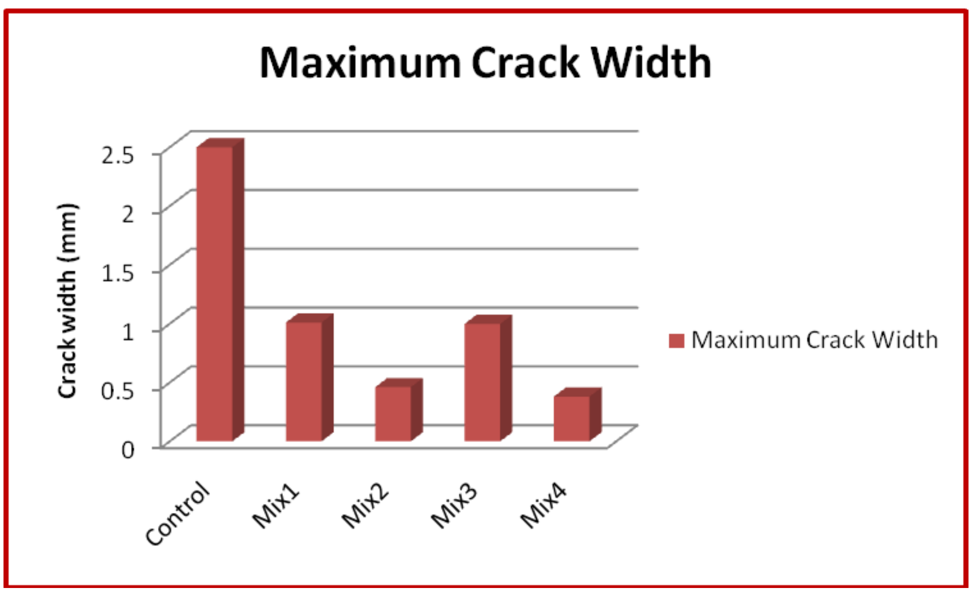


Fig 8: Comparison of Maximum Crack Width for different Glass fiber

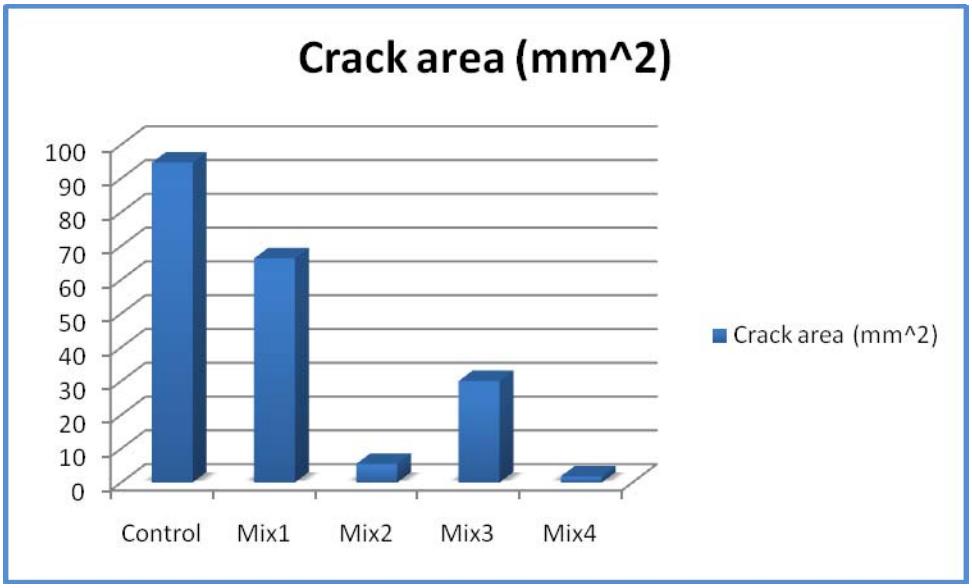


Fig 9: Comparison of Crack Area for different Glass fiber

Moreover it can also be assumed that, Glass fiber is more compatible with concrete ingredient than others, because the density (2500 kg/m$^3$) is very close to that of the overlay mortar (2377 kg/m$^3$) has been evaluated. As a result, the fiber is better integrated with the concrete as it will neither segregate from the concrete mix materials nor float towards the surface during pouring and setting as is the tendency for polypropylene and nylon reinforcing fiber, thus providing the better fiber distribution throughout the concrete.

Also, at a given fiber volume fraction, a finer fiber will allocate more fibers crossing a given section. This will allow for an efficient truncation in the lengths of unsupported matrix cracks between fibers, reduce the stress concentration. Overall glass fiber has finer diameter than that of other fiber, it improves the resistance to crack growth perceptibly.

**CONCLUSION AND RECOMMENDATION**

Effect of Recycled Glass fiber on improvement of resistance to Plastic Shrinkage crack was investigated for 4 different mixes. Various conclusions can be drawn from the experimental study as follows:

1. The test results indicate that glass fiber is highly effective in controlling plastic shrinkage cracking in concrete. In general, Glass fibers reduce the total crack area, maximum crack width and the number of cracks. This is because may be Glass fiber is more compatible with concrete mix than others having similar density which offer an integrated bond of fiber-matrix.
2. It can also be stated that the shorter fiber is more effective in plastic shrinkage crack control than the longer ones. The reason can be described, as because for the same volume fraction of fiber the number of fiber will be increased for the shorter ones which will ensure the more fibers and an even distribution all over a cross section area.
3. From the test results it can also be declared that, the presence of fines has a dramatic effect on shrinkage crack control. The cause behind this is because for the fines, the surface area is being increased for the same volume fraction of fiber in comparison to others. An enlarged surface area

offer more involvement of water in the mix which reduce bleeding and segregation. Thus less water available for evaporation and less overall free shrinkage.

For the future study it can be recommended to do more variation in terms of fiber volume fraction in FRC and analyze which volume fraction has the best results for controlling Plastic Shrinkage Crack. This result can be compared with the other fiber (polypropylene, Nylon etc).

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# IMPLEMENTATION OF H/V SPECTRAL RATIOS ON AMBIENT VIBRATIONS FOR SITE CHARACTERIZATION

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## ABSTRACT

Site response analysis is considered to be the fundamental step of seismic hazard analysis. Among the different available methods for evaluating site effects, use of the H/V spectral ratios on ambient vibrations has become widespread because of its low-cost, fast deployment and simple analysis procedure. The H/V spectral ratio is an empirical method that computes the spectral ratio between horizontal and vertical components of the seismic noise recorded simultaneously at a given location with a 3D seismometer placed at the ground surface. In the case of a stratified soil profile composed of a soft layer at the top of a stiffer layer, the 1D amplified frequency $f_0$ may be estimated according to the equation $f_0=V_s/4H_s$, where $H_s$ is the thickness and $V_s$ is the shear wave velocity of the topmost layer, respectively and when the S-wave contrast is sufficiently large. This simple relation linking fundamental frequency, shear wave velocity and depth is useful to detect the sedimentary zones that could amplify seismic ground motion. The H/V technique has been frequently adopted in seismic microzonation investigations to map the fundamental period of the site and help constrain the geological and geotechnical models used for numerical computations. The method is especially recommended in areas of low and moderate seismicity, where there is lack of significant earthquake recordings. In addition, this technique is also useful in calibrating site response studies at specific locations. This method can also be used to image shear wave contrasts (slip surfaces) and characterize bedrock geometries in 3D for landslide sites where geophysical imaging methods like seismic reflection or tomographies are difficult and expensive to perform.

In this paper, an implementation of the H/V spectral ratio technique using ambient vibrations has been presented associating field experiment, data processing and interpretation of the results. The investigation was carried out at 5 m intervals on a 135 m long seismic section. The site is a soft-rock landslide area of the South French Alps, known as Saint-Guillaume, where independent geotechnical and geophysical information are known from the tests performed earlier. The geophysical software Geopsy was used to process the acquired ambient noise data for H/V analysis. The first peaks for the recording points were observed mostly to be in the frequency range of 0.5 -1.25 Hz. Average shear wave velocity was taken as 350 m/s from previously performed tomography results and the bedrock depth (H) variation was calculated as 70 – 100 m. The nearest borehole data to the site shows a bedrock depth of 61.7 m, so the result can be said to be in the same order of magnitude as the known

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geotechnical data. The H/V amplitudes for all the points were observed to be more than 3, which is an indicator of the lower bound of ground motion amplification for the site.

**Key Words:** Site Response, Ambient Vibrations, H/V method, Fundamental Frequency, Shear Wave Velocity, Microzonation, Geopsy

## 1. INTRODUCTION

Site effects in terms of amplification of ground motion on soft and surficial soil is a very important issue in earthquake hazard analyses due to their potential consequences like instabilities leading to natural landslides or significant settlements of foundation. Therefore, the knowledge about the spatial distribution of soft layers, their thicknesses, as well as their mechanical characteristics is of great interest for landuse planning, hazard mapping and geotechnical engineering. Geotechnical investigations (e.g. boreholes) combined with geomorphological observations are generally used for site characterization. These studies are essential because they provide direct information of the site. Since the soft soils may concern sprawling area, the geotechnical methods are not always appropriate, especially for the sites with strong lateral variability of the bedrock and sliding depth. The time and cost involved with these methods and their limited spatial representativeness obstruct their use in 3D studies. The limited depth of investigation is also another inconvenience in case of thick sediments. For all these reasons, geophysical methods (seismic refraction, reflection, tomography), which are able to cover a wide area with continuous imaging of the subsurface zone and hence can address 2D/3D problems have gained high acceptability in site characterization studies. But these methods are heavy to set up, require some complicated processing tools to implement; as a result they are expensive and time consuming to some extents and thus recommended mostly for high risk areas. Consequently fast and easy to deploy method involving reduced cost of investigation is required which can at least locate the slip surfaces and characterize bedrock geometries. Seismic noise method of H/V ratio requires lighter instrumentation, easier processing tools and thus can be used to represent the soil profile with much less effort especially for the landslide areas difficult to access and thus are extensively applied for seismic hazard mapping in the recent years. The investigation intends to obtain fundamental frequency of the soil and corresponding depth to S-waves velocity ratio. Using H/V ratios, when velocity is known depth of the layer, and vice versa, can be calculated.

The aim of this paper is to present an application of the H/V spectral ratio using ambient, applied to a site in Saint-Guillaume, a small town located to the South of Grenoble (French Alps). Geomorphological-geotechnical survey has been deployed on the site since 1984. The information obtained from the boreholes was used to compare and valid the results deduced from seismic noise survey.

## 2. BACKGROUND: THE SITE

The commune of Saint Guillaume is located on the Trièves Plateau in the départment of Isère and the Rhône-Alpes region in France (Figure 1). The plateau is composed of varved clays, finely laminated glacio-lacustrine deposits dating from the Pleistocene (Wurmenien) period [1]. Saint-Guillaume rests on 40 to 60 metres glacio-lacustine clays from the Wurmian period, overlying Oxfordian marly limestone [2] (Figure 2). Due to the mountain/valley topography the clays are slowly slipping down slope into the Gresse River. Light seismicity in the area contributes to this slope instability. This landslide has been triggered during the Holocène; the displacement velocity range from 1.5 to 3 cm.year-1 [3]. The borehole drilled in the study area (shown in Figure 3) have pointed out the existence of a varved clay/marly limestone transition zone located 38.50m, 61.7m and 33.10m depths at I1, I3 and I4 boreholes, respectively. Two of the boreholes (I1 and I4) show a sliding interface at between 27 and 34.5 metres deep. However, the other borehole (I3) shows two sliding planes at 13.5 and 36.5 metres deep. All these values are consistent with van Asch's (1996) [1] observations of the landslides in the region. As borehole I3 is nearest to the investigation site, the subsurface for this area may be formed of two sliding interfaces above the bedrock.

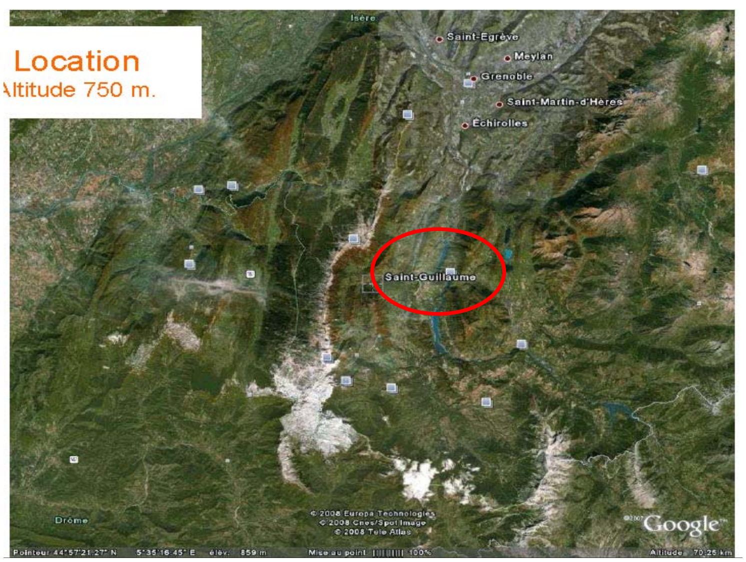


Figure 1: Location of Test Site Saint Guilaumme

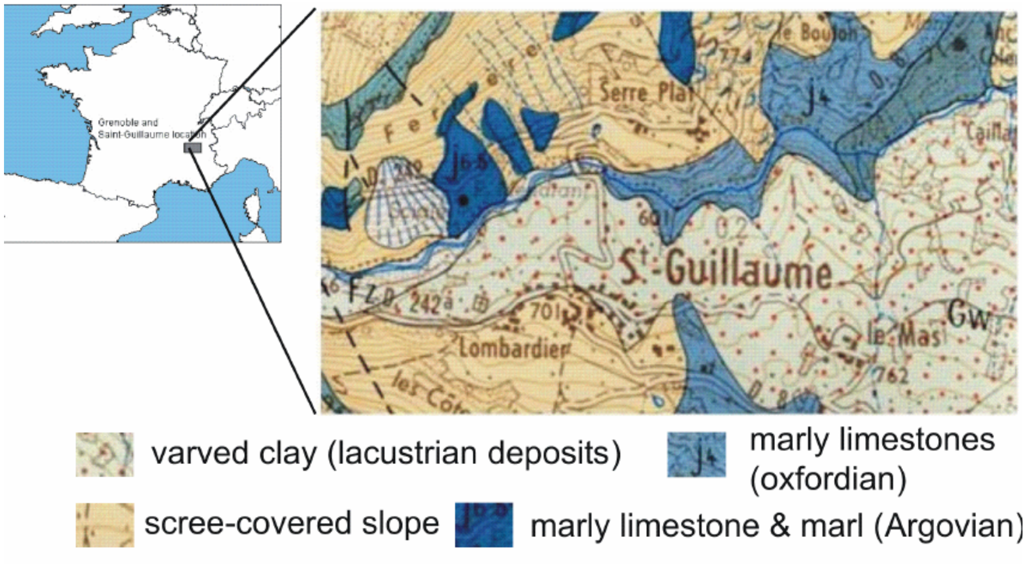


Figure 2: Geological Setting of the Site

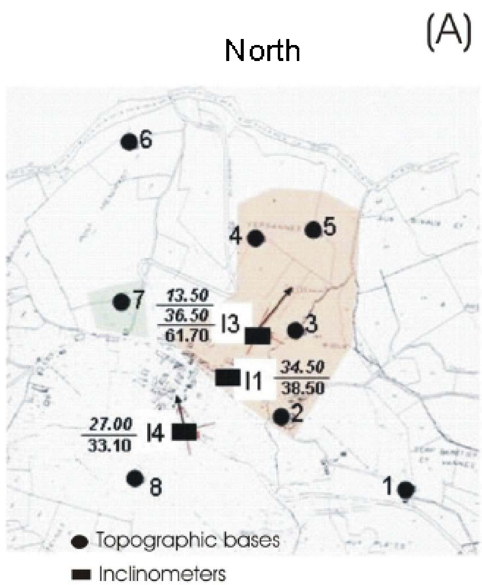


Figure 3: Existing Geotechnical Data for the Site

## 3. H/V SEISMIC NOISE METHOD

The H/V method computes the spectral ratio between horizontal and vertical components of the seismic noise recorded simultaneously at a given location with a 3D seismometer placed at the ground surface. Nakamura [4] first proposed the use of the H/V method as a tool to estimate the seismic response of the surface layers. This method has since been widely diffused around the world by Nogoshi & Igarashi [5]. The validation of the H/V spectral ratio using noise has been since confirmed both experimentally and from theoretical and numerical studies. In the case of a stratified soil profile composed of a soft layer at the top of a stiffer layer, the 1D amplified frequency $f_0$ may be estimated according to the equation $f_0=V_s/4H_s$, where Hs is the thickness and $V_s$ the shear wave velocity of the topmost layer, respectively [6]. By knowing the shear wave velocity $V_s$ of the upper layer, thickness of this layer can be obtained from the equation. Shear wave velocity can be derived from S-wave refraction or surface wave analyses. The underlying basic assumption to use this simple relation considers the profile to be 1D model which is not the geometry of most valleys. The resonance frequency deduced from ambient seismic noise can be affected strongly by strong 2D effect of valley shape. It has been shown that the peaks in this spectral ratio H/V (ratio of horizontal fourier spectra to the vertical fourier spectra) can be accurate in assessing the fundamental frequency due to the nature of the ellipticity of Rayleigh waves. As the vertical component of Rayleigh waves approach zero near the fundamental frequency, a peak in the H/V ratio is observed. The reliability of the value increases with the sharpness of the H/V peak, no straightforward information can be directly linked to the H/V peak amplitude $A_0$. This amplitude value may be considered as indicative of the impedance contrasts at the site under study: large H/V peak values are generally associated with sharp velocity contrasts.

## 4. ON-SITE INVESTIGATION

In the field the ambient vibrations at 27 locations with 5 m spacing were recorded using a 3D Lennartz five-second sensor. Measurements were taken in fifteen minute time intervals along three directional components (vertical, horizontal EW, horizontal N-S). The sampling frequency was 200Hz. During the survey seismic noise method was carried out for the site along the seismic line shown in Figure 4.


Figure 4: Locations of Noise Record Points on Seismic Line

## 5. DATA PROCESSING & RESULTS OBTAINED

Geophysical Data Processing Software Geopsy was used to process the data. According to the SESAME Guidelines for the Implementation of the H/V Ratio Technique on Ambient Vibrations [7] a reliable H/V curve needs to have the natural frequency ($f_0$) greater than 10 divided by the time window length. This data was processed using a 50 second time window, meaning that the natural frequency should be greater than 0.2 Hz. All the fundamental frequencies obtained from this analysis were greater than 0.2 Hz, mostly being in the range of

0.5 to 1.25 Hz, so this criterion was fulfilled. The weather on the day of the field experiment was clear, but windy. Wind can cause a significant level of noise to be observed from the trees and grasses at the site. This means that the wind will influence the results by introducing low frequencies in the H/V curves which was clearly observed in the results. Data Processing window in Geopsy is shown in Figure 5. The resulting H/V curves after reprocessing are shown in Figure 6. The gray stripes represent one standard deviation either side of the frequency peak.

Figure 5: H/V ratio Vs frequency curves for the receiver points

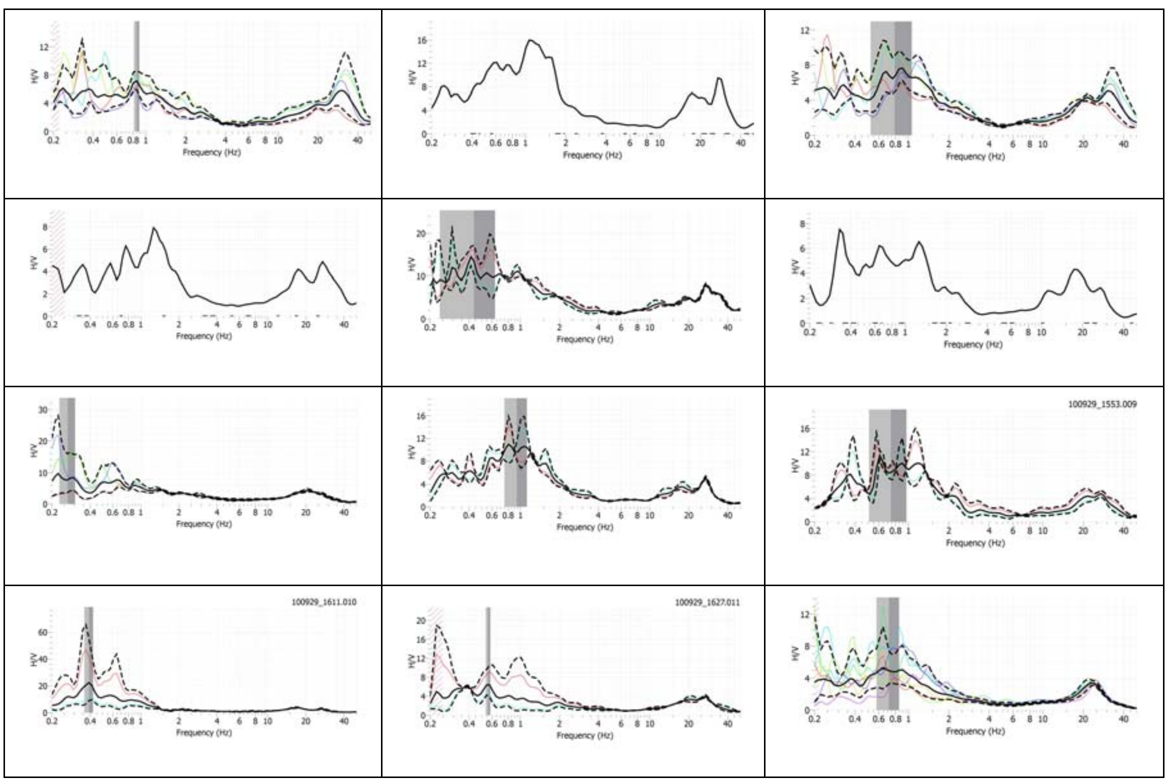


Figure 6: H/V ratio Vs frequency curves for the receiver points

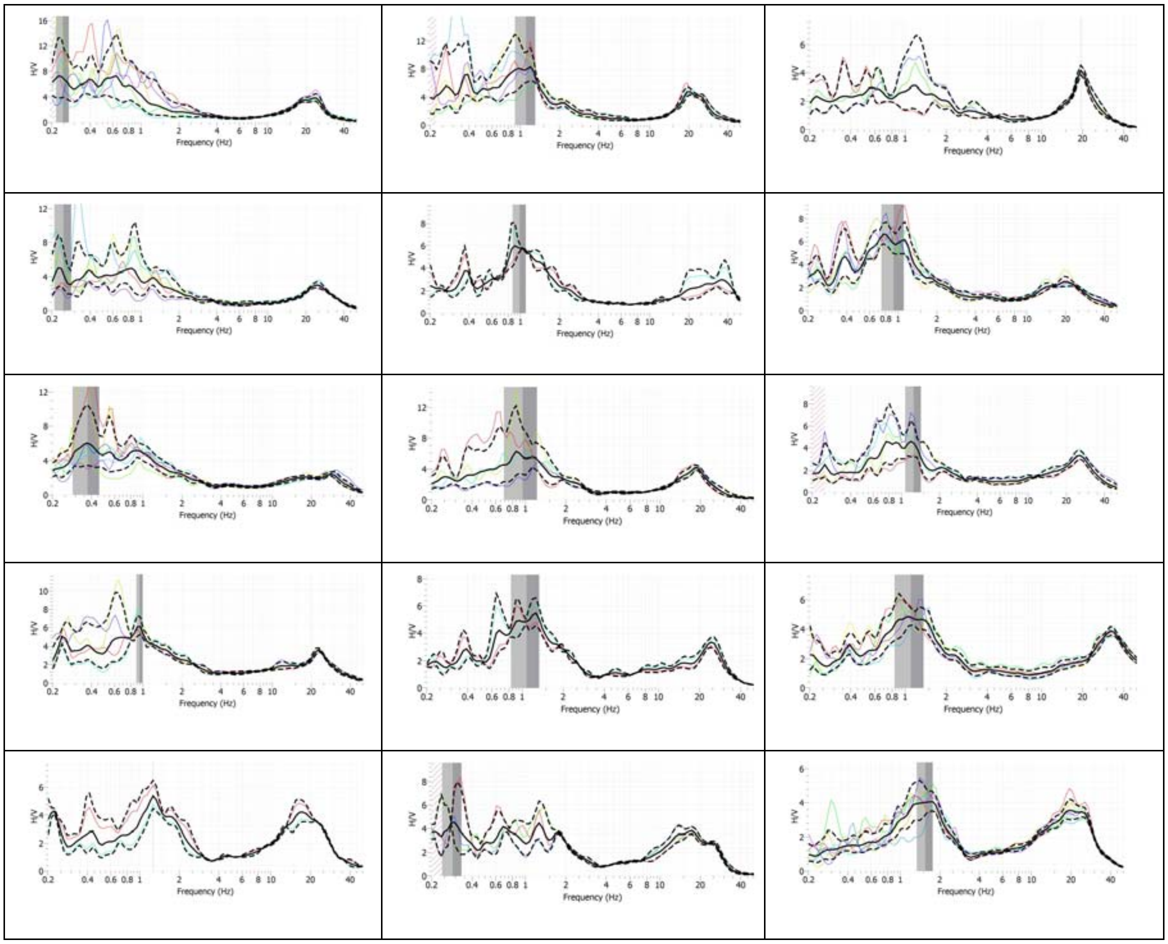


Figure 6 (contd.): H/V ratio Vs frequency curves for the receiver points

## 6. RESULTS INTERPRETATIONS

The interpretation of the H/V spectral ratio is dependent both on the sources of these vibrations and on the underground structure. It is also related to the effects of the different kinds of seismic waves (e.g. body waves, surface waves) on the H/V ratio including higher modes of surface waves. Therefore it is important to collect available geological and geotechnical information as well as prior rough estimations of impedance contrasts to compare with the results obtained.

The results of the analysis showed a dispersion of first peaks concentrated mostly between 0.5 and 1.25 Hz. However, the clear peaks were not always observed in the plots. It can be deduced here that the actual natural frequency of the ground profile is somewhere less than 2Hz. The primary reason for the errors would be the high levels of low-frequency noise from the weather conditions. As local atmospheric conditions typically have frequencies of ~1Hz, wind can introduce noise at low frequencies in the H/V curves making this band more likely to be noisy. A filter could be applied to the data to limit the amount of unwanted noise. As H/V method is affected by the noise penetrating through the ground column, a high pass filter of 1 Hz could be useful.

In some of the cases H/V curves exhibited a fuzzy, unclear low frequency peak (at frequencies lower than 1 Hz), or a broad peak. It may have been caused due to a low frequency profile with either moderate impedance contrast at depth, or a velocity gradient, or a low level of low frequency ambient vibrations. Additional measurements performed over a longer time or in quieter environment can improve this condition. The natural frequency shows a slight increasing trend from the first to the last record (i.e. north to east). This could be construed as a slight decrease in bedrock depth between the northern and eastern part of the seismic line.

A second peak was observed around the frequency 20 Hz which might be indicative of shallower depth. It implies likely two large contrasts at shallow and large depth at two different scales. These points require cross-check with geology. Anyway, no data above 15Hz was used, the higher natural modes of the substructure is not of interest in the analysis.

Using the relation $f_0 = V_s/4H_s$, the depth to bedrock was estimated. A value of the average shear wave velocity to the bedrock is needed to be calculated from other geophysical results. For the frequency to depth conversion, an equivalent velocity of 350 m/s was taken. This value was deduced from S-wave refractions and surface wave analyses, performed on the site along with the H/V records. The low frequency was picked and converted into depth, allowing obtaining an image of the bedrock geometry. The lateral variation of fundamental frequencies for the 27 points along the seismic line and corresponding bedrock depth profile have in shown in Figures 7 and 8. The derived curve is relatively well consistent with the I3 deduced bedrock depth.

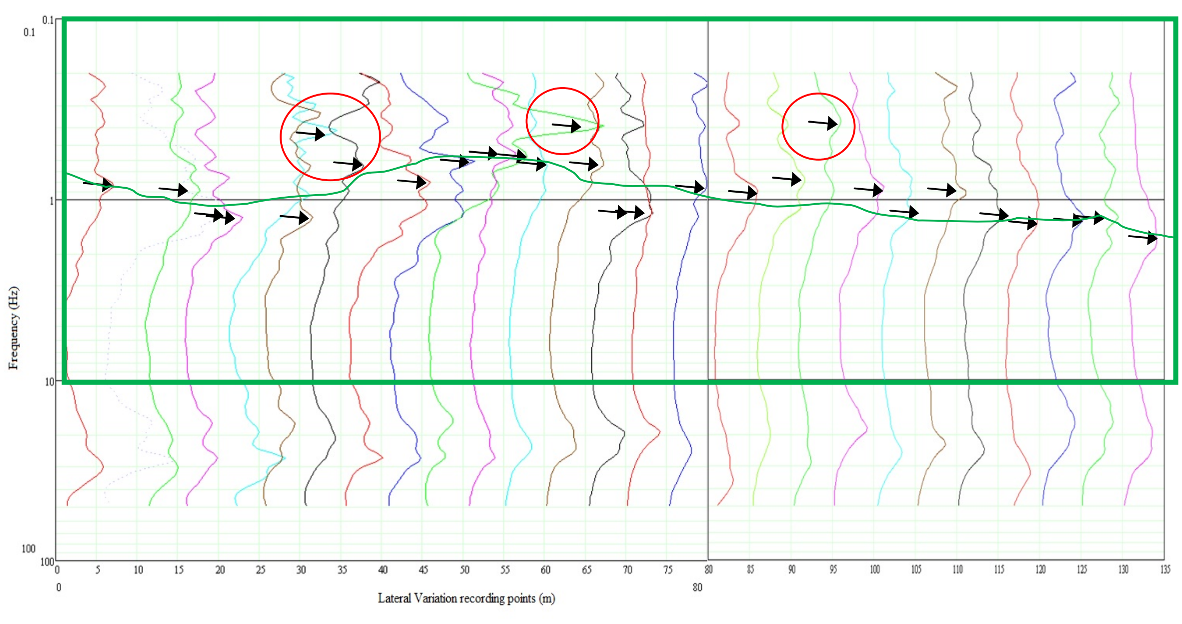


Figure 7: Fundamental Frequency profile along seismic line

The H/V amplitudes for all the curves in Figure 6 are mostly between 3 and 7 apart from some extremely high values. Although H/V ratios and ground motion amplifications are not directly correlated with each other, the ratio of H/V is often an indicator of the lower bound of ground motion amplification. In accordance with the SESAME Guidelines [7], the H/V results indicate that there is an 80% chance that the ground motion at the surface will be more than 3 times greater than that at the bedrock.

From the estimate (Figure 8), the approximate bedrock depths were calculated as 60 to 300 m, which can be averaged as between 70 – 120 m variation, by neglecting the high values of depths resulting from the very low fundamental frequencies. The nearest borehole to the site (I3) shows a bedrock depth of 61.7 m, so the result can be said to be in the same order of magnitude as the known geotechnical data. The profile shows strong lateral variations of the topmost layer. The major inconsistency for few points could be due to the lack of precision in the data.

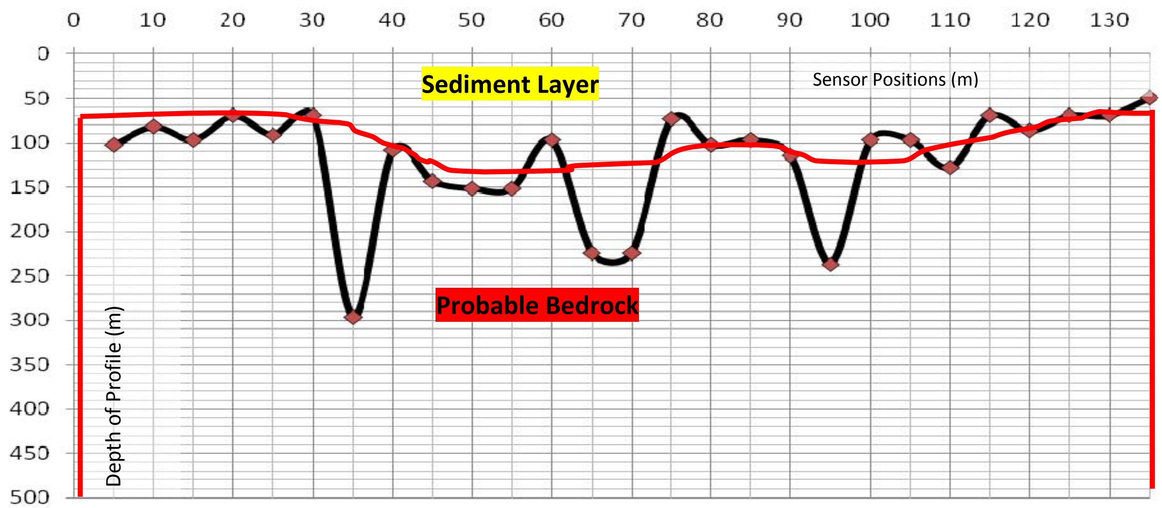


Figure 8: Bedrock depth profile along seismic line

## 7. LIMITATIONS

The H/V spectral ratio method is an experimental technique to evaluate some characteristics of soft-sedimentary (soil) deposits. It is widely used in seismic microzonation investigations due to its low cost and easy deployment. The method has proven to be useful to estimate the fundamental period of soil deposits where large contrast between the soil layers exists. However, this technique alone is not sufficient to characterise the complexity of site effects and in particular the absolute values of seismic amplification. Thus it can be used to map the fundamental period of the site and help constrain the geological and geotechnical models used for numerical computations. In addition, this technique can also be used in calibrating site response studies at specific locations. The method is especially recommended in areas of low and moderate seismicity, due to the lack of significant earthquake recordings, as compared to high seismicity areas. The measurements and analysis should be performed with caution. The recommended use of the H/V method is to combine several other geophysical and geotechnical approaches with sufficient understanding of the local geological conditions. In such a case, the interpretation of the H/V results can be improved significantly in the light of the complementary data.

## 8. CONCLUSIONS

The purpose of the Saint-Guillaume site investigation was to investigate the landslide and develop a model of the subsurface of along a section of the site. It is assumed from the H/V results that the interface between the clay layer (velocity 350-400 m/s) and bedrock is at 70~100 m depth. The nearest borehole to the seismic line shows bedrock depth at ~62 m which is quite comparable with the obtained result. The result calculated here is larger than the known data, but it is possible that the bedrock does not have either a flat or simple dipping interface. If the bedrock beneath the seismic line was sincline, the results obtained here could be considered reasonable. Moreover, for this particular study the duration of record was only 15 minutes and the length of the profile was 135 m only which are not sufficient to obtain higher accuracies in the results. Longer records and larger section should be considered to get a clear picture of the profile. However, here the H/V spectral ratio was used in order to check its efficiency and limitation to define the lateral variations of a very surficial layer characterized by a sliding motion. There is no doubt that the H/V spectral ratio is rather limited to define all the mechanical properties of such geotechnical formation. Nevertheless, within the limitations of the study, a compatible correlation has been found between the H/V spectral ratio and the classical geophysical method which was also confirmed by the geotechnical borehole data. This method is very useful and can be applied in addition to classical geotechnical survey to deduce the topmost layer topography for profiles containing homogenous layer.

## 9. ACKNOWLEDGEMENT

This study is a part of the geophysical field survey, held in September 2010 for MEEES class, to characterize the soil profile of a translational landside site, Saint Guillaume. The author humbly acknowledges to Philippe Guéguen, Researcher, Institut des Sciences de la Terre, UJF, Grenoble for guiding in field work, data processing and data analysis.

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# ESTIMATING ICTHIOFAUNAL BIODIVERSITY THROUGH PARTICIPATORY LEARNING ACTION

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## ABSTRACT

The present paper has been the outcome of a rigorous research work to identify the factors attributing to the fast reduction of local fish biodiversities. The indigenous fish goners are the most important bio-ecological indicators to measure the intensity of changes disturbing ecological balances of any microfarming system both in intrinsic and extrinsic manner. Some local and innovative measuring devices, elicited by the stakeholdsers themselves, were applied to calculate the FMV and fish landing in different local markets. This would ultimately make the researchers draw conclusion that the factors like chemical loads in agriculture, occupational change of the rural people, destruction of local bodies, indiscriminate use of pesticides in agricultural field and adjoining water bodies are all responsible for ushering a faster decline of these local fish species. The decline of species has been measured in terms of loss of decadal score down the years and declining availability of these fishes across the spatial distribution had been statistically intercepted to get the most expected estimation of species count and the factors contributing to them. Other PRA tools had been administered and subsequently been quantified for facilitating the objective analysis and drawing thereby a logical conclusion.

**Key words**: Icthiofaunal diversity, climate change, ecology, chemicals, microfarming system

## 1. INTRODUCTION

Fishes exhibit enormous diversity in their morphology, habitats and their biology. Unlike the other commonly recognized vertebrate groups, fishes represent a heterogeneous faunal assemblage. Fishes also constitute almost one-fourth of the total number of vertebrates. An estimated 21,723 living species compared with 21,450 extant tetrapods have been described from the globe (Nelson,1984). It was also noticed that a total of 28,500 fin fishes have so far been recorded from different parts of the globe of whicvh India shares around 2,200 (Anon., 1998 a ). All individuals of most species of fish live entirely in fresh or saline waters. A few are diadromous, a part of their life cycle, they spent in fresh water and rest part in the seas. The approximate ecosystem wise distribution of fish genetic resources of India are 73 species (3.32 %) in cold waters, 544 species (24.73 %) in fresh water of plains, 143 species (6.50 %) in brackish water and 1440 specie (65.45 %) in seas around the country (Das,2002).

A large number of fish species had once been very common in different water bodies of different ecological conditions all over India a few decades back but due to the destruction of habitats, pollution of water, introduction of exotic species, systematic elimination from culture system, overexploitation, population of a number of fish species have been depleting steadily from different corners of the world. Besides, ecodegradation, owing to varied natural

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and anthropogenic factors, the water bodies are gradually becoming non-productive (Jhingran, 1988; Pandit et al., 1994). Therefore, the situation warrants for identification of fishes and categorization including prioritization of the need based problems. The fish genetic resources which are at an eloping state, if proper conservation strategies are not worked out based on the baseline information with regard to biology and ecology of fishes will be lost for ever in near future.

## 2. OBJECTIVE

1) To enlist different icthiofaunal components inhabiting different water bodies of the area and to classify them on the basis of their availability and abundance.
2) To assess icthyofaunal productivity (production of fish/unit area/unit time).
3) To identify and assess different biosocial and techno-managerial factors related to icthiofaunal diversity and icthiofaunal productivity.
4) To study biology of one threatened fish so that similar studies may be taken up as a part of conservation strategy of threatened categories.
5) To generate avenue for delineating strategic intervention towards providing efficient and sustainable management approaches and techniques in fish production and management in le3ntic water bodies of the area.

## 3. METHODOLOGY

The deliberation on the methodology has been made to understand the concepts, methods and techniques used to design the study, by collecting the icthiofaunal information, analyzing data and interpreting the findings. Fish species are collected from different selected locations of rivers, lakes, ponds, canals, streams, paddy field etc. through random nettings with the help of drag-nets, caste-nets, gill-nets, different types of local traps, barriers etc. as well as from the fisherman community and also from different local markets during different seasons. Immediately after collection, the specimens were preserved in 5 % buffered formalin solution. Indigenous naming of different fishes was determined through focus group discussion (Mukherjee, 1995). The specimens were subsequently identified following standard references (Day, 1978; Jayaram,1981; Menon,1987; Talwar and Kacker,1984;Talwar and Jhingran,1991).

The experiment was conducted in aquariums, three ponds each with an area of 2.5 decimal, 10 decimal and 33 decimal, respectively situated at East Singh, Jharkhand, India. Live specimens of *Puntius sarana* were brought to the laboratory from different collection sites viz aquarium, earthen tank and open water bodies like Dimna Lake and Subarnarekha River for further studies. The colour, external appearance of mouth, nostril, burbles, operculum, trunk, unpaired and paired fins, scales, anus, tail, skin and lateral line were recorded through visual observations and with the help of vernier scale. The fecundity of *P. sarana* was estimated by studying 25 individuals after being collected from well managed culture ponds which were catched by caste nets and at the same time matured females of *P. sarana* were also collected from large open water bodies by both caste nets and gill nets. Participatory Learning Action (PLA) is a methodology, which helps in interacting with local communities, understanding them and learning from them. It helps in the process of involvement with local communities for indigenous knowledge-building exercise.

General analysis of specific topic, question or problem; needs assessment;Feasibility studies;identifying priorities for development activities; implementing development activities where new information needs to be collected; and monitoring and evaluation of development activities.

A pilot survey was conducted in the selected villages before constructing and finalizing the data collecting devices. In course of this survey, informal discussion was carried out with some fishermen, local leaders and extension agents of the localities. An outline of the socio-economic background of the fishermen of the concerned villages, their opinion towards pisci-culture and prevailing problem concerned with the pisci-culture were enumerated to construct the structured schedule for the study.

**A. Dependable Variables.**

Fish productivity (Y)

**B. Independent Variables**

Age of pond holder ($X_1$),Educational qualification ($X_2$),Training taken ($X_3$),Family members ($X_4$),Gross monthly income ($X_5$), Ownership of pond ($X_6$),Water area ($X_7$),Depth of pond ($X_8$),Water retention period ($X_9$) ,Distance of pond from residence ($X_{10}$),Transparency of pond water ($X_{11}$),pH of pond water ($X_{12}$),Plankton present in the date of survey ($X_{13}$),Free $CO_2$ ($X_{14}$),Gross alkalinity ($X_{16}$),Stocking density ($X_{17}$),Gross cost of inputs ($X_{18}$),Size of fish fry ($X_{19}$) and Gross investment cost ($X_{20}$)

## 4. RESULTS AND DISCUSSION

### 4.1 Trend Analysis (Decade Wise Fish Availability)

Participatory trend analysis on decadal distribution starting from 1960 to 2000 depicts the availability of seventy five fish species in terms of percentage of population depletion in East Singhbhum District (Table - 1). To analyze the nature of increase and decline of the populace of target fishes over decades taking reference from the age-old and experience profiles of 150 local fishermen.

The graphical presentations can be conceived as the results of the PLA exercises. The bar diagrams (fig. 1) depicted the quantification of different decline of a species over different decades. This has provided an inkstand vision of the decline trend and character of a given species over different decades.

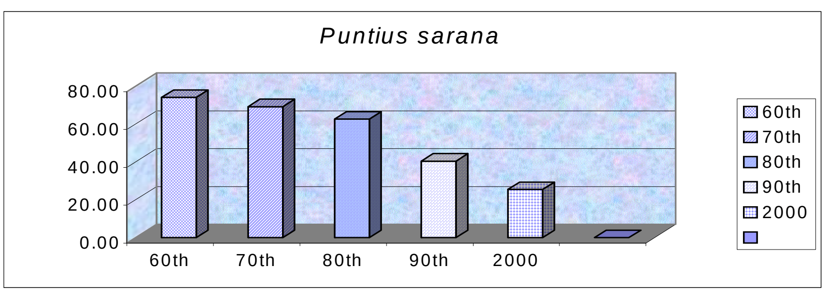


**Figure 1:** illustrate the distribution and decline of an economically and ecologically viable indigenous cyprinid fish ***Puntius sarana*** over different decades as percept and assessed by the fishermen from their profile of experiences and collective wisdom.

### 4.2 Multiple regression analysis: Fish production and twenty other causal variables.

It was envisaged from the multiple regression analysis (table 4) that the variables plankton quantity ($X_{13}$), stocking density ($X_{17}$), cost of inputs ($X_{18}$), size of fry ($X_{19}$) and the gross investment cost ($X_{20}$) had played the most significant roles in fish productivity. It was also discernible from the table that, a unit change in plankton density had been resulted into 0.375 unit change in the productivity. The higher abundance of plankton in a water body had a decisive effect on the feeding of fishes and their subsequent growth which ultimately increased the body weight vis-à-vis productivity.

Cost of inputs ($X_{18}$) had recorded a strong regressional effect on the fish productivity. This would mean that with the increase in allocation of expenditure on critical inputs, the output per unit area had gone high up. As usual it would have been, the same causal relation had also been reflected in between gross investment cost and increase in productivity. The $R^2$ value being 0.5227 it can be inferred that all the variables (twenty) jointly had explained 52.27 per-cent of the variability in the consequent factor i.e. productivity of fish.

The variable size of fry recorded the significant regress ional effect on the fish productivity. In case we ignore the cost of fish fry, the size of the fry had a strong effect on the productivity of per unit area. Higher size of fish fry means the higher rate of survivability, which ultimately would breed on the productivity of fish. Of course, optimization of the economic size of fry itself should be a serious consideration while cost benefit ratio, input output ratio or efficiency factor is taken care of.

This would suggest that inclusion of more number of logical and contextual causal variables in the study could have explained higher amount of variability embedded with the consequent factor of productivity of fish.

**4.3 Path analysis: Direc, Indirect and Residual effect of exogenous variables on the consequence of variables of fish productivity.**

From the path analysis (table 3) it was found that the variable plankton quantity had exercised the highest direct effect on the fish productivity. This finding went had a gross compliance with the earlier findings as in found in the co-efficient of co-relation study. So, any fish manager now had to concentrate more on generations of plankton in a given pond area to adopt befitting management practices. In the higherarchy of importance, variable cost had occupied the second position. Variable cost implied expenditure incurred after yeomen inputs, having an immediate effect on productivity. The result rightly implied that the more the investment of the pisci-culture management the higher had been the productivity. The third variable in the tally of importance had been the stocking density ($X_{17}$). In the rearing stage, the density of fish populations per unit area had a decisive effect on the fish productivity. The level of stocking density had a stress on the food and had a stress on the availability of plankton, oxygen, and other materials to thrive in. Again, a judicious stocking density would help the most clandestine exploitation of the ichthyofaunal ecosystem to attain the desire productivity. In the fourth position, the variable was size of fish fry, which had also exerted the substantial direct effect on the fish productivity. The size of the fish fry helped to make a good take off in the realm of fishery management and ultimately to contribute to the level of fish productivity. It was also to be kept in mind that, in the arena of multivariate analysis, no single factor in a linear way can be helped unilaterally, and so also was the size of the fish fry. That was why only the size of a fish fry could not be, in a linear way, connected with the production.

From the tariff of the substantial indirect effect, it was found that through the variable plankton quantity ($X_{13}$) the highest indirect effect of nine variables had been channeled. Thus, in the web of interaction, the role of plankton quantity ($X_{13}$) in impacting the fish productivity had become unquestionable. So, intervention is to be made to increase the plankton quantity as to make the other factors adequately operable in increasing the fish productivity per unit area. The residual effect had been 0.4773 and it was to infer that 47.73 per cent of the variations in the consequent variable i.e. fish productivity per unit area, could not be explained by the constellation of twenty antecedent variables only. Thus, it would further be suggestive that inclusion of more number of pertinent and contextual antecedent variable would have provided higher efficiency for explaining more variations embedded in the consequent variable i.e. productivity per unit area.

### 4.4 RBQ: The Rank Based Quotient

Six groups meeting with 150 local fishermen, having at least 40 years of experience in fishing, were organized to generate information on factors responsible for the problems related to ‘why fish population had gone a sharp decline over the decades’. These problems were identified through participatory interactions and also had undergone categorizations, sorting and screenings. The number of participants in these interactions was 25 for each focus group. Four such groups were undergone for necessary interactions to generate adequate data. This type of participatory tool (RBQ) has already been successfully applied to assess and document the nature and degree of decline of a score of selected species over decades (1960 – 2000) (Patra et. al. 2005).

Following Rank Based Quotient (RBQ), it was found that (1) use of pesticide in different fields occupied the first rank followed by destruction of brood fishes during monsoon (2), lack of water retention capacity (3), different diseases resulted out of fish production (4), sharing problems of water bodies (5), destruction of fish spawn and fry (6), lack of financial support (7), lack of knowledge (8), destruction of breeding ground (9) non-availability of fish spawn (10), fishes grown in stagnant water due to sloppy land (11), lack of machinery (12), rapid urbanization and population explosion (13), high cost of pisci-cultural equipments (14) and problems of natural calamities (15). During last few decades, mass mortality of fishes has been observed in India and elsewhere as a result of disease associated with eco-degradation (Tarzwell and Henderson 1957; Saunders 1969; Konar 1975).

## 4. CONCLUSIONS: STRATEGICAL IMPLICATIONS

Conventional researches on any biotic resources have so far ignored the aspect of social need like resource and livelihood, managing resources and peoples participation, productivity and social ecology etc. Mere counting of abundance or rearity of any species could not derive any clear-cut finding on how to make proper interventions in properly dealing with the issue.The study had rightly placed laboratory-based observations in the core of people’s wisdom and experiences over time to be matched verified refined and tested. Success was achieved to observed that the factors as identified and quantified through PLA techniques (**Resource diagramming, Vector scoring, Time line, Matrix ranking, RBQ value, Causal diagram and Trend analysis**) had got a strong scientific as well as empirical evidences generated through conventional research process.In attaining sustainability as an impact of a pro-people research, technology generated there form must be need based, eco-friendly, resource-friendly, non depletive etc.Hence the research in an innovative way had derived certain social and economical dimension implanted organically with a conventional research approach.

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Table- 1 : Decade wise trend analysis of fishes of East Singhbhum, India.

| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Catla catla* (Hamilton-Buchanan) | Catla | 72.80 | 70.93 | 2.57 | 67.87 | 4.33 | 67.33 | 0.78 | 64.33 | 4.56 |
| 2 | *Cirrhinus mrigala* (Hamilton-Buchanan) | Mirik,Mrigal | 73.47 | 70.27 | 4.36 | 68.13 | 3.03 | 65.47 | 3.92 | 62.90 | 3.93 |
| 3 | *Cirrhinus reba* (Hamilton-Buchanan) | Saruansh,Nuni | 66.53 | 62.93 | 5.41 | 59.33 | 5.72 | 47.87 | 19.33 | 35.87 | 25.07 |
| 4 | *Labeo rohita* (Hamilton-Buchanan) | Rahu,Rui | 74.80 | 72.27 | 2.67 | 69.87 | 3.32 | 66.53 | 4.77 | 66.53 | 1.00 |
| 5 | *Labeo calbasu* (Hamilton-Buchanan) | Calbagus,Calbosh | 55.07 | 49.87 | 9.44 | 42.80 | 14.18 | 34.93 | 18.39 | 22.13 | 36.64 |
| 6 | *Labeo bata* (Hamilton-Buchanan) | Bata | 62.56 | 56.48 | 9.71 | 44.96 | 20.39 | 38.88 | 13.52 | 21.76 | 44.03 |
| 7 | *Labeo pangusia* (Hamilton-Buchanan) | Birbal | 58.20 | 50.80 | 12.71 | 40.00 | 21.26 | 24.40 | 39.00 | 13.45 | 44.88 |
| 8 | *Labeo angra* (Hamilton-Buchanan) | Perih | 63.20 | 53.00 | 16.14 | 49.20 | 7.17 | 35.00 | 28.86 | 18.25 | 47.86 |
| 9 | *Puntius chola* (Hamilton-Buchanan) | Puthi | DATA DEFICIENT | | | | | | | | |
| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
| 10 | *Puntius gelius* (Hamilton-Buchanan) | Tit puthi | 60.68 | 52.43 | 13.59 | 47.65 | 9.12 | 34.80 | 26.97 | 27.33 | 21.47 |
| 11 | *Puntius sarana sarana* (Hamilton-Buchanan) | Potha,Sar puthi | 74.00 | 69.07 | 6.66 | 62.53 | 9.45 | 40.40 | 35.39 | 25.33 | 37.30 |
| 12 | *Puntius japanicus* (Hamilton-Buchanan) | Japani puthi | 0.00 | 0.00 | 00.00 | 0.00 | 0.00 | 12.48 | | 26.67 | -110.51 |
| 13 | *Puntius sophore* (Hamilton-Buchanan) | Puthi | 74.53 | 72.27 | 3.05 | 68.00 | 5.91 | 64.67 | 4.89 | 62.93 | 2.69 |
| 14 | *Puntius ticto* (Hamilton-Buchanan) | Dingla puthi | 61.07 | 55.60 | 8.96 | 50.80 | 8.63 | 41.47 | 18.37 | 29.87 | 27.97 |
| 15 | *Puntius puntio* (Hamilton-Buchanan) | Kankoi | DATA DEFICIENT | | | | | | | | |
| 16 | *Chela faciata* (Silas) | Chela | 66.73 | 60.27 | 9.69 | 54.93 | 8.84 | 44.80 | 18.44 | 28.80 | 35.71 |
| 17 | *Salmostoma bacaila* (Hamilton-Buchanan) | Banspata | 73.25 | 69.87 | 4.61 | 61.20 | 12.41 | 42.53 | 30.51 | 24.43 | 42.56 |
| 18 | *Rasbora daniconius* (Hamilton-Buchanan) | Ramshal | DATA DEFICIENT | | | | | | | | |
| 19 | *Hypopthalmichthys molitrix* (Valenciennes) | Silvercarp | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 13.33 | | 32.00 | -140.06 |
| 20 | *Ctenopharyngodon idella* (Valenciennes) | Grasscarp | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.73 | | 27.87 | -137.59 |
| 21 | *Cyprinus carpio* (Hamilton-Buchanan) | Commoncarp, American | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 22.80 | | 36.40 | -59.65 |
| 22 | *Amblypharyngodon mola* (Hamilton-Buchanan) | Mourla, Morula | 75.33 | 70.93 | 5.84 | 65.87 | 7.15 | 51.60 | 21.66 | 35.73 | 30.76 |
| 23 | *Rohtee cotio* (Dey) | Chandkura | 63.20 | 54.00 | 14.56 | 50.80 | 5.93 | 43.73 | 13.92 | 29.87 | 31.72 |
| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
| 24 | *Danio dangila* (Hamilton-Buchanan) | Darnke | 66.00 | 59.47 | 9.89 | 52.40 | 11.89 | 41.47 | 20.86 | 28.00 | 32.48 |
| 25 | *Chela labuca* (Hamilton-Buchanan) | Darnka | 60.16 | 55.68 | 7.45 | 44.00 | 20.89 | 29.28 | 33.45 | 19.04 | 34.97 |
| 26 | *Omobranchus zebra* (Bleeker) | Luli | 75.00 | 74.53 | 0.62 | 70.80 | 5.00 | 66.27 | 6.39 | 59.47 | 10.26 |
| 27 | *Esomus danricus* (Hamilton-Buchanan) | Darnka , Darnke | 73.60 | 73.20 | 0.54 | 70.63 | 3.51 | 67.33 | 4.67 | 60.80 | 9.69 |
| 28 | *Garra annandalei* (Hora) | Garra | DATA DEFICIENT | | | | | | | | |
| 29 | *Lepidocephalicthys guntea* (Hamilton-Buchanan) | Genti | 71.47 | 67.73 | 5.22 | 63.87 | 5.71 | 58.27 | 8.77 | 48.93 | 16.01 |
| 30 | *Botia lohachata* (Chaudhuri) | Pathar chata | 68.53 | 64.53 | 5.84 | 56.67 | 12.19 | 47.87 | 15.53 | 32.40 | 32.32 |
| 31 | *Hyporhamphus limbatus* (Valenciennes) | Gangdhara (Small) | DATA DEFICIENT | | | | | | | | |
| 32 | *Xenentodon cancila* (Hamilton-Buchanan) | Gangdhara (Big) | 47.95 | 37.60 | 21.58 | 25.20 | 32.98 | 11.20 | 55.56 | 0.00 | 100.00 |
| 33 | *Monopteras* (Amplinpinim)cuchia | Cuchia | 57.87 | 51.73 | 10.59 | 44.67 | 13.67 | 31.47 | 29.55 | 16.03 | 49.03 |
| 34 | *Monopterus albus* (Zuiew) | Bhunia | 58.27 | 47.55 | 18.39 | 34.70 | 27.02 | 23.47 | 32.36 | 1.33 | 94.29 |
| 35 | *Mystus gulio* (Hamilton-Buchanan) | Tangra | 62.93 | 54.80 | 12.92 | 46.27 | 15.57 | 27.87 | 39.77 | 11.83 | 57.51 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | *Mystus cavasius* (Hamilton-Buchanan) | Tangra | 64.40 | 56.67 | 12.00 | 48.00 | 15.29 | 33.87 | 29.44 | 14.73 | 56.48 |
| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
| 37 | *Mystus tangra* (Hamilton-Buchanan) | Tangra | 68.00 | 58.20 | 14.41 | 47.20 | 18.90 | 29.60 | 37.29 | 11.75 | 60.30 |
| 38 | *Mystus vittatus* (Bloch) | Tangra | 67.60 | 56.80 | 15.98 | 45.80 | 19.37 | 25.80 | 43.67 | 8.20 | 68.22 |
| 39 | *Aorichthys seenghala* (Sykes) | Arh | 65.47 | 61.20 | 6.52 | 53.47 | 12.63 | 42.27 | 20.95 | 22.40 | 47.01 |
| 40 | *Ompok pabda* (Hamilton-Buchanan) | Pabda | 62.80 | 56.00 | 10.83 | 47.60 | 22.55 | 32.13 | 32.50 | 11.73 | 63.49 |
| 41 | *Ompok bimaculatus* (Bloch) | Pabda | 64.53 | 58.80 | 8.88 | 54.00 | 8.16 | 39.33 | 27.17 | 20.00 | 49.15 |
| 42 | *Wallago attu* (Schneider) | Boal, boar | 64.53 | 59.23 | 8.21 | 49.33 | 16.71 | 35.87 | 27.31 | 16.53 | 53.89 |
| 43 | *Pangasius pangasius* (Hamilton-Buchanan) | Pangas | 59.07 | 49.87 | 15.57 | 39.73 | 20.33 | 24.00 | 39.59 | 0.00 | 100.00 |
| 44 | *Clarias batrachus* (Linnaeus) | Magur | 68.67 | 62.67 | 8.74 | 57.87 | 7.67 | 46.40 | 19.82 | 36.00 | 22.41 |
| 45 | *Heteropneustes fossilis* (Bloch) | Singhi | 62.80 | 57.47 | 8.49 | 51.47 | 10.44 | 34.40 | 33.16 | 13.73 | 60.08 |
| 46 | *Clarias gariepinus* (Hamilton-Buchanan) | Hybrid magur | 0.00 | 0.00 | | 0.00 | | 16.28 | | 30.80 | -89.18 |
| 47 | *Lates calcerifer* (Bloch) | Bhetki | 45.20 | 36.40 | 19.47 | 22.40 | 38.46 | 9.75 | 56.47 | 0.00 | 100.00 |
| 48 | *Chanda nama* (Hamilton-Buchanan) | Chanda | 69.20 | 65.60 | 5.20 | 57.60 | 12.19 | 52.00 | 9.72 | 44.40 | 14.62 |
| 49 | *Pseudambassis ranga* (Hamilton-Buchanan) | Pitpiti, Chanda | 68.00 | 65.07 | 4.31 | 58.67 | 9.84 | 55.33 | 5.68 | 46.67 | 15.67 |
| 50 | *Pseudambassis lala* (Hamilton-Buchanan) | Do | 68.67 | 64.33 | 6.31 | 59.07 | 8.19 | 54.80 | 7.23 | 47.07 | 14.12 |
| 51 | *Pseudambassis notetus* (Blyth) | Do | 68.13 | 64.67 | 5.09 | 59.73 | 7.62 | 54.13 | 9.38 | 46.13 | 14.78 |
| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
| 52 | *Nandus nandus* (Hamilton-Buchanan) | Nedhas, Nedha | 44.80 | 41.47 | 7.43 | 32.13 | 22.49 | 13.73 | 57.27 | 0.00 | 100.00 |
| 53 | *Badis badis* (Hamilton-Buchanan) | Koi | DATA DEFICIENT | | | | | | | | |
| 54 | *Oreochromis mojambica* (Hamilton-Buchanan) | Tilapia | 28.00<br>38.00 | | 35.71 | 34.40 | 9.47 | 51.07 | 48.46 | 61.73 | -20.89 |
| 55 | *Oreochromis niloticus* (Hamilton-Buchanan) | Nilotika | 0.00 | 0.00 | | 0.00 | | 17.00 | | 38.60 | -127.05 |
| 56 | *Liza parsia* (Hamilton-Buchanan) | Perse | 50.93 | 46.40 | 8.89 | 33.87 | 27.00 | 18.40 | 45.67 | 0.00 | 100.00 |
| 57 | *Rhinomugil corsula* (Hamilton-Buchanan) | Cactus, Tarai | 51.07 | 47.87 | 6.27 | 33.73 | 29.52 | 18.40 | 45.45 | 0.00 | 100.00 |
| 58 | *Glossogobius giuris* (Hamilton-Buchanan) | Bele, Bhatu, Bhelsa | 68.67 | 66.00 | 3.89 | 62.67 | 5.05 | 50.53 | 19.36 | 31.87 | 36.95 |
| 59 | *Anabas testudineus* (Bloch) | Koi | 56.93 | 52.00 | 8.66 | 42.80 | 17.69 | 35.87 | 16.19 | 17.87 | 50.18 |
| 60 | *Colisa feciatus* (Schneider) | Kholse | 64.45 | 61.60 | 4.42 | 54.67 | 11.25 | 48.53 | 11.21 | 38.67 | 20.34 |
| 61 | *Aplochielus dayi* (Hamilton-Buchanan) | Techokha | DATA DEFICIENT | | | | | | | | |
| 62 | *Aplocheilus panchax* (Hamilton-Buchanan) | Do | 58.00 | 54.93 | 5.29 | 46.67 | 15.06 | 38.93 | 16.56 | 25.47 | 34.60 |
| 63 | *Channa gachua* (McClelland) | Chang | 74.67 | 72.40 | 3.04 | 69.20 | 4.42 | 63.73 | 7.91 | 56.93 | 10.67 |
| 64 | *Channa marulius* (Hamilton-Buchanan) | Shal | 48.00 | 40.96 | 14.67 | 26.88 | 34.38 | 12.20 | 54.61 | 0.00 | 100.00 |
| 65 | *Channa striatus* (Bloch) | Shole | 64.67 | 57.73 | 10.72 | 51.73 | 10.39 | 40.80 | 21.13 | 18.93 | 53.60 |
| **Sl No** | **Scientific Name** | **Local Name** | **1960** | ***1970*** | **+** | **1980** | **+** | **1990** | **+** | **2000** | **#** |
| 66 | *Channa punctatus* (Bloch) | Gorai, Latha | 73.07 | 71.33 | 2.37 | 66.40 | 6.91 | 61.47 | 7.42 | 54.53 | 11.27 |
| 67 | *Macrognathus pancalus* (Hamilton-Buchanan) | Khet truh | 72.67 | 68.27 | 5.56 | 64.53 | 5.46 | 58.00 | 10.12 | 43.33 | 25.29 |
| 68 | *Rhynchobdella aculeata* (Hamilton-Buchanan) | Turh | 72.80 | 67.60 | 7.14 | 61.47 | 9.07 | 55.87 | 9.11 | 46.67 | 16.47 |
| 69 | *Mastacymbalus armatus* (Lacepede) | Ban | 68.40 | 64.27 | 6.04 | 59.47 | 7.47 | 50.80 | 14.58 | 37.33 | 26.52 |
| 70 | *Amblyceps mangois* (Hamilton-Buchanan) | Chaldhua | 71.73 | 61.92 | 13.68 | 56.60 | 8.59 | 33.33 | 41.11 | 15.30 | 54.09 |
| 71 | *Notopterus notopterus* (Pallas) | Pholad, Pholui | 66.13 | 62.13 | 6.05 | 55.07 | 11.38 | 48.53 | 11.86 | 35.87 | 26.11 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | *Notopterus Chitala* (Hamilton-Buchanan) | Chital | 49.52 | 44.32 | 10.5 | 28.80 | 35.02 | 12.80 | 55.56 | 0.00 | 100.00 |
| 73 | *Gadusia chapra* (Hamilton-Buchanan) | Gaducia | DATA DEFICIENT | | | | | | | | |
| 74 | *Hilsa ilisha* (Hamilton-Buchanan) | Ilish | 56.27 | 50.40 | 10.43 | 36.93 | 26.73 | 28.13 | 23.83 | 15.87 | 43.62 |
| 75 | *Chanos chanos* (Forsskal) | Chanos | DATA DEFICIENT | | | | | | | | |

**LEGEND**

- = % of decline over previous year. # = mean decline

**Table- 2 : Identification of causal factors responsible for extinction of fish species**

| Sl.No. | General Pisci-cultural Problems | Ranking by rural fishermen | | | | | | | | | | Rank base Quation Value % | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **(RBQ %)** | |
| 1 | Lack of Knowledge | 3 | 2 | 2 | 2 | | 1 | | | | | 33.2 | |
| 2 | Lack of financial support | 8 | 2 | 1 | | | 1 | | | | | 44.4 | |
| 3 | Lack of water retention capacity | 13 | 4 | 1 | 2 | | | | | | | 75.2 | |
| 4 | Use of pesticide in different fields | | | | 8 | | 2 | 1 | 2 | 1 | | 42.2 | |
| 5 | Non-availability of fish spawn | | | 2 | 3 | 1 | 4 | | 1 | | | 26.4 | |
| 6 | Lack of machinaries | | | | | | | 1 | 2 | | 1 | 4 | |
| 7 | Different diseases resulted down fish production | | | | | | 1 | 2 | 1 | 3 | | 8.8 | |
| 8 | In stagnant of water due to sloppy land | | | | | | | | 1 | 1 | | 2 | |
| 9 | Destruction of brood fish during monsoon | | 4 | 3 | 1 | 2 | 1 | | | | | 32.4 | |
| 10 | Destruction of breeding ground | | | 2 | 1 | 3 | 2 | | | | | 20.4 | |
| 11 | Destruction of fish spawn & fry | | | | | | 1 | 3 | 2 | | | 4 | |
| 12 | Sharing problems of water bodies | 14 | 3 | 2 | | 1 | | | | | | 75.6 | |
| 13 | Problems of natural calamities | | | | | 1 | 2 | 2 | | | 1 | 10 | |
| 14 | High cost of pisicultural equipment | | | | | | | 1 | 2 | 2 | 1 | 5.6 | |
| 15 | Rapid urbanization and population exploration | | | | | | | | | 1 | 1 | 1.2 | |

**Table – 3 : Path analysis to delineate that direct and indirect effect of exogenous variables on the consequent of variable fish productivity.**

| Sl No | Variables | Gross Effect(r) | Direct Effect(β) | Indirect Effect(r-β) | Substantial Indirect Effect | | |
|---|---|---|---|---|---|---|---|
| | | | | | I | II | III |
| 1. | Age ($X_1$) | 0.0273 | 0.0240 | 0.0033 | $X_{13}$ -0.0334 | $X_{17}$ 0.0292 | $X_{18}$ 0.0246 |
| 2. | Educational qualification ($X_2$) | 0.0921 | 0.0490 | 0.0431 | $X_{19}$ 0.0675 | $X_{20}$ -0.0537 | $X_{13}$ 0.0292 |
| 3. | Training experience ($X_3$) | 0.0263 | -0.0850 | 0.1113 | $X_{18}$ 0.0706 | $X_{13}$ 0.0494 | $X_{20}$ -0.0409 |
| 4. | Family size ($X_4$) | 0.1032 | 0.0780 | 0.0252 | $X_{13}$ 0.0333 | $X_{17}$ -0.0195 | $X_{18}$ -0.0189 |
| 5. | Annual income ($X_5$) | -0.0393 | 0.0050 | -0.0443 | $X_{20}$ -0.0645 | $X_{19}$ 0.0458 | $X_{10}$ -0.0289 |
| 6. | Ownership of pond ($X_6$) | 0.0442 | 0.1010 | -0.0568 | $X_{19}$ -0.0553 | $X_{20}$ 0.0475 | $X_{13}$ -0.0382 |
| 7. | Water area ($X_7$) | -0.21167 | -0.0430 | -0.1737 | $X_{20}$ -0.0743 | $X_{13}$ -0.0556 | $X_{17}$ -0.0350 |
| 8. | Depth of pond ($X_8$) | 0.0837 | 0.0220 | 0.0617 | $X_{19}$ 0.0333 | $X_{13}$ 0.0242 | $X_{20}$ -0.0204 |
| 9. | Water retention period ($X_9$) | 0.1491 | 0.0560 | 0.0931 | $X_{19}$ 0.1061 | $X_{20}$ -0.0684 | $X_{13}$ 0.0354 |
| 10. | Distance of pond from residence ($X_{10}$) | -0.1589 | -0.0740 | -0.0849 | $X_{13}$ -0.0519 | $X_{19}$ 0.0258 | $X_{20}$ -0.0508 |
| 11. | Transparency of pond water ($X_{11}$) | -0.1201 | -0.0610 | -0.0591 | $X_{13}$ -0.0732 | $X_{17}$ -0.0409 | $X_{19}$ 0.0346 |

**Table – 4 : Multiple regression analysis between fish production and other 5 causal variables.**

| Sl. No. | Variables (X) | β | β x R | Regression coefficient (β) | SE(β) | T-value of (β) |
|---|---|---|---|---|---|---|
| 1. | Plankton ($X_{13}$) | 0.416 | 48.444 | 75.050 | 9.965 | 7.531 |
| 2. | Stocking density ($X_{17}$) | 0.288 | 23.618 | 7.858 | 1.541 | 5.098 |
| 3. | Gross cost of inputs ($X_{18}$) | 0.183 | 15.297 | 0.114 | 0.039 | 2.944 |
| 4. | Size of catch fish ($X_{19}$) | 0.212 | 14.082 | 0.045 | 0.014 | 3.203 |
| 5. | Gross invest ($X_{20}$) | -0.264 | -1.441 | -0.024 | 0.006 | 4.142 |

Multiple $R^2$ value = 0.4809; F value for R = 35.95 with 5 and 194 DF

# MATHEMATICAL MODELING FOR PREDICTION OF ARSENIC REMOVAL BY ELECTROCOAGULATION: A FACTORIAL DESIGN APPROACH

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## ABSTRACT

Mathematical model has been developed by two-level full-factorial designed-experiment to predict arsenic removal from contaminated water by electrocoagulation (EC). Four factors namely ‘current strength’, (I); ‘solution volume’, (V); ‘EC current processing time’, (t) and ‘electrode area’, (A) were investigated. Among the factors solution volume (V) has negative effect whereas EC current processing time (t) and current strength (I) have positive effect on arsenic removal. Within the studied level of the factors, variance analysis at 5% significance level indicated that electrode area is not a significant factor in arsenic removal by electrocoagulation. The analysis suggests that most main factors and a few low order interactions are significant in predicting the removal. The model predicted excellent arsenic removal. Optimum removal (99.66%) is obtained at lower volume (1 L), higher current (3 amp) and higher current processing time (120 s).

**Key words:** model; factorial design; arsenic; electrocoagulation; current; volume; electrode area.

## 1. INTRODUCTION

Throughout the world, arsenic is creating potentially serious environmental problems for humans and other living organisms. Arsenic contamination is caused by both natural and anthropogenic activities. The chronic toxicity of arsenic in drinking water is known to cause various types of melanosis, cancer, black foot disease and keratosis. Countries like Bangladesh, India, Taiwan, Argentina, Chile, arsenic concentration have been reported to reach levels up to 1 mg/L [1]. Arsenate ($HAsO_4^{2-}$, $H_2AsO_4^-$) is likely to predominate in aerobic surface water, whereas arsenite ($HAsO_3^{2-}$ or $H_2AsO_3^-$) in groundwater. Arsenite is considerably more mobile and toxic than arsenate. The actual valence states and chemical form, however, depend on the redox environment, pH and the presence of complexing ions in the water systems of interest [2].

Electrocoagulation (EC) is a process by which sacrificial anode (iron/aluminum) is used to deliver coagulant for both water and wastewater treatment. EC can remove both arsenite and arsenate at same level; however, arsenate removal was more efficient than arsenite removal by chemical coagulation .In EC charge density (Coulomb/L) has been found to be the more appropriate parameter than current density (amp/cm$^2$) [3]. It is reported that electrocoagulation can effectively reduce 550 – 580 μg/L arsenic (including both As(III) and As(V) in a 1:1 ratio) to below the WHO recommended maximum limit of 10 μg/L in

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synthetic Bangladesh groundwater containing relevant concentrations of competitive ions such as phosphate, silicate and bicarbonate [4]. Ramakrishna et al. [5] and Pokhrel et al. [6] used factorial design approach to predict arsenic removal from aqueous solution for different coating parameters of iron upon sand and fungal biomass, respectively. Study on optimization of energy consumption by Taguchi method during EC for arsenic removal revealed that electrode area to volume ration (A/V) and current density (I) are the least effective process parameter [7].

Electrocoagulation is a low-cost and effective treatment technology for arsenic removal. Systematic studies on electrocoagulation are not reported. Some reported positive effect [8] while others reported no effect [7, 9] of current density (amp/$cm^2$) on wastewater treatment or arsenic removal. In most of the studies the effect of the factors were studied taking one factor at a time. Thus the influence of other factors and the interactions among the factors are ignored. So it was felt necessary to develop a model using factorial design approach so that the effects of main parameters as well as the interactions among the factors can be identified during electro-arsenic removal and effective and optimum performance for arsenic removal can be predicted from contaminated water for community water treatment units.

## 2. EXPERIMENTAL SECTION

Stock arsenate solution of 1000 mg/L was prepared by dissolving desired amount of sodium arsenate (As(V)) (Merck) in 100 ml deionized water and preserved with acidification by $HNO_3$. Laboratory tap water (Table 1) was spiked with aliquots of this stock solution to get an influent arsenate concentration of 0.85 mg/L. The EC experiments were conducted in a glass jar in batch. A DC 32 voltage source (Model No. 3005 32V/5A, PSD series DC Power Supplies, Scientific, India) was used to supply desired operating current. The electrodes were two mild steel plates of industrial grade. Electrodes areas were varied by immersing the required depth in the glass jar. The model was operated at galvanostatic condition. After passing desired amount of current for stipulated time, the contents were briefly stirred and allowed to settle for 30 minutes. A small portion (100 ml approx.) of the content was withdrawn and filtered through 0.45 µm filter paper and the filtrate was preserved with $HNO_3$ for arsenic analysis. Arsenic was analyzed with the help of an Atomic Absorption Spectrometer with attachment of continuous Hydride Vapor Generation (AA-202, Chemito, India) as per Standard Methods [10]. The different levels of the factors tested are presented in Table 2. The variance analysis (ANOVAN) and solution for the regression model by least square technique was carried out by MATLAB 7.0 software. Optimization of the operating variables was carried out by LINGO software.

## 3. RESULTS AND DISCUSSION

Table 3 represents the full factorial orthogonal combinations of the factors and the corresponding removal in each run. The variance analysis at 5% significance level of the $2^4$ factorial experiments up to three factors interactions are presented in Table 4. The main factors and factor interactions having P-values in the last column (Table 4) less than 0.05 are significant. Thus, electrode area 'A' and interaction with other parameters with 'A' are insignificant at 95% confidence limit. However, at 90% confidence level 'V*A' interaction term can be incorporate into the model. We developed the model considering 95% confidence level. It is clear that at 95% confidence level three main factors namely current strength 'I', solution volume 'V', current processing time 't'; three two-factor interaction terms namely 'I*V', 'I*t', 'V*t' and a three factor interaction term such as 'I*V*t' will be incorporated into the model. The relationship between the coded and the natural value of the factors may be represented by Eq (1).

Table 1: Characteristics of laboratory tap water

| Parameter | Range |
|---|---|
| Alkalinity | 320-350 mg/L as $CaCO_3$ |
| pH | 7.3-7.55 |
| Hardness | 700-750 mg/L as $CaCO_3$ |
| Conductivity | 3.35 ms/cm |
| Chlorides | 650-700 mg/L |
| Iron | 0.6-1.0 mg/L |
| Arsenic | NIL |
| Phosphate | 1.24 mg/L |
| Silica | 16.71 mg/L as Si |
| Sulphate | 1.39 mg/L |
| Nitrate | 1.082 mg/L |

Table 2: Levels of design variables studied

| Variable | Symbol | Low | High | Unit |
|---|---|---|---|---|
| Current | I | 0.6 | 3.0 | Amp |
| Volume | V | 1 | 3 | L |
| Time | t | 30 | 120 | s |
| Electrode area | A | 57 | 91 | $cm^2$ |

Table 3: Full factorial experiments

| (I) | (V) | (t) | (A) | Experimental removal (%) | Predicted removal (%) | Residuals (%) |
|---|---|---|---|---|---|---|
| -1 | -1 | -1 | -1 | 97.06 | 96.77 | 0.29 |
| -1 | -1 | -1 | 1 | 96.47 | 96.77 | 0.30 |
| -1 | -1 | 1 | -1 | 98.82 | 98.82 | 0.00 |
| -1 | -1 | 1 | 1 | 98.82 | 98.82 | 0.00 |
| -1 | 1 | -1 | -1 | 65.76 | 65.76 | 0.00 |
| -1 | 1 | -1 | 1 | 65.76 | 65.76 | 0.00 |
| -1 | 1 | 1 | -1 | 94.35 | 94.47 | -0.12 |
| -1 | 1 | 1 | 1 | 94.59 | 94.47 | 0.12 |
| 1 | -1 | -1 | -1 | 98.94 | 98.88 | 0.06 |
| 1 | -1 | -1 | 1 | 98.82 | 98.88 | -0.06 |
| 1 | -1 | 1 | -1 | 99.88 | 99.88 | 0.00 |
| 1 | -1 | 1 | 1 | 99.88 | 99.88 | 0.00 |
| 1 | 1 | -1 | -1 | 89.88 | 90.06 | -0.18 |
| 1 | 1 | -1 | 1 | 90.24 | 90.06 | 0.18 |
| 1 | 1 | 1 | -1 | 99.06 | 99.24 | -0.18 |
| 1 | 1 | 1 | 1 | 99.41 | 99.24 | 0.17 |
| 0 | 0 | 0 | 0 | 91.88 | 92.98 | -0.10 |
| 0 | 0 | 0 | 0 | 93.18 | 92.98 | 0.20 |
| 0 | 0 | 0 | 0 | 91.41 | 92.98 | -0.57 |

$$C_v = [C_n - (C_h + C_L) / 2] / [(C_h - C_L) / 2] \quad \ldots\ldots (1)$$

Where, $C_v$ = coded value of the factor, $C_n$ = natural value of the factor, $C_h$ = higher level of the factor, $C_L$= lower level of the factor.

### 3.1. Effect of Volume

Table 5 presents the effect estimates of all significant (having $P \leq 0.05$) main and interaction factors. The effect estimate of a parameter is defined as the difference between the average response (here removal) at lower level of the parameter to that of the higher level of the same parameter. It is observed from Table 5 that the effect estimate of solution volume (V) is negative. This indicates that for same charge density (C/L), if the volume is increased the removal will be decreased. Fig 1 shows the plot of effect estimates of all the main factors. The figure also suggests that when solution volume is increased, removal is decreased.

Table 4: Variance analysis of test result up to three factors interactions

| Source | Sum Sq. | d.f. | Mean Sq. | F | Prob>F |
|---|---|---|---|---|---|
| I | 259.85 | 1 | 259.85 | 85902.28 | 0.0022 |
| V | 502.21 | 1 | 502.21 | 166019.21 | 0.0016 |
| t | 419.02 | 1 | 419.02 | 138519.31 | 0.0017 |
| A | 0.00 | 1 | 0.00 | 1.19 | 0.4723 |
| I*V | 167.57 | 1 | 167.57 | 55396.04 | 0.0027 |
| I*t | 105.99 | 1 | 105.99 | 35037.03 | 0.0034 |
| I*A | 0.06 | 1 | 0.06 | 18.26 | 0.1464 |
| V*t | 303.28 | 1 | 303.28 | 100258.59 | 0.0020 |
| V*A | 0.17 | 1 | 0.17 | 56.93 | 0.0839 |
| t*A | 0.06 | 1 | 0.06 | 18.26 | 0.1464 |
| I*V*t | 85.38 | 1 | 85.38 | 28224.00 | 0.0038 |
| I*V*A | 0.00 | 1 | 0.00 | 0.00 | 1.0000 |
| I*t*A | 0.03 | 1 | 0.03 | 10.71 | 0.1888 |
| V*t*A | 0.01 | 1 | 0.01 | 4.76 | 0.2736 |
| Error | 0.00 | 1 | 0.00 | | |
| Total | 1843.64 | 15 | | | |

Table 5: Effect estimates of significant main and interaction factors

| Factor and factor interaction | Effect estimate |
|---|---|
| I | 7.9424 |
| V | - 11.4126 |
| t | 10.1174 |
| A | 0.03 |
| V*I | 6.4726 |
| I*t | - 5.0574 |
| V*t | 8.7676 |
| V*I*t | - 4.6474 |

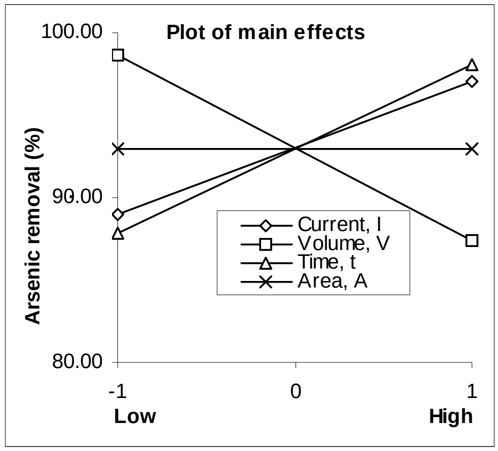


Fig 1: Effect estimate of all main factors

### 3.2. Effect of Current, Time and Electrode Area

Similarly, from Table 5 it is clear that effect estimates of current (I), time (t) and electrode area (A) are positive, which implies that removal will be increased if current, current processing time and electrode area are increased. It is seen from Fig 1 that when current and / or current processing time is increased, the removal is increased. This is due to the fact that when either or both are increased, iron dose increased and subsequently show higher removal [3]. The effect estimate of area has been found to be negligibly positive (effect estimate 0.03) compared to effect estimates of current and time. This is due to the fact that electrode area is not significant (P = 0.4723). This finding corroborates to the findings that current density will have no effect on arsenic removal if the factor effect is studied by varying the electrode area [7]. Thus this parameter has been dropped out from the model.

## 4. THE MODEL

Considering the significant main and interaction terms, the model equation obtained by least square regression method to predict the percent arsenic removal ($P_r$) by EC is given by Eq (2).

$$P_r = 92.9838 + 4.0300*I - 5.6025*V + 5.1175*t + 3.2363*I*V - 2.5737*I*t + 4.3537*V*t - 2.3100*V*I*t \quad (2)$$

The co-efficient of determination ($R^2$) of the model is 0.9998 and adjusted $R^2$ ($R^2_{adj}$) is 0.9993. The values of both $R^2$ and $R^2_{adj}$ are close to each other which indicate that no insignificant terms are included in to the model. The $R^2$ value of the model suggests that more than 99 % of variability of the response can be explained by the model variables.

### 4.1. Checking of Model Adequacy

The basic assumption of developing the model is that the errors should be normally distributed. This normality assumption may be checked by normal probability plot of the residuals. The residuals are the difference in removal between experimental and predicted values and are presented in Table 3. Fig 2 represents the normal probability of residuals of all the ($2^4 = 16$) observations. By visualizing the straight line, with more emphasis on the central values of the plot than on the extremes, the plot resembles a straight line, which supports that the underlying errors are normally distributed. The residuals (errors) and the predicted removals by the model are presented in Fig 3. It is observed from Fig 3 that the residuals are structure less with no obvious patterns; this indicates that the model is adequate [11]. As effect estimates of three factors namely I, t and V are large, this three factors are the most concerning in predicting arsenic removal. Sparsity of effect principle states that most systems are dominated by some main effects and a few low order interactions and most high order interactions are negligible. The effects that are negligible are normally distributed with mean zero and variance $\sigma^2$ and will tend to fall along a straight line on normal probability plot, whereas significant effects will not lie along the straight line (Fig 4) [12]. The effects outliers from the straight line are of most concern. So from Fig 4 it is reasonable to conclude that the three variables namely I, t and V are the most concerning in predicting the arsenic removal by electrocoagulation.

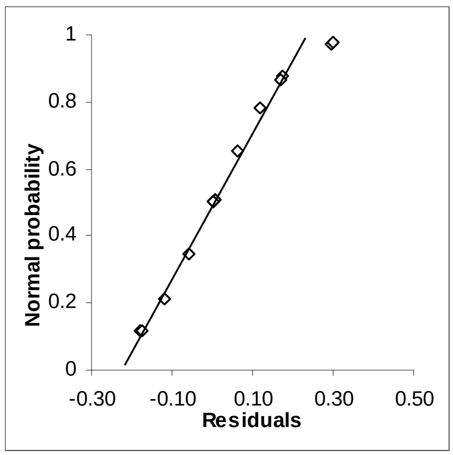


Fig 2: Plot of residuals vs. normal probability

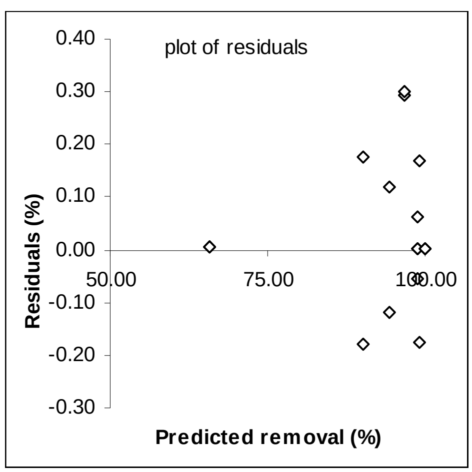


Fig 3: Plot of predicted removals vs. residuals

### 4.2. Model Validation

The last three runs in Table 3 represent the removal of arsenic at central value of the factors studied. The average removal of these three runs is found to be 92.16% whereas; the predicted removal by the model at this central value of the factors is 92.98%. Low residual (less than 1%) values indicate reasonably good prediction of arsenic removal by the model.

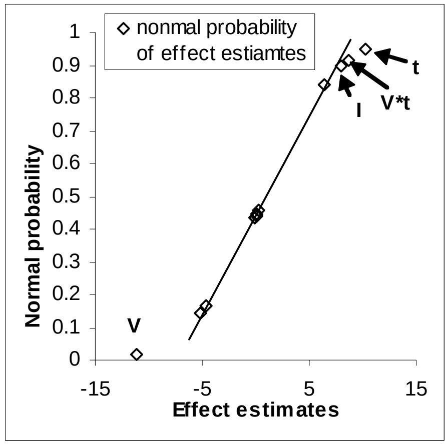


Fig 4: Normal probability plot of effect estimates

## 5. CONCLUSION

Full factorial design helps us to investigate the model at all interaction levels and to choose the significant factors and interactions for model development. The salient findings of this study are summarized as below:

- Time (t) and current (I) are found to favor the removal. Volume (V) has negative effect. Electrode area (A) and most of the higher order interactions were found to be insignificant. As far as the effect of electrode area is concerned, the area should be such that it can carry required amount of current to deliver requisite amount of charge at stipulated time with existing conductivity of the solution and the available driving force, the voltage.
- The model developed takes into account the presence of naturally occurring solutes. Thus, the model can be used to predict the removals of such arsenic contaminated groundwater whose characteristics are resemble to studied water.
- Optimum removal (99.66%) is obtained at lower volume (1 L), higher current (3 amp) and higher current processing time (120 s).
- The experiments are conducted in batch mode. Continuous flow electrocoagulation systems are also required to be mathematically modeled.
- The effects of four factors were studied within a selected range of values with arsenate. In this study arsenic concentration was kept constant. Further studies are recommended with arsenic as a variable with wider range of factor levels.

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# SLOPE STABILITY ASPECTS: A CASE STUDY OF THE ROAD SIDE HILL CUTS NH-8, BETWEEN UDAIPUR-AHEMDABAD, RAJASTHAN, INDIA

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## ABSTRACT

Roadside hill cut slopes are unsafe all along the national highway between Udaipur-Ahemdabad. These cuts were developed due to cutting of hills in the Aravalli Mountainous region. The preliminary geological, geotechnical and stability analysis carried out using Galena software shows that most of the slopes are having factor of safety less than one. The stress concentration pattern obtained by finite elemental analysis shows that in the toe area of the cut is indicative of its criticalness from failure aspect.

**Keywords:** Road side hill cut, geotechnical, FEM.

## INTRODUCTION

The national highway is passing through undulating hilly terrain of southern part of the Aravalli Mountain of India, comprises of the meta-sedimentary rocks subsequently multi-phased deformed. Highway is running almost N5$^o$ to 10$^o$ NE-SW and the rock layers also trending in similar direction. The numbers of hills were cut for the road passage. The rock layers in the road side hill cut slopes are dipping in the east direction with dip angle 56$^o$ to 85$^o$ and at many places shows verticality (Naha 1965; Mamtani 2000). The main litho units in the road section identified are greywacke, siliceous phyllite, quartzite and weathered phyllite. The height of road side cut cliffs varies from 1.0 m to 20 meters. The terrain is undulating one and number of curves are made in the road. There are 50 to 100 vehicles per minute, passing through the road and continuously transmitting feeble intensity vibrations to the rocks of the cut slopes. The noise generated by movement of vehicle with the road, produces resonance effect, which ultimately loosens the cut slopes. The measured values of noise produced are at the rate of 40 to 100 dB (Sheikh et al. 2005). Diurnal Temperature along the road tract is (-)5$^o$C to 20$^o$C in winter and 25$^o$C to 48$^o$C in summers, which in turn results in the differential volumetric expansion of the various litho-units of the cut slopes. The last five years rainfall trend of the area shows precipitation 0.5-200 mm during rainy season at an interval of 10-12 hourly (CTAE, 2009). The rain water acts as a lubricant and weak planes becomes more and more loosens.

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The road is passing through the rock layers and three different combinations of side cut slope face and rock layers produced i.e., the side cut slopes becomes nearly parallel to the

rock layers, at some angle and across the rock layers. The road side hill cuts are more sensitive where little or nearly parallel to the road and becomes risky, causing fatality by sliding of rock blocks towards the road.

India has a large road network of over 3.314 million kilometers of roadways, making it the second largest road network in the world (Infrastructure 2008). Statistics shows that almost 80% of passenger traffic and about 65% of freight movement is handled by this vast network. The lengthwise details of road network shows that the national highways length is 0.66 million km and rest of the roads belongs to state highways, major district roads and rural roads. Roads are constructed by cutting the hills, which constitute rocks in different form; shape, orientation, hardness etc. The national highway road length is 2% of total road length of the country roads as shown in Fig 1.

The geological and geo-technical aspects of road side hill cuts play its own role in the stability of the cut slopes. The rock aspects are texture and structure of rock, development of joints, faults, fold, status of weathering etc.; these decides the side cuts safety and stability. It provides direction to the road side cut slope design, maintenance, site improvement techniques, developing and planting grasses or vegetative cover for making stable cut sides (Anthoni, 2000). The physico-mechanical properties including strength of rock layers compressive strength, smith rebound hardness, stress pattern, etc. are additional geotechnical parameter for hill cuts analysis and modeling (Obert et al. 1967).

The strength varies widely with the size of the road side cut rock mass. The rock mass is heterogeneous and anisotropic carrying all the defects at the field scale. The slope in the cut is determined by the stresses, which are imposed on it. The effect of water i.e. truly free water exist in the rock mass, in fractures, where it influences stability by adding its additional magnitude of force in failures (Brown et al. 1970; Brown 1989). The safety factor can be measured as the ratio of the available resistance to sliding to the tangential force i.e. driving force. Other approach to measure the safety factor is stress concentration and the stresses are evaluated, usually modeled through numerical analysis procedures (McCullough 1993). The Coulomb’s theory suggests that cohesion and friction are more reliable factor to understand the stability of the hill cut slopes (Hoek 1990, 2007).

## GEOLOGICAL AND GEO-TECHNICAL STATUS OF THE HILL CUT SLOPES

The Udaipur city lies on the Golden Quadrilateral, midway between Delhi and Mumbai National Highway (NH) 8; it is around 700 kilometers from either metro. The East West Corridor, which starts from Porbandar and ends at Silchar passes and is intersecting the Golden Quadrilateral (Novogrod, 2009). The four-lane National Highway No-8 Udaipur-Ahemdabad, India, falls in the survey of India GT Sheet No. 45H/10, it lies at latitude 24$^{o}$28’30” and 73$^{o}$40’30”, as shown in Fig 2. It runs in the difficult Aravalli mountainous terrain, has a number of road side hill cuts. The road length under study is nearly 276 kms and out of these 150 is a difficult terrain.

The road traversing particularly through the Udaipur Groups rocky terrain is more risky as evident by the exposed rock layers on the route. The road starts from Udaipur, lies on the rocks of Udaipur Group, which continued up to 75 kms from Udaipur. After 75 kms it cuts the rocks of Jharol Group, which terminate nearly 10 kms before reaching Himmatnagar town of Gujarat. The rocks of Udaipur Group comprises of phyllites and siliceous phyllites, meta-siltstone, graded bedded meta-graywacke, graywacke pebble meta-conglomerate, dolomite, carbonaceous phyllite, quartzite, locally dolomites are sulphide bearing etc. (Sharma, 2009; Gupta et al. 1981).

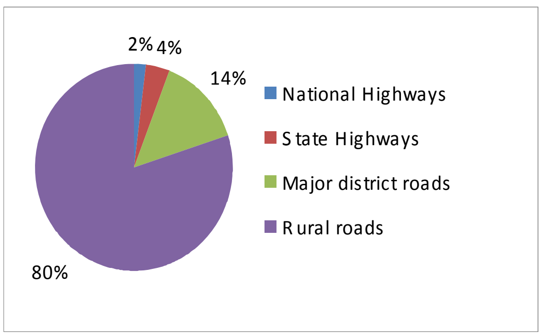



Fig 1: Indian road network share

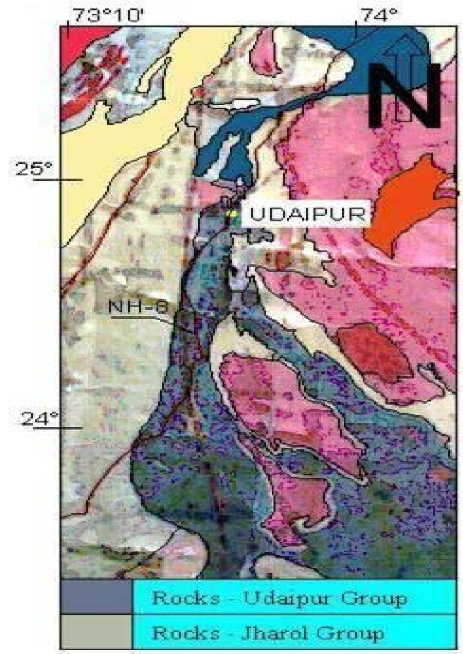
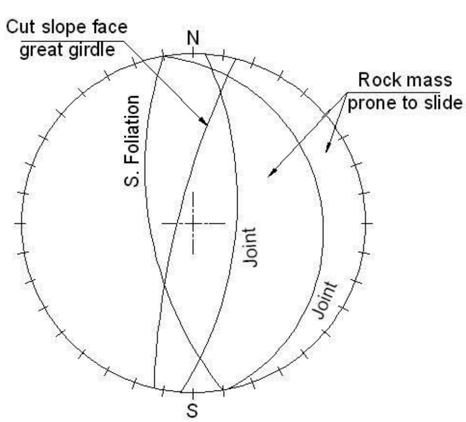



Fig 2: Map showing NH-8 between Udaipur-Ahemdabad (Modified after Gupta S.N. et al 1980)

The cut slope selected by observation of various cut slopes viz. collected geological, joint pattern and groundwater related information along the road. After observation, seven critical hill cut slopes were selected between 5 kms to 150 kms from Udaipur. The selection criterion for the critical hill cut slope was based on the stereo plots, RSR values and factor of safety (FoS analysis carried out with the help of GALENA software version.4.01).

The stereo plots drawn for discontinuities and the hill cut face indicating size of the wedges produced and direction of failures as shown in Fig 3 (Ragan, 1985).



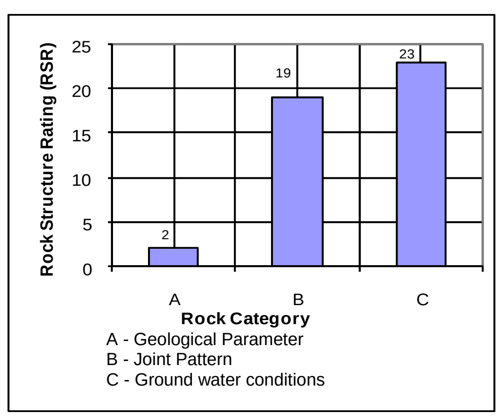



Fig 3: Stereo-plot of planes in the road side cut rock mass NH-8

Fig 4: Rock category v/s R.S.R. (after Wickham, et al. 1972)

The joint roughness coefficient (JRC) field estimates are made by comparing the appearance of joint surface with standard profiles given by the Barton and Choubey (1977) and others (Barton 1973, 1976). The JRC value is estimated for seven cut slopes that varies from 0 to 6 (Wines et al. 2003).

The RSR plotting shows the rock category parameters, where the minimum value of RSR shared by the category-A, is showing similar trend in all seven slopes Fig 4. The overall RSR value calculated for cut slopes varies from 35 to 51. The cut slopes of the area, having RSR value less then 44 belongs to the category of wedge failure and above 44 comes under different combinations of failure. The sudden failure of faces is prone to cause fatality. The cut slope with RSR value 44, JRC value 0 to 2, face length 25 m and height 9.5 m to 12 m, was selected for the present study, belongs to the typical failure mode (Hoek et al. 1992, 2005, 2006, 2007). Tri-axial outfit test carried out with 54 mm cores obtained in laboratory from the collected sample of the hill cut mass and the cohesion and friction angle $\phi$ were calculated with the help of ploting Mohr envelopes.

The factor of safety is defined as ratio of strength to vertical stress induced and it is one of the reliable factors about the stability of the rock mass cut. There are various approaches to determine the safety factor (Obert et al. 1967; Gaziev et al.1977). The multiple stability analysis by GALENA software results in terms of factor of safety and final angle of inter-slice forces calculated as 0.63 and $78.2^{o}$ respectively Fig 5. The result shows the critical failure conditions in the hill cut slope. Further deterioration may causes in monsoon season due to rain fall; the cohesive force becomes variable i.e. instaneous changes (Barton et al. 1982, 1990; Hoek et al. 1992).

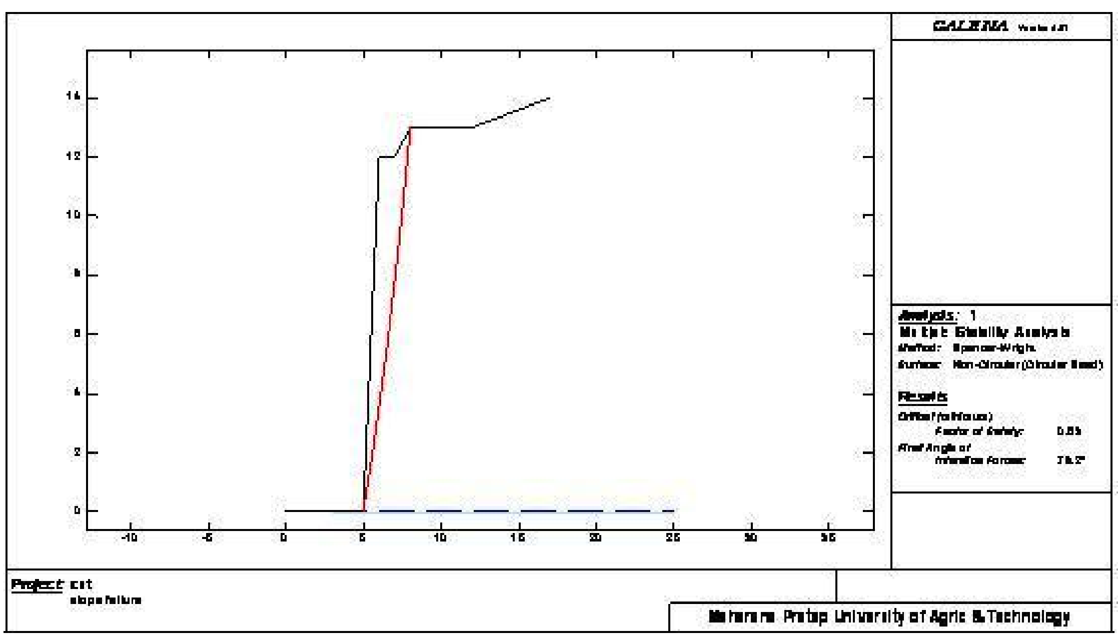



Fig 5: Slope stability analysis with GALENA software.

The slope angle of hill cut face under study varies from 86$^o$ to 89$^o$. The hill cut face is making an angle with the road, which is 1$^o$ to 2$^o$ angle toward east. The rock layers in the hill cut portion of the hill are dipping towards west, at an angle of 88$^o$ to almost vertical and show reversal in the dip direction as shown in the field photograph Fig 6 & 7.


Fig 6: Roadside hill cut slopes NH-8 between Udaipur-Ahemdabad

Fig 7: Field photographs showing view of roadside hill cuts NH-8

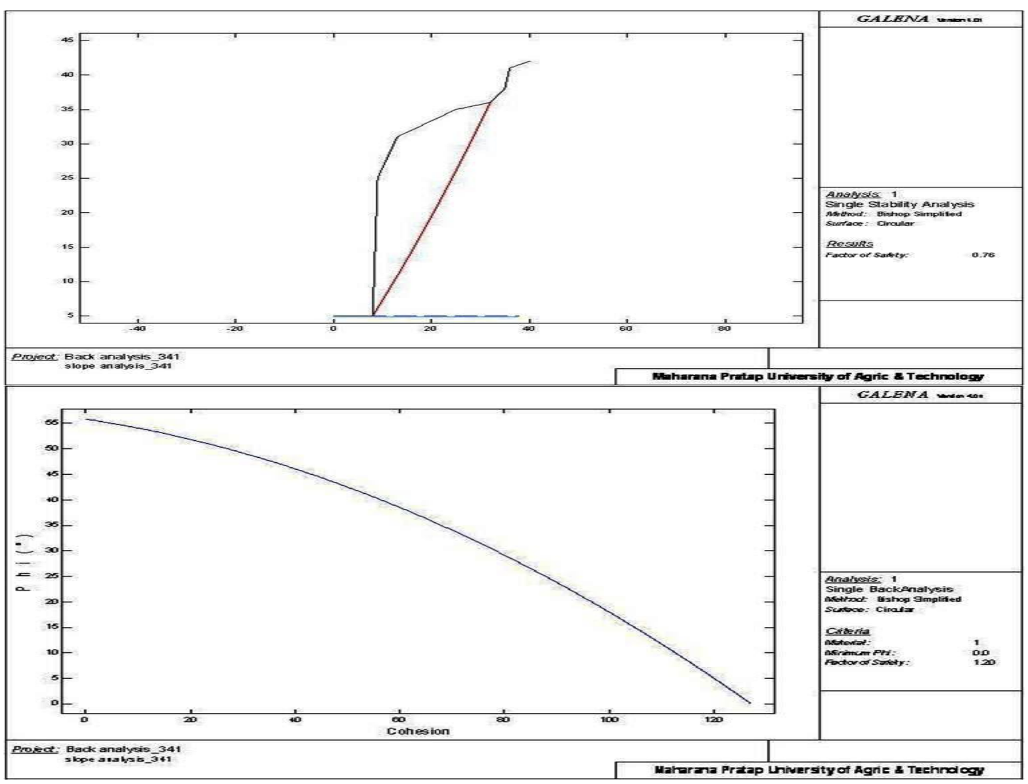



Fig 8: Showing failure plane and back analysis plot of a typical hill cut

In a typical hill cut, the back analysis results depicted in Fig 8 establishes a relationship of physico-mechanical as well as geotechnical status of rock and slope to be maintained.

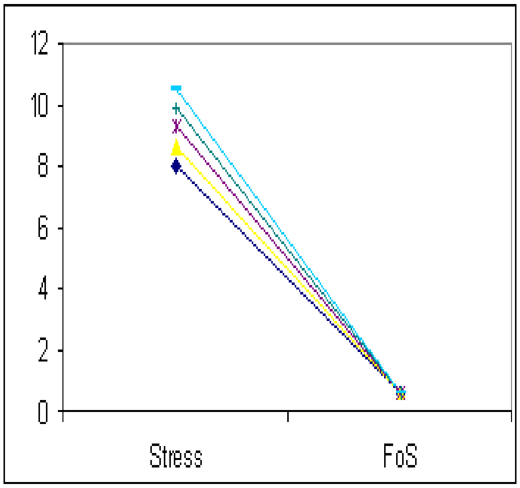



Fig 9: Relationship between factor of safety and stress value

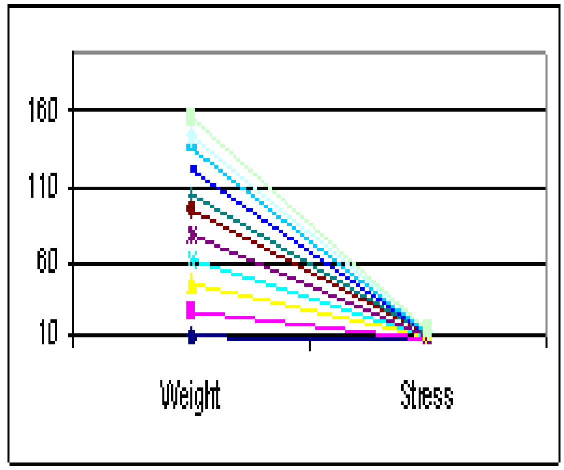



Fig 10: Relationship between weight of rock mass and stress value

The factor of safety & stress value; weight of rock mass & stress value is directly proportional to each other as shown in Fig 9 and 10.

**SLOPE STABILITY ANALYSIS**

There are number of tools available for stability analysis of the road side hill cut slopes including physical scale model, mathematical model i.e., limit equilibrium analysis, stress/strain analysis, and specific analysis i.e., inclined wedge method, cylindrical arc, surface varying curvature and finite element method (Brawner et al. 1970**).** The FE analysis is being popular for simulation of the modeled object or system. It gives approximately reliable results without actual deformation of the material. The FEA method is a stress/strain type of analysis that involves dividing the rocks into a mesh of linear, triangular or rectangular elements.

**MATERIALS AND METHOD**

The FE analysis was done with the help of a digital computer Intel(R) Pentium(R) 4, CPU 3.06GHz, 1GB of RAM, 80GB Hard Disk. The Abaqus/CAE Version 6.8-1 was taken as FEA tool for the analysis. A typical view of FE analysis model in the software window is shown in Figure 8. The finite element analysis (FEA) was done for the slope risk analysis of the selected hill cut rock slopes. The FEA model developed for 25 meter long and 10 meter wide section of the hill was taken under the case study. The hill was segmented into six layers of quartzite (Q) and siliceous-phyllite (P) with minimum height 9.5 meters and maximum height 12 meters as shown in Fig 11(a, b). Considering the layers $10^o$ North-East and inclined by $88^o$ towards west and assumed to be homogeneous and attached to each other. The deformation modulus (Young's Modulus) of a rock mass is often not a well known or easily measured parameter. However, it is a required input parameter for various types of numerical analyses (e.g. finite element stress analysis), therefore it is considered for the present study, which involves deformations **(**Hoek et al., 2002, 2006). The values of density, young's modulus, poison ratio and yield stress are strictly on the basis of review of data referred in the earlier studies and calculated values for siliceous-phyllite and quartzite rocks, given below in the table 1.

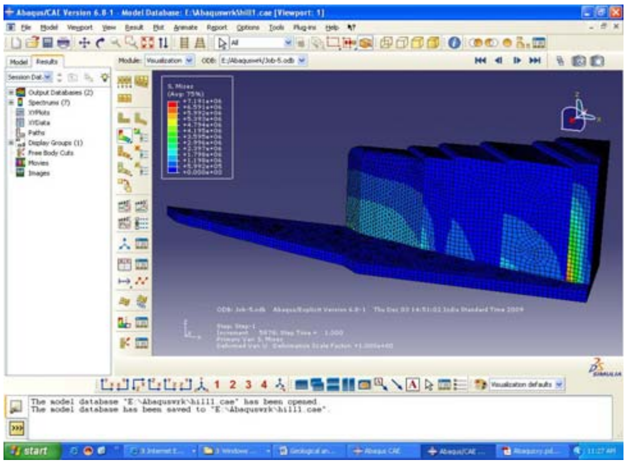


Fig 11(a): Abaqus tool for FEM analysis of the selected hill section

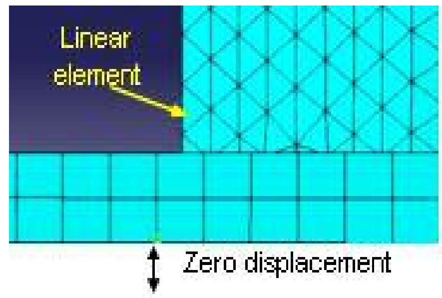



Fig 11(b): Finite element mesh for hill cut slope

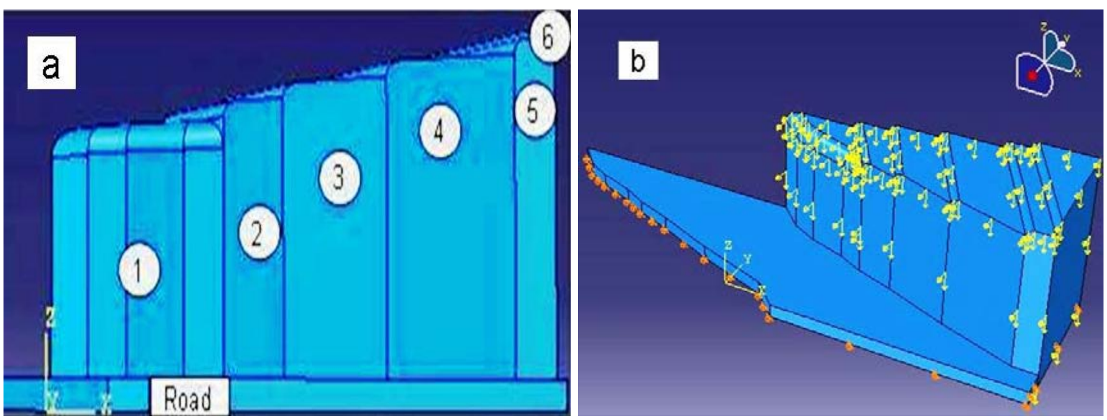



Fig 12: FEA model (a) Hill cut slope of the hill and (b) Effective gravity and displacement direction.

In this study, gravity effect of the rocks was considered and other effects i.e. road vibration due to vehicle, earthquake, heavy rains, winds etc. were neglected. The rocks were constrained vertical and allowed to move toward road side as shown in Fig 12. The whole model was meshed using linear elements of 0.4 m global sizes. The total number of elements 87926, number of nodes 48224. A typical mesh generated by FEM tool is shown in Fig 11(b).

Table 1: Geo-technical Properties of the Rocks

| Type of rock | Properties | | | |
|---|---|---|---|---|
| | Density ($kg/m^3$) | Young's modulus ($N/m^2$) | Poisson's ratio | Yield stress ($N/m^2$) |
| Siliceous-phyllite(P) | 2600 | $1x10^9$ | 0.2 | $4x10^6$ |
| Quartzite(Q) | 2650 | $1.5x10^9$ | 0.2 | $8x10^6$ |

(After Goodman 1989)

The FE analysis was done for Abaqus/Explicit solution. Gravity effect was given as input load and output data generated, were taken for the resultant mises stresses developed on the strata. Finally, the nodes displacement status of layers produced. The Fig 13 shows stress pattern developed in the entire cut slope and enlarged view of typical stress behaviour at the toe portion of the cut slope. The distribution of stresses in the x-direction shows the maximum stress concentration in the toe portion and its typical distribution pattern is shown in Fig 14.

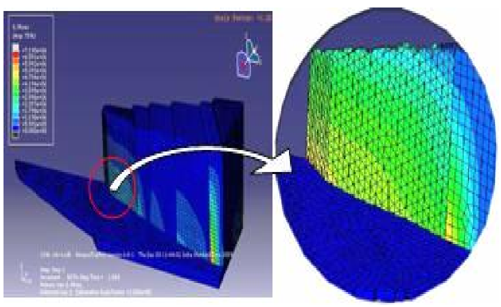


Fig 13: Stressed toe section

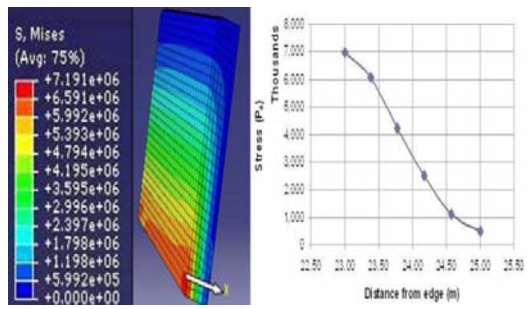



Fig 14: Stresses distribution along x-direction

The plot between height Vs original and displaced coordinate, depicts that after deformation, rock layer incline toward the cut side and deformed height reduces than the original height. The typical displacement pattern, obtained in road side hill cut slope is shown in Fig 15.

The displacement can be correlated to a failure criterion and if it exceeds a critical value, for particular section, that portion of the rock will have reduced strength. Therefore by using a series of value in the analysis, a simple form of progressive failure can be modeled.

## SCALED DEFORMATION ANALYSIS

Objective of the analysis is to study the deformation pattern when disturbing forces are scaled up. The developed model was scaled up along with related parameters, as discussed above.

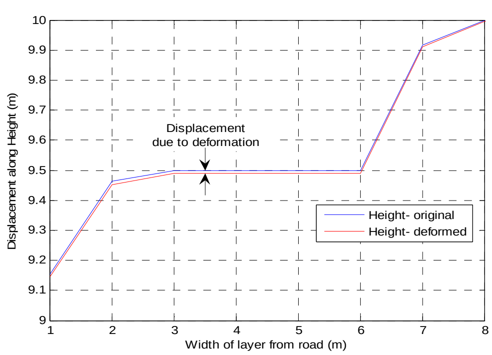



Fig 15: Displacement trend in the hill cut rock mass.

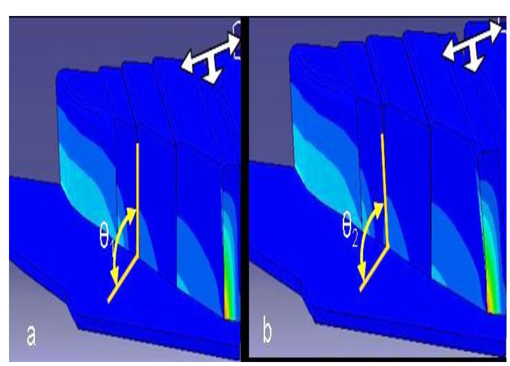



Fig 16: Scaled deformation of hill cut slope (a) 5 times and (b) 10 times.

The analysis was done for the increased parameters and finite element analysis showing the deformation pattern. Scaled deformation in finite element analysis of road side hill cut slope rock layers Fig 16. This deformation shows 5 times and 10 times scale up values. The angle $\theta_2$ is less than $\theta_1$, leading to the more inclination of the rock layers and the block arrow down pointing the maximum deformation zone.

## RESULTS AND DISCUSSION

The slope stability analysis tools and techniques has been suggested by various researchers time to time, where scope lies in further improvements as well as modifications. The basic reason behind is the nature of rock and rock mass i.e. heterogeneity, anisotropies, discontinuities, weathering effect, water saturation and local climatic factors (Barton et al. 1982). The RSR value of rocks of the cut faces varies from 35 to 51 is indicating the poor conditions of rock from compactness point of view. The RSR values show that the parameter A, contributes lowest and highest by parameter C. The joint roughness coefficient of joint planes developed is 0 to 2, which is another supportive cause to rock slope slide, because of its smoothness. The situation in most of the roads crossing the Aravalli Mountain is similar kind. The factor of safety less than one is showing critical unsafe conditions of the cut slopes.

The geometry of the stress distribution pattern at the toe of the road side hill cut slope is elliptical and toe is the centre of the ellipse. This clearly indicates ultimate damage to be resulted in terms of failure Fig 13.

The finite element scaled value analysis carried out and showing encouraging results to understand about the failure of the road side cuts. It shows that the road side hill cut slope becomes unstable with the increase in scaled up values Fig 16. The rock layers displacing in to the road side and after exceeding calculated limit of scaled values, it may fall on the road. There are many uncontrollable/natural factors i.e. rain, earthquake, road vehicle vibrations, blown winds etc. affect the rock stability and may cause the sudden damage, causing fatality to the moving vehicles.

## CONCLUSIONS

The geotechnical parameters of the road side hill cut slope obtained by the field observations, stereo plotting, rock structure ratings (RSR) and factor of safety analysis by GALENA software, is showing its criticalness along NH-8, Udaipur-Ahemdabad, India. It is serious all along the four lane roads passing through Aravalli Mountain of India. Finite element is an established and proven technique for slope stability analysis and the present study shows that the scaled up value analysis is identified as another suitable method for road side hill cut slope stability analysis. The road side hill cut slopes failures all along the highways in Aravalli Mountains are recommended for the stability analysis and mitigative measures are strongly recommended.


## ACKNOWLEDGEMENTS

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# "BIODIVERSITY" - A WONDERFUL TOOL TO ERADICATE POVERTY

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## ABSTRACT

The need for Biodiversity conservation is being increasingly realized during recent days. Conservation and sustainable use of biological resources is ingrained in Indian values, cultures, customs and ethos. Being located at the confluence of Indo-China, Indo-Burma & Indo Myanmar and sundaland biodiversity hotspots, the north-east India harbours a good number of flora and fauna; some of these are found in Barak valley as well. During recent days, increased anthropogenic activities pose a considerable threat to this diversity and hinder their survival in a big way. The poor are particularly vulnerable to these consequences because they are often directly dependent on biodiversity for their day to day survival. 70% of the world's poor live in rural areas and depend directly on biodiversity for their survival and wellbeing. Biodiversity interactions provide us a number of essential Ecosystem services which can shape the development paths of a country. The present paper makes an attempt to address all these issues in the ambience of Barak Valley, Assam (India).

**Keywords:** Biodiversity Conservation, Ecosystem services, Poverty Alleviation, Barak Valley, Assam, India.

## INTRODUCTION

Biodiversity - the term is gaining more and more importance in the era of industrialization and rapid technological advancement. UNESCO has celebrated year 2010 as the International Year of Biodiversity. This has tempted the conservationists to take pledge for safeguarding the biodiversity during recent years and also in the years to approach.

India is one of the 12 mega biodiversity countries in the world. The diverse physical features and climatic situations of India have formed varied ecological habitats like forests, grasslands, wetlands, coastal, marine and desert ecosystems etc. All these harbor and sustain immense biodiversity. The country is considered to be the homeland of 167 important plant species of cereals, millets, fruits, vegetables, pulses, fibre crops and oilseeds. About 4,900 species of flowering plants are endemic to the country. Most of these are found in the floristically rich areas of North-East India, although some others are found in the Western Ghats, North-West Himalayas & the Andaman and Nicobar Islands. Approximately 65% of the total geographical area has been surveyed so far. Based on this, over 46,000 species of plants and 81,000 species of animals have been described by the BSI and ZSI respectively. This entire quantum identified so far is just the tip of the iceberg as considerably big number of flora and fauna are yet to be explored and identified. If using all available knowledge and wisdom, in a holistic

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way, the vast Biodiversity resources are managed by all the stakeholders can definitely help to improve the life-support system of the poor mass which ultimately can act to alleviate the poverty level of all the developing nations at large.

**Indian Scenario:** India is the seventh largest country in the world and Asia's second largest nation with an area of 3,287,263 square km. The Indian mainland stretches from 8 4' to 37 6' N latitude and from 68 7' to 97 25' E longitude. It has a land frontier of some 15,200 kms and a coastline of 7,516 km [1]. India's northern frontiers are with Xizang (Tibet) in the Peoples Republic of China, Nepal and Bhutan. In the north-west, India borders on Pakistan; in the north-east, China and Burma; and in the east, Burma. The southern peninsula extends into the tropical waters of the Indian Ocean with the Bay of Bengal lying to the south-east and the Arabian Sea to the south-west. The country is home to around 846 million people, about 16% of the World's population.

The northern plains of India stretch from Assam in the east to the Punjab in the west, extends southward to terminate in the saline swamplands of the Rann of Kachchh (Kutch), in the state of Gujarat. Some of the largest rivers in India including the Ganga (Ganges), Brahmaputra, and the Yamuna flow across this region. The delta area of these rivers is located at the head of the Bay of Bengal, partly in the Indian state of west Bengal but mostly in Bangladesh [2].

Physically the massive country is divided into four relatively well defined regions - the Himalayan mountains, the Gangetic river plains, the southern (Deccan) plateau, and the islands of Lakshadweep, Andaman and Nicobar. The highest mountain in the Indian Himalayas is Kanchenjunga (8586 m) which is located in Sikkim on the border with Nepal. To the south of the main Himalayan mass lie the Lesser Himalaya, rising to 3,600- 4,600 m, and represented by the Pir Panjal in Kashmir and Dhaula dhar in Himachal Pradesh.

The vast tract of diverse ecological habitats of the subcontinent forms life supporting niche for immense biodiversity. Conservation and sustainable use of biological resources based on local knowledge systems and practices is ingrained in Indian ethos. The country has a number of alternative medicine systems, the preparations and formulations of which are predominantly based on plant based raw materials. The strategies for conservation and sustainable utilization of biodiversity have comprised providing special status and protection to biodiversity-rich areas by declaring them as national parks, wildlife sanctuaries, biosphere reserves etc.

Several significant wetlands of India have been declared as "Ramsar Sites" under the Ramsar Convention. Under the World Heritage Convention, another five important natural sites have been declared as "World Heritage Sites". To conserve the representative ecosystems, a Biosphere Reserve Programme is being implemented. Twelve biodiversity rich areas of the country have been designated as Biosphere Reserves applying the UNESCO’s Man and Biosphere (MAB) programme. Ministry of Environment & Forests (MoEF) is funding for preparing detailed National Biodiversity Strategy and Action Plan (NBSAP) using participatory planning approach and this is currently being implemented. The country has recently worked out bio-diversity legislation. It aims at regulating access to biological resources. Under "Eco-development" programme, the economic needs of the local communities are being taken care of through provisioning of alternative sources of income and a steady availability of forest and related produce.

Approximately, 4.2 per cent of the total geographical area of the country has been earmarked for extensive in-situ conservation of habitats and ecosystems. To complement in-situ conservation, attention has been paid to ex-situ conservation measures. Central government and state governments together run and manage 33 botanical gardens. Some of the universities have their own botanical gardens. The Assam University has Eco-forest of its kind.

**North-east India scenario:** North-east India, being located at the confluence of Indo-Malayan, Indo-China and Indo-Malayan and Sundaland Biodiversity hotspot, forms diverse ecological habitats which are the abode of large number of big and small animals and many plants.

***Fauna:*** To mention some of the important animals are One horned Rhinoceros (*Rhinoceros unicornis*), Western Hoolock Gibbon, (*Hoolock Hoolock hoolock*), Eastern Hoolock Gibbon, (*Hoolock Hoolock leuconedys*), Golden Langur (*Presbytis geei*), Slow Loris (*Nycticebus coucang*), Wild buffalo (*Bubalus arnee*), Swamp Deer (*Cervus duvaceli*), Indian Elephant (*Elephas maximus*), Pygmy hog (*Sus sulvanius*), Hispid hare (*Caprolagus hispidus*), Gangetic ghorial *(Gavialis gangeticus)* many species of avifauna, herpeto-fauna and a large no of invertebrates.

***Flora:*** Studies carried out on the vegetation of the area reveals that the area is generally varied and botanically interesting. It has been observed that the vegetation cover in the study area varies from tropical to sub-tropical evergreen moist deciduous forests, bamboo forests and grasslands and riparian forests. The predominant plant species that are found in the area include *Ficus sp., Macarangas sp., Duabanga sp., Lagerstroemias sp., Bombax sp.,*etc. Various fern species that occur are *Cyathea gigantean, Angiopteris evecta, Pteris sp.* etc. Timber species include, *Dipterocarpus sp., Terminalius sp., Michelias sp., Artocarpus sp., Kayaassamica sp., Tetrameles sp., Duabanga sp., Gynocordia odorata Aquilaria agallocha* and *Tree fern* etc. The epiphytic flora is very rich and diverse and include *Dischidia sp., Hoya sp., Pothos sp., Raphidophora sp.,* etc. Orchids of the species *Dendrobium* and *Cymbidium* are quite abundant. Thus the area represents as the gene bank of a good number of plant species. Of these, the species that deserve special attention are *Michelias sp., Magnolias sp., Bucklandia populanea, Podocarpus nerifolia, Cyathea gigantean, Cycads, Caryota sp., Licula sp., Pinaga sp.,*and rare ochids like *Lilium macklieae, Paphiopedilum spicerianum*, and *Paphiopodium villosum* [3].

***Barak valley scenario:*** The Barak Valley districts of Assam are considered as one of the rich biodiversity zone in terms of its floristic and faunal composition. The area is characterized by both evergreen and semi evergreen deciduous forest covers which harbour various endangered and threatened species of plants and animals. The area is notable for Gangetic River Dolphin, Hoolock Gibbon, Slow loris, many species of vultures, besides some other invertebrate & vertebrate diversity. A large no. of rare plants and orchids and endangered flora are the characteristic feature of the valley.

During recent days, increased anthropogenic activities pose a considerable threat to this diversity and hinder their survival in a big way. Poaching and illegal killing of animals for various body parts are often reported. Various species of monkeys, deer, owls, turtles and

Fig. – 1. Turtles-Victims for delicious flesh.

Fig. –2. Medicine from animal body parts

Fig. – 3. Illegal trade for skin.

Fig. –4. Tablets from Monkey oils

Fig.-5.Fishing owls-poaching for medicine.

Fig. –6. Indigenous weapons to kill animals.

Fig. – 7. Rhesus monkey.

Fig. – 8. Man-face Stink bug (*Catacanthus incarnatus*)

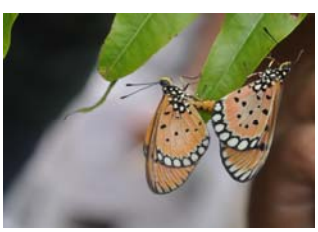

Fig.-9. Butterflies- the winged hexapods.

Fig.–10. Crop field (Paddy) under flood water tortoises and many other animal and plant species are the soft target of this trade (Fig. 1- 9). The lack of awareness and proper knowledge about protection and conservation of flora and fauna, coupled with increased deforestation and other vicious activities, cause considerable damage to their survival and existence. Consequent upon this, many species have been forced to become extinct forever and some more are on the verge of extinction.

## MILLENNIUM ECOSYSTEM ASSESSMENT

The Millennium Ecosystem Assessment (MEA) has indicated that climate change is likely to become one of the dominant direct drivers of biodiversity Loss by the end of the century. This particular aspect seems to be pertinent to the Barak valley conditions as well as it has been witnessed that unprecedented flood has caused severe crop loss (especially paddy) in some areas during late August, 2010. Consequently the farmers are counting days with boundless uncertainty (Fig.- 10). The prediction of climate change (i.e., increases in temperatures of 1.4°C to 5.8°C by 2100) will affect species in several ways like changes in distribution of plants and animals, increased extinction rates, changes in reproduction timings, and changes in length of growing seasons for plants.

Forests are the cradle of biodiversity. They provide a wide range of ecological, economic and socio-cultural benefits for the communities as well. However, the dynamics of forest management in our country is unique, as the multiple uses of forests are clearly felt in a multi-stakeholder environment. The revised National Forest Policy has focused on the maintenance of environmental stability, conservation of natural heritage by preserving the natural forests and meeting the basic needs of people, and also maintaining the relationship between the tribal and other dependent people. The sustainability of people-oriented management initiatives like joint forest management can be enhanced by involving the local communities. It is imperative that we take care of the institutionalization and capacity-building needs of the communities.

Some of the other contributing factors that cause the biodiversity to decline are the lack of conservation education, awareness, community development programme etc. It must be emphatically mentioned here that biodiversity interactions provide us a number of essential natural services (Ecosystem services) like food production, soil fertility, climate regulation, carbon storage and the likes, which can shape the development paths of a country. The most important threats to biodiversity have long been habitat loss, due to large scale conversion of land to agriculture and urban centres, introduction of invasive alien species, overexploitation of natural resources, and pollution.

## BIODIVERSITY & POVERTY ALLEVIATION

The poor are particularly vulnerable to the consequences of loss of biodiversity because they are often directly dependent on biodiversity for their day to day survival. 70% of the world’s poor live in rural areas and depend directly on biodiversity for their survival and wellbeing [4]. More than 3 billion people in our country rely on variety of biodiversity and 1.6 billion people rely on forests and non-timber forest products for their livelihoods. The urban poor also rely heavily on biodiversity. Though human well-being is dependent on the continued provision of ecosystem services, biodiversity is very rarely included in our economic outlook because it is mainly a public good, sending no signals through markets. This particular aspect pertaining to the ‘Biodiversity management’ deserves serious attention of all the stakeholders.

In Barak valley of Assam (India) various forest produce and Non timber forests products (NTFP) are not managed in a scientific way. Although the forest (Conservation) Act, 1980 is in force, but the lackadaisical approach in legal enforcement segment has facilitated ruthless harvesting of NTFP's, leaving the area almost barren. Various forest products like Bamboo baskets, cane and its various products, materials for making incense sticks, sweeping broom, farmer's cap and many small industries of its kind can be promoted through entrepreneurship development. This would in turn help in improving the overall socio-economic status of the poor mass of the fringe areas of forest villages, which, in turn, would help in developing interest to take care of the forest produce with a socio-cybernetic approach.

## INITIATIVES TAKEN

With a view to enrich the biodiversity vis-a-vis the green cover in our vicinity, often plantation schemes are taken by government agencies, NGO's and the like. As a matter of common practice, quite a good number of saplings are planted on the World Environment day everywhere. When planting saplings, we may think about poverty and development issues that prevail in our vicinity. The type of species we choose may symbolize a development goal. For instance, planting a species with medicinal value for good health; planting a species that produces fruits, nuts or other foods for eradication of hunger.

The theme for the 2010 - the International year of Biodiversity has been, "Biodiversity, development and poverty alleviation". Development means that all people have the opportunity to live a good life, without hunger, misery, danger, illness and illiteracy. Biodiversity gives us a wonderful key to reduce poverty because it provides people with basic ecosystem goods and services. It provides goods such as food, fibre and medicine and services such as air and water purification, climate regulation, erosion control and nutrient cycling and what not!

## CONCLUSION

The urgent need of the hour is to act upon knowledge systems that each one of us can relate with, and therefore are able to participate in a process that links Biodiversity conservation with sustainable development and Poverty alleviation. In this manner, thus, we would be able to cope with emerging socio-ecological & economic uncertainties in a rapid changing world. The slogan of the International Year reminds us, "Biodiversity is life…Biodiversity is OUR life". This should be the guiding force behind all future endeavors of all the conservationists.

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# CLIMATE CHANGE SCENARIO WITH REFERENCE TO BARAK VALLEY, ASSAM (INDIA)

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## ABSTRACT

Drastic changes in earth's climate systems both on global and regional scales, particularly after the industrial revolution have been recognized. The global climate change, which assessed at the macro level, is the outcome of myriads of micro level assessments, happening at the regional and local levels. The present paper highlights some of the ambient contributing factors of climate change like, weather (Temperature, humidity, rainfall, flood scenario, forest & biodiversity, SPM etc) and makes an approach to correlate the entire climate change scenario and its impact from macro to micro level with special reference to climatic conditions of Barak Valley, Assam (India).

**Key Words**: Barak Valley (India), Biodiversity, Climate change, Flood, Met data, SPM.

## 1. INTRODUCTION

There has been radical change in the earth's climate both on macro and micro levels, particularly after the industrial revolution. It's true that the United Nations Conference on Human Environment (UNCHE) at Stockholm in 1972, followed by United Nations Conference on Environment and Development (UNCED) at Rio de Janeiro, Brazil in 1992 and Japan's Kyoto Protocol in 1997 could impose some mandate on the more GHG emitting countries. The purpose of the Copenhagen Climate Council was to create global awareness in line with the previous climate Summits. The main aim of the Copenhagen Climate Council was to demonstrate that achieving an effective global climate treaty is not only possible, but necessary. The summit, as anticipated, could work as a yardstick that would take a toll of the situations as to what extent progress has been achieved. The ever continuing debate between 'have' and it's 'have not' counterparts could result only in maintaining the stalemate in status quo situation.

India's initiative, like some other developing nations to combat climate change is praiseworthy. The Hon'ble Prime Minister of India released a series of eight missions under the National Action Plan on Climate Change (NAPCC) to outline its strategy to meet the challenge of Climate Change [1]. The global climate change, which assessed at the macro level, is the outcome of myriads of micro level assessments, happening at the regional and

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local levels. The local level factors and the pattern of their shift has been observed with minutiae details and elaborated in the forthcoming paragraphs;

## 2. ENVIRONMENTAL CONDITIONS OF BARAK VALLEY

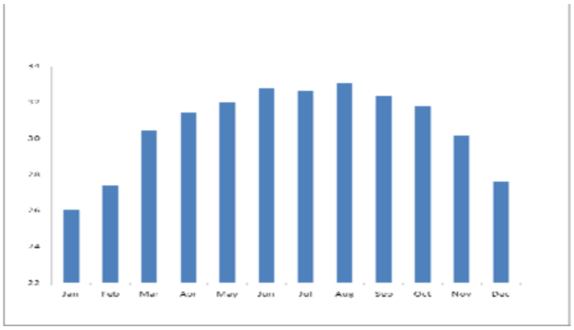
The weather conditions that have been studied at the local level are Temperature (Maximum and Minimum), Humidity (Morning and Afternoon) and Rainfall. An average of data (since 1989) have been computed that would reflect the true mean over a long span of seasons and thus minor year to year variations can be ruled out.

**2.1. TEMPERATURE:** analysis of meteorological data reveals that average temperature in the north-east india range between 8.93 to 34.07 (range of maximum temperature= 21.05*c to 34.07*c/ minimum temperature = 8.93*c to 25.12*c) in different months of the year. During coldest months of the year (i.e., december/ january) the average maximum temperature does not drop below 21.05*c. The data on temperature of the valley (fig-1) reveal that the average highest monthly maximum temperature during the hottest month is 33.06*c (during august) and mercury soared as high as 40*c ( may, 6, 2007). The average minimum temperature during the coldest months (i.e., january) is the lowest (8.93*c) and in some recent past years it has gone down to 7.5*c (january, 16, 2007) and 8*c (on january, 18, 2011) [2].

**2.2. Humidity:** The air around us is a huge reservoir of water which it holds in the form of invisible water vapour. The latent water content of the air, referred to as Relative Humidity (RH) shows diurnal variation. The relative humidity of a place usually is the maximum during the morning hours, prior to sunrise (6.19 Hrs IST) and minimum during the afternoon hours (recorded at 13.19 Hrs IST). Analysis of fifteen year's data (1989-2003) reveals that in Barak Valley the average morning humidity is highest during December/ January (98.7%), while the ambience gets fully saturated (100%) during winter months in some years. The bottom line of the same has been found to be 47.5% during February. (FIG-2)

A synergic effect of prolonged rainfall and a long spell high humidity continued for days together during May-June, 2010, as a result of which on one occasion, a very rarely observed phenomenon i.e., 'Sweating of Floor' occurred in which all the floors of the houses in all the houses of Barak Valley districts witnessed oozing out of water vapour on June, 9, 2010.

**2.3. Rainfall:** During May to August, especially during June/July, heavy precipitation occurs due to south west monsoon in all the areas of north east India. Analysis of fifteen years meteorological data (1989-2003) reveals that during monsoon, highest precipitation occurs in the area. On the other hand, the rest six months of the year suffer from water stress and consequently drought occurs. (FIG-3). Irregularity in rainfall, i.e., late arrival of monsoon and subsequent scanty rainfall has caused drought like conditions during certain years, i.e., June-July, 2009.



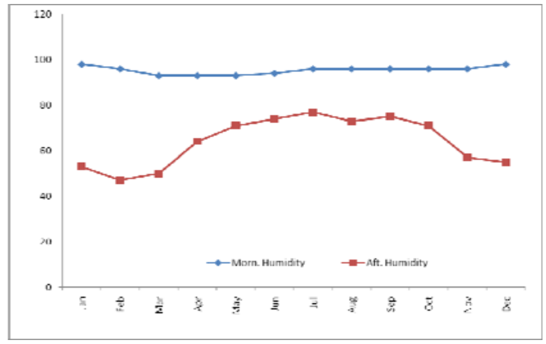
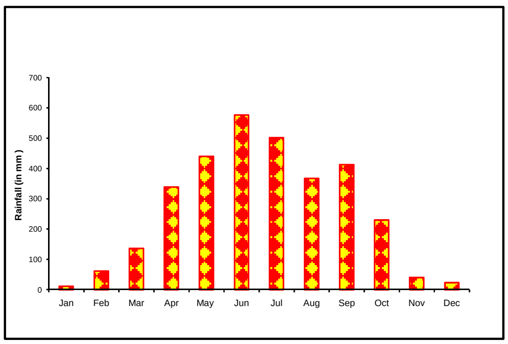




Fig.1.Temperature (Max$^{m}$) in Barak Valley, India. Fig.2. Humidity(Morn & Aft),Barak Vall



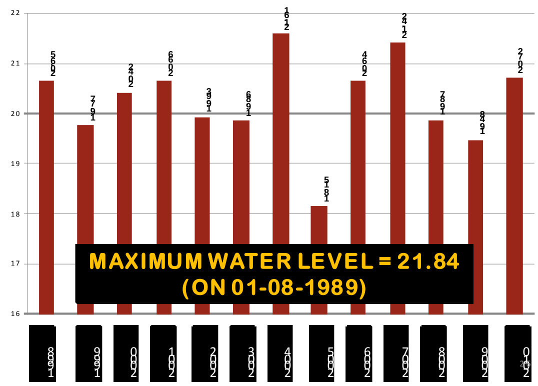
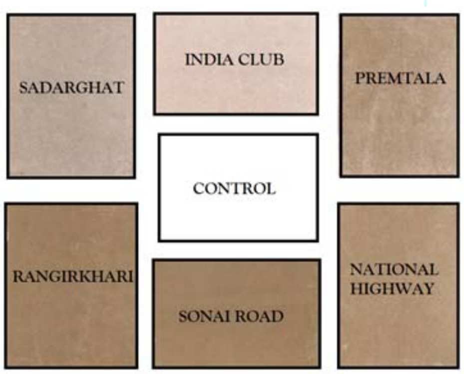




Fig.3. Average rainfall pattern in Barak valley(India) Fig.4. Highest Flood Levels in River Barak



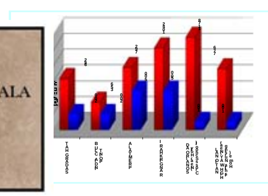



Fig.5. SPM Scenario in urban Silchar area. Fig. 6.Levels of SPM at different places of the town

## 3. FLOOD SCENARIO

Barak Valley experiences frequent flood. Almost every alternate two or three years, the valley gets submerged with water. During recent past, the valley experienced flood in 1989, 1991, 1997, 2004 and minor flood like situations in some more years. Highest water level of river Barak is given in the Fig.-4. The devastating flood causes great loss to the environment and livestock of the valley besides creating panic situation for the mass people. The distressing flood in 2004 had put the three districts of the valley in endless hassle which is elaborated below;

***Cachar district***: Out of five revenue circles, three (i.e. Silchar, Udarbandh and Katigorah) were affected. Flood water had inundated some prominent areas of Silchar town like Fatak Bazaar, Kalibari road, Janiganj etc. People had taken shelter in schools and other government buildings. Road communication in NH-53 Silchar-Imphal road was disrupted due to overflowing of river Barak at several places. Silchar-Kumbhirgram road (Airport road) was under water. Railway route between Silchar-Badarpur- Lumding remained closed due to heavy landslide in the N. C .Hills. The NH-44 i.e. Silchar –Guwahati road was closed due to heavy landslide in Sonapur area, Garo hills of Meghalaya. About 300 meters of the highway (which is the only lifeline highway for entire Barak Valley, Tripura, Mizoram and Manipur) was blocked.

***Karimganj district***: Four revenue circles, i.e., Patherkandi, Nilambazar, Badarpur and Karimganj were mainly affected. Approximately 6010 hector areas have been affected. 22000 people were flood victim. Total crop area affected was about 5900 ha. People had taken shelter in the temporary shelters made in schools and other elevated place.

***Hailakandi district***: All the revenue circles were affected by the flood. In Agalpur revenue circle, 22 no. of villages got marooned. Road communication between Silchar- Hailakandi and Hailakandi- Karimganj was under submergence for about a couple of weeks.

## 4. FOREST & BIODIVERSITY

Forests provide a wide range of ecological, economic and socio-cultural benefits for the communities. However, the dynamics of forest management in a developing country is unique, as the multiple uses of forests are clearly felt in a multi-stakeholder environment. The forestry sector in India is among the first in the world to be managed on the lines of modern scientific management. Indian National Forest Policy focused on the maintenance of environmental stability, conservation of natural heritage by preserving the natural forests and meeting the basic needs of people, and also maintaining the relationship between the tribal and other dependent people. The sustainability of people-oriented management initiatives like joint forest management can be enhanced by involving the local communities. It is imperative that we take care of the institutionalization and capacity-building needs of the communities. Forests are the one of those rich habitats which maintains a conducive atmosphere for thriving various forms of plants and animals. The effects of climate change coupled with ruthless exploitation of forests has caused many a species to become extinct forever and many more are following that trend. The species of animals which were once found in the forests and its adjoining areas of Barak Valley, but now have become extinct includes various species of vultures, Rhinoceros (last Recorded 1967, at Sonai Reserve Forest (Cachar), Ghorial, (seen till

1955; A full grown ghorial was killed in 1960 at Fulertal, Cachar, Assam), Wild buffalo, Tiger etc., While, slow Loris, Hoolock gibbon, Gangetic River dolphin and such many other species are surviving under stress.

## 5. SUSPENDED PARTICULATE MATTER (SPM)

Particulate Matter is recognized as solids or liquids that are distributed in ambient air. The term particulate refers to the particles, dust, mist, fumes and smoke that become airborne in surrounding air. The SPM is viewed with lesser importance as regards climate change is concerned [3].

A pilot study was conducted to estimate the presence of Suspended Particulate Matter (S P M) in the urban areas of Silchar, Cachar, Assam during February, 2009. The study was done on a single day at six different localities in the town [viz, Sadarghat, India club point, Premtala point, Rangirkhari point, Sonai Road (near Holy cross school), National Highway (near Ishita nursing home)], from morning till evening. The Suspended Particulate Matter was measured with the help of High Volume Sampler (Nettel Chromatograph make). The study revealed significantly higher levels of particulate matters in all the six areas, as compared to the standard laid down by CPCB (FIG-5 & 6). Needless to say, of the six study sites, some were near school, hospital and its adjoining areas, urban areas, residential areas and the like. Un-metallic and deteriorated road conditions, among other factors are largely responsible for triggering the S. P. M. level.

It is needless to mention here that SPM affects adults and children differently. According to physicians, what is most disturbing is the increasing evidence of a link between ultra fine particle pollution and heart disease, asthma & chronic lung diseases. Children spend more time outdoors and are exposed to pollution in daytime when the respiratory SPM (RSPM) level is high. Children are engaged in vigorous activity like running and hence have a higher breathing rate. The effects are, increased acute respiratory diseases, lowered lung function in children, increased sickness rates, increases in mortality and increase in allergic skin reactions. The observations indicated that the SPM levels at all the sites are in critical level (>100/200/500 µg/m3). In all the areas as there are no adequate particulate emission control. The Green Belt constituting high dust capturing plant species may be the option for control of particulate matter in environment around residential areas/ industrial area, since trees can act as efficient biological filters, can cost effectively remove significant amounts of particulate pollution matters from urban atmosphere.

## 6. INDIA GOVERMNENT INITIATIVES

Hon'ble Prime Minister of India released the National Action Plan on Climate Change (NAPCC) on *30th June 2008* to outline its strategy to meet the challenge of Climate Change.

Eight National Missions are, National Solar Mission, National Mission on Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Eco-system, National Mission for a Green India, National Mission for Sustainable Agriculture and National Mission on Strategic Knowledge for Climate Change.

**7. CONCLUSION**

From the foregoing discussions, it is evident that the effect of climate change at the micro level (i.e., barak valley) is a phenomenon that is witnessed here. Climate of the valley during certain period of time show extreme variations, occasionally too high or too low temperature, excessive rain or drought in some years, occasional floor sweating and excessive humidity during other times cause quite nuisance and havoc in the valley. Unprecedented flood causes several problems like road inundation, submergence of agricultural field and national highways, inundation of houses of people living in low land and also damage to livestock. The effect of climate change is also witnessed in the forest environment where significant deterioration in the quality of forest cover, life form, both flora and fauna have been observed. The spm study has also revealed excessive dust in the ambience of barak valley at large. The aspects through which the effects of climate change have been studied in the valley stands at par with the effects as observed elsewhere. Therefore, the present micro-level observations need further research based investigations to correlate with the climate change scenario that has been happening on a global basis.

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# IMPACT OF URBAN DEVELOPMENT AND CLIMATE CHANGE ON BIODIVERSITY WITH SPECIAL ATTENTION TO THE HERPETOFAUNA IN BARAK VALLEY, NORTH EAST INDIA

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## ABSTRACT

Barak Valley Region of Northeast India is a part of the Indo-Burma hotspot, which is one of the 34 global biodiversity hot spots. Agriculture and tea cultivation are important economic activities in the region. However, development and expansion of urban areas is taking place at a fast rate and it is also accompanied with changing climatic conditions like erratic rainfall pattern, reduction of rainfall, rising temperature and degradation of freshwater habitats. This region abounds in variety of habitat suitable for herpetofauna, which includes amphibians and reptiles. The amphibians and reptiles form an important part of the food chain in the ecosystem being both predators and preys. They serve as predators for insect pest and themselves are the food of higher animal groups like birds and mammals. They form important vertebrate biomass in the ecosystem. The paper analyses the impact of urban development and its related activities and the recent changes in climatic conditions observed in this region on the herpetofaunal diversity and puts forward some suggestions which would help design conservation strategies for this lesser studied group of vertebrates.

**Key Words:** urbanization, erratic rainfall, herpetofauna, habitat degradation and fragmentation, pollution, conservation.

## 1. INTRODUCTION

The northeastern region of India is a part of the Indo-Burma hotspot, which is one of the 34 global biodiversity hot spots and is the home of about 72 plus species of amphibians [1]. The Barak Valley districts of South Assam comprises three districts viz. Cachar, Hailakandi and Karimganj (24˚ 8′ N and 25˚ 8′ N latitudes and 92˚ 15′ E and 93˚ 15′ E longitudes). The region has myriad freshwater ecosystems along with thick tropical vegetation which offer excellent habitats for amphibians and reptiles. Habitat loss is generally considered the most important cause of amphibian population decline [2]. Urbanization and other developmental activities have led to habitat fragmentation, degradation and loss along with pollution of natural habitats creating unsuitable conditions for the survival of herpetofaunal diversity. During a survey conducted in this region twelve species of anurans belonging to ten genera and six families where recorded [3,4] and twelve species of reptiles belonging to eleven genera and six families were identified. Another study recorded 23 species of anurans and 45 species of reptiles from the Barail Wildlife Sanctuary which borders the Barak Valley region in the north [5]. In 2004 the Barail hill range in the north of the valley was granted wildlife sanctuary status and it covers 326 sq km area. In still another record a Caecilian –

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*Gegeneophis fulleri (Alcock, 1904*) was reported from Kuttal (Kathal) in Cachar district by Taylor in 1968 [6].

## 2. STUDY AREA

The present study was carried out in Barak Valley Region of South Assam. It encompasses an area of 6992 sq. km. occupying about 9% of the total land area of Assam and has a population of over 30 lakhs. The valley, drained by river Barak and its tributaries, is bounded by the North Cachar Hills district of Assam and Jaintia Hills districts of Meghalaya in the North, Mizoram in the South, Manipur in the East and the state of Tripura and Sylhet district of Bangladesh in the West. This region abounds in freshwater systems including wetlands in the flood plains of River Barak and its tributaries, tanks and ponds of varying sizes, streams, pools, marshes and others. The hilly region has tea plantations and agriculture dominates the plains area. The primary vegetation is tropical semi -evergreen to moist evergreen forest. The secondary landscape includes cultivated flatlands, bamboo plantation, arecanut and betel vine plantation as well as village gardens. A large part of agricultural land is being converted into brick kilns in recent years due to more profitable source of income and lowlying lands are being used for residential construction as more urbanization is taking place.

## 3. MATERIAL AND METHODS

Visual sighting and counting was carried out. Hand collection was done and net was used for collection wherever necessary. Tadpoles and aquatic anuran adults were collected by dip net. For more terrestrial species the area was actively searched and visual inspection of various habitats was carried out during the day and night. Adults were caught by hand and flashlights were used during the nocturnal survey [7]. Tadpoles collected by using net were reared to adult stage and then identified.

During breeding season the call of the male anurans helped in tracing out the frogs/toads. The microhabitat of each species was noted. Adults were collected from paddy fields, marshy land, grassy meadows, heterogeneous areas having human habitations, wet and wastelands. Most of these sites were located in urban and rural areas while a few were inside forests. The dominant marginal vegetation included *Cynodon dactylon, Commelina benghalensis, Cyperus sp., Linderina crustacea, Enhydra fluctuans,* etc. The major species in the forests was *Artocarpus chaplasha* Some of the specimens collected were deposited at the Zoological Survey of India, Kolkata for identification and for preservation as voucher specimens while some were caught, identified and released back into its habitat for conservation purpose. Photographs were taken wherever possible.

## 3. RESULT S

The inventory of anuran and reptilian species of Barak Valley recorded during field surveys is presented in Table 1. During the survey twelve species of anuran amphibians belonging to ten genera and six families and twelve species of reptiles belonging to eleven genera and six families were collected and identified from various habitats of Barak Valley. The habitats of both types of herpetofauna and breeding seasons of the anurans were also identified.

Table 2 represents the herpetofauna of the region as reported by other workers.

The maximum and minimum air temperature, percent relative humidity and rainfall for 1997-2009 were collected from the Tea Research Association at Silcoorie Tea Estate, near Silchar, Cachar, Assam. The air temperature and percent relative humidity in the field was measured by using a thermohygrometer and water temperature was recorded with a mercury bulb thermometer. Figs 1-3 represent the annual rainfall, maximum and minimum temperatures and percent relative humidity for the region during the last ten years.

The region is undergoing urban development which is reflected in the form of road construction, conversion of meter gauge railway tract to broad gauge, construction of residential complexes, deforestation, earth cutting, increase in population accompanied by pollution, conversion of agricultural land into brick kilns, etc. The amphibian and reptilian fauna inhabits diverse habitats and water availability and moisture condition influences the selection of habitat. Anurans (frogs and toads) breed in ponds, lakes, marshy areas and ephemeral pools and hence dry periods affect the breeding process. Water quality and the structure of the vegetative community are seen to affect the survival of anurans.

During recent years the region is undergoing lot of Urban Development and the impact is seen in the form of :

1. Reclamation of ponds and wetlands and filling up these habitats for building of residential complexes. This has led to loss of breeding grounds of the amphibian fauna.
2. Excessive construction work is taking place and there is loss of the faunal diversity. Construction of roads and lying of railway tracts has depleted the habitat and degraded the habitat conditions. It has also led to fragmentation of the habitat and loss of good living conditions. Construction of the Maha Sadak from Silchar through the area adjacent to Borail Wildlife Sanctuary is having its impact on the wild fauna and flora. Earth cutting and deforestation are part of the process of development which is leading to habitat loss.
3. Road kill of amphibians and snakes have become very common. Vehicular traffic has increased many fold and slow moving amphibians and reptiles, like slow moving toads and snakes are killed by the speedily moving vehicles particularly during the breeding season.
4. Snakes are killed by people out of fear and lack of awareness regarding their utility in the ecosystem. People are unable to differentiate poisonous or non-poisonous snakes, hence resort to killing them.
5. Increase in urban population generates more amount of solid waste and their disposal creates pollution problems and degradation of the anuran breeding habitats.
6. Urbanization has impact on the land use pattern and during the past decades several agricultural land has been converted to brick kilns and this has severe impact on the herpetofaunal population.
7. Wetlands are very good habitats of the amphibians because of their diphasic life style but due to urbanization many wetlands are becoming silted and lost. Quality of the wetlands have degraded due to pollution. Scarcity of food of the amphibians like algae, detritus and insects etc. will also affect their survival.

Climate change and its impact: Another important change that the region is witnessing is changes in climatic conditions. Climate change is one of the most serious problems the human civilization is confronting in the recent years. Globally climate change is evident in the form of global warming, melting of glaciers, rise in sea level, unprecedented floods, drought or even cloud blast, increase in $CO_2$ concentration, rise in incidence of pests and pathogens and in incidence of diseases etc. Rainfall in the whole of Northeast India has always been adequate and some times more than the expected, creating devastating floods. The rainfall in NE India ranges between 2000mm to 3000mm [8] and the rainfall pattern in general reveals that 61 % of the rainfall is between June to September (Monsoon), 30 % is between March to May i.e. Premonsoon and 9 % is between October to February i.e. Post monsoon. However, recently erratic rainfall is being observed both in terms of frequency and occurrence, there is a rise in monsoon rainfall (June –Sept) and a decrease in the winter rainfall (Dec-Feb). The data on rainfall in the region shows peak rainfall of about 439mm-687mm in monsoon season and around 0mm rainfall in December. There is a declining trend of annual rainfall in the Barak Valley region (Fig.2) with more number of rainless days and scorching heat.

Rainfall, humidity and temperature are three major factors influencing the distribution of amphibians and reptiles globally. Breeding is influenced by all the factors and any change or alteration leads to disruption of anuran lifecycle. The pattern of rainfall in recent years has shown a change, with more spells of dry days and fewer days of heavy rainfall leading to drying up of shallower habitats. Flash floods have also become more common. Shallower habitats are the preferred breeding sites of most anurans. According to the South Assam Meteorological Subdivision (that covers the hills of Nagaland, Mizoram, Manipur and Tripura and parts of Borail Hills in South Assam) a significant change in seasonal rainfall has been observed. The summer monsoon rainfall is found to be decreasing over this region significantly during the last century, approximately 11mm per decade [9]. According to reports [8] rainfall in the region was scantiest in 2006 (considering data for a period of last 25 years) since 1982. The high diurnal temperature along with low rainfall leads to the drying up of temporary pools which are the preferred breeding sites of the anurans. The temperature and % relative humidity for 1997-2009 (Fig 2 and Fig 3) are both significantly high in the region.

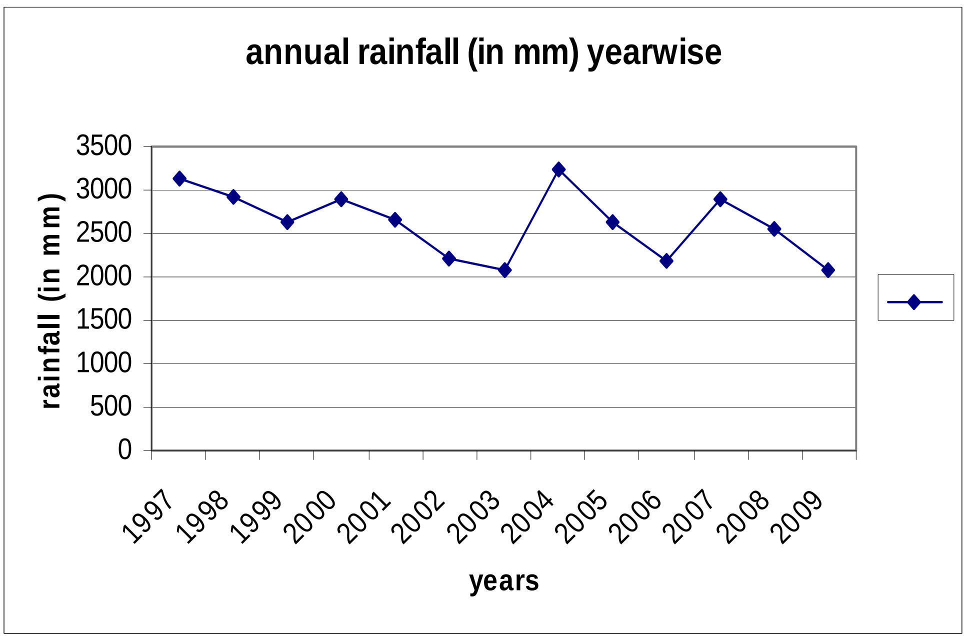


Fig 1. Annual rainfall (in mm) yearwise

Table 1: Inventory of herpetofauna from Barak Valley, India.

| S.No | Scientific Name and common name. | Order/Family | Habitat | Status |
|---|---|---|---|---|
| 1 | *Duttaphyrnus. melanostictus* (Schneider,1799) ZSI A 9092 9093 | Anuran, Bufonidae | Nocturnal, terrestrial, found near horticultural gardens, hillocks, near human dwelling | Abundant Common |
| 2 | *Euphylctis cyanophlyctis* (Schneider,1799) ZSI A 9076 9081 – 86 | Anuran, Dicroglossidae | Diurnal and nocturnal, all types of water bodies | Abundant Common |
| 3 | *Fejarvarya sp 1* *( F. limnocharis)* ZSI A 9087, 88 | Anuran, Dicroglossidae | Nocturnal, moist terrestrial areas, near ponds and in water logged paddy fields | Abundant, Common |
| 4 | *Fejarvarya sp 2* | Anuran , Dicroglossidae | Nocturnal, moist terrestrial areas, near ponds and in water logged paddy fields | Abundant Common |
| 5 | *Rana. taipehensis* ( Van Denburgh,1909) ZSI A 9090 | Anuran, Ranidae | Nocturnal, found in marshy areas among thick vegetation of water hyacinth (*Eichhornia crassipes*) | Rare in the region. (Legal protection WL(P)A,1972 Schedule IV)* |
| 6 | *Rana leptoglossa (Sylvirana leptoglossa)* (Cope,1868) | Anuran, Ranidae | Forest, mud walled well away from urban locality | Common (Legal protection WL(P)A,1972 Schedule IV)* |
| 7 | *Hoplobatraschus tigerinus* (Daudin,1803) ZSI A 9089 | Anuran, Dicroglossidae | Nocturnal, deep ditches, semiaquatic, mud wells, ditches and ponds, near paddy fields | Common (Legal protection WL(P)A,1972 Schedule IV CITES-AppendixII) * |
| 8 | *Microhyla ornata* (Dume´ril & Bibron,1841) ZSI A 9080, 9079 | Anuran, Microhylidae | Nocturnal, terrestrial habitat, on shrubs and small trees | Common |
| 9 | *Kaloula pulchra* (Gray,1831) ZSI A 9094 | Anuran, Microhylidae | Nocturnal, moist terrestrial habitat and man made water bodies in breeding season. It was caught from the terrace of a three storied building showing it is a good climber. | Common |

| | | | | |
|---|---|---|---|---|
| 10 | *Polypedates leucomystax* (Gravenhorst,1829) ZSI A 9091 | Anuran, Rhacophoridae | On trees, especially banana trees, near human settlements, marshy thick vegetated area, dense forest, creamy white in colour. | Abundant |
| 11 | *Leptobrachium smithi* ( Matsui, Nabhitabhata & Panha,1998) | Anuran, Megophyridae | Forest edge and near water bodies. | Rare, Uncommon |
| 12 | *Rana sp* | Anuran, Ranidae | Forest and near water bodies. | Rare |
| 13 | *Gecko gecko* (Linnaeus, 1758) (Tokay Gecko) | Reptile, Squamata, Gekkonidae | Inside university campus among vegetation and human habitation. | NE |
| 14 | *Calotis versicolor* (Daudin,1802) (Indian garden lizard) | Reptile , Squamata, Agamidae | Near human habitation and among shrubs and road side vegetation. | Common. NT |
| 15 | *Hamedactylus frenatus* (Dumeril and Bibron,1836) (Asian House Gecko) | Reptile; Squamata, Gekkonidae | human habitation | Common. NT |
| 16 | *Eutropis macularia* (Blyth,1853) (Bronze Grass Shink) | Reptile; Squamata, Scincidae | Inhabits forest and seen in human habitations. | Common LC |
| 17 | *Eutropis multifasciata* (Kuhl,1820) (Many- lined Grass Shink) | Reptile; Squamata, Scincidae | Forest, near wetlands, near human habitation and in plantations. | Common. NT |
| 18 | *Ahaetulla prasina* ( Shaw,1802) (Short-nosed Vine Snake) | Reptilia; Serpentes, Colubridae | Inside the university campus and in ecoforest. Caught and rescued from a construction site inside university campus.Found near human habitation. | Common,EN (Legal protection WL(P)A,1972 Schedule IV)* |
| 19 | *Psamodynastus pulvurentus* ( Boie,1827) (Common Mock viper) | Reptilia; Serpentes, Colubridae | Inside the university campus in the ecoforest.. | Common,VU (Legal protection WL(P)A,1972 Schedule IV)* |
| 20 | *Lycodon aulicus* (Linnaeus, 1758) (Common Wolf Snake) | Reptilia; Serpentes, Colubridae | In and around human habitation, forest edge. | Common,NT (Legal protection WL(P)A,1972 Schedule IV)* |
| 21 | *Ramphotyphlops braminus* (Daudin,1803) (Brahminy Blind Snake) | Reptilia; Serpentes, Typhlopidae | Usually found under logs, stones and rotten leaves. | Common.NT (Legal protection WL(P)A,1972 Schedule IV)* |
| *22* | *Xenochrophis piscator* (Schneider,1799) (Checkered Keelback) | Reptilia; Serpentes, Colubridae | Active during day and night. Inhabits ponds, drains and paddy fields. | Common.NT (Legal protection |

| | | | | |
|---|---|---|---|---|
| | | | | WL(P)A,1972 Schedule II)* |
| *23* | *Bungarus niger* (Wall,1908) (Greater Black Krait) | Reptilia; Serpentes, Elapidae | Forest, near wetlands, near human habitation and in plantations. | Rare (Legal protection WL(P)A,1972 Schedule IV)* |
| *24* | *Typhlops diardii* (Schlegel,1839) (Diard's Blind Snake) | Reptilia; Serpentes, Typhlopidae | Forest, Under leaf litter and rotten logs and near human habitation | Common. (Legal protection WL(P)A,1972 Schedule IV)* |

The terms abundant, common, rare, not evaluated (NE), near threateaned (NT) etc. refer to the observed status of the species in Barak Valley and do not refer to the IUCN criteria or terminology.

*As quoted by Das, *et.al* (2009)

Table 2: Record of herpetofauna of the region reported by other workers.

| Name of Species | Type | Location | Reported by |
|---|---|---|---|
| *Gegeneophis fulleri* | Caecilian | Kathal TE | Taylor,1968 (Source Dutta,1997) [6] |
| 23 anurans and 45 reptilian species | -- | Borail Wild life Sanctuary | Das, *et.al* 2009 [5] |
| 4 species of turtles | -- | Silchar | Das and Gupta,2004 [10] |

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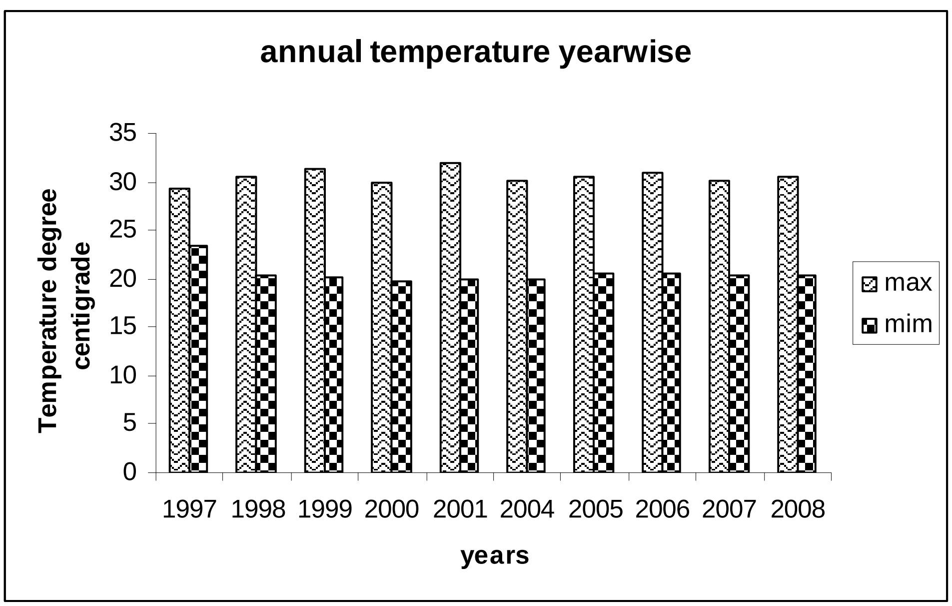


Fig.2 Average annual temperature (in º C) yearwise

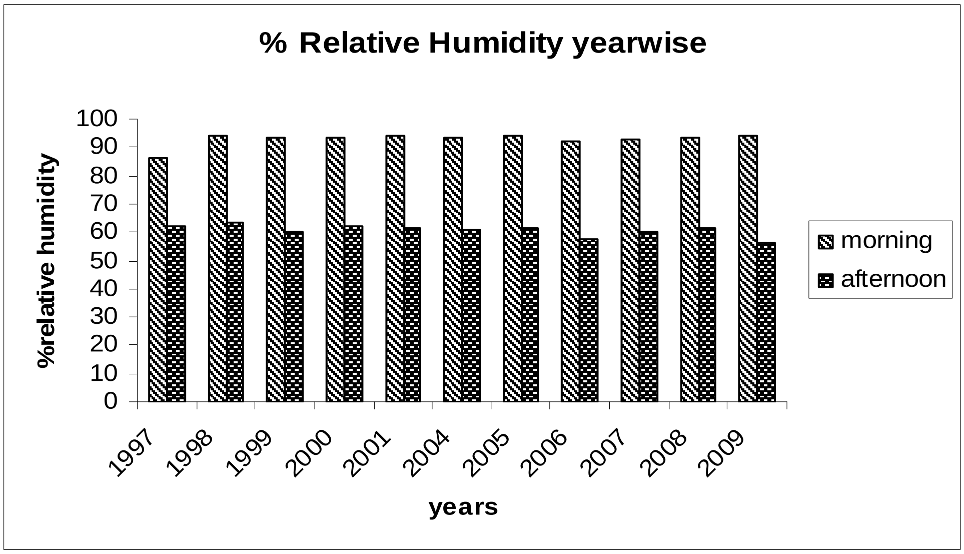


Fig 3. Average annual % relative humidity yearwise

**DISCUSSION**

The composition of herpetofaunal communities in an area is primarily controlled by water regimes, the quality of the water, and the structure of the vegetative community. A significant mention has been made of salt concentration in water by [11]. The breeding season varies in the different species but in general breeding coincided with advent of rainfall and cloudy, humid days. The preferred breeding sites were temporary aquatic habitats like small pools, ditches, tanks, and water logged paddy fields. It was seen that the breeding sites were not fixed and the anurans were found to be opportunistic breeders, selecting sites at random. Choice of breeding site is a very significant factor in the anuran life cycle and is seen to vary considerably. Large and permanent ponds bear the threat of predation and in this study also preference was seen for small water bodies. However, small and shallow water bodies have the risk of drying up which becomes more severe when rainfall occurs with long gaps. Predation, pool persistence and availability of resources in the breeding site influences breeding success. A close relationship between rainfall and breeding success in numerous species over a 16 year period has been documented [12]. Unpredictability of habitats, especially ephemeral pools and their short duration with sudden spells of long rainless days exert a strong pressure and desiccation is one of the major hazards for the anuran larvae in tropical climate [13,14]. Severity of winter is also increasing and winters are becoming rainless. Analysis of long term temperature data distinctly points towards a rise in surface air temperature and the annual mean max temperature is rising at the rate of +0.11°C per decade [8].

Winter rainfall has reduced and this may affect the breeding potential of *D.melanostictus* which breeds during winter months. Warmer and drier conditions affect not only reproduction but also food availability for both tadpoles and adults. Barak Valley region along with other parts of north eastern India have experienced drought like conditions in recent years [15,16]. Natural changes in moisture, such as wet or dry weather periods, can have significant effects on populations of certain species [17]. Changes such as wetland filling or draining, urbanization, and clear-cutting can significantly change the moisture regime, resulting in changes to the herpetofaunal community. A shift towards a drier environment would tend to reduce the number of wetland-dependent species such as

amphibians and increase the number of species able to withstand dry conditions, such as some lizards and snakes.
Shrinking of wetlands and water bodies has led to loss of habitat, breeding grounds as well as shortage of food. Loss of habitat due to reclamation of land for construction of residential houses has become a common feature in urban localities. *Rana taipehensis* has been reported from this valley from one site in Silchar in 1997 and 1998 but has not been seen since then. This locality has undergone rapid residential development and aquatic habitats have become the disposal site for domestic waste disposal. Ponds and ephemeral pools have been lost. Similarly a Caecilian-*Gegeneophis fulleri* was sighted and reported from Kuttal (probably Kathal tea estate) in Cachar district in 1968 but since then could not be located in this site nor in other part of Barak Valley. Due to various construction activites, herpetofauna specially the snakes, face the risk of being killed due to fear. In addition the pesticides used in tea gardens and agricultural fields flow into the burrow and aquatic bodies making it unsuitable for the survival. Turtles are sold for their meat and conservation measures are considerably poor.
Reptiles and especially amphibians have been used as indicators of change in habitats. Their reliance on moist areas, a limited home range, and the relatively long life spans of some species make them sensitive to changes in the hydroperiod of their habitats. Habitat fragmentation increases the likelihood of particular populations becoming extinct. Urbanization and development have become a necessity but has negative impact on biodiversity. Both reptiles and amphibians are important because of their position in food chain. Degradation and loss of habitat endanger this important group and so conservation strategies have to be appropriately designed.
To conserve herpetofauna in urban areas we need to maintain structural complexity in remnant habitat patches, and implement strategic policies and management actions that protect habitat remnants and habitat corridors. Afforestation programs have to be undertaken so as to make up the effect of deforestation. Construction of roads should involve adequate planning before implementation and execution so as to reduce the adverse impacts. However, all declines across the globe cannot be explained by changing weather patterns and prolonged study needs to be conducted. Long term study covering different aspects need to be undertaken to get a perfect idea about their population size, distribution and the present status so that proper management strategies may be formulated.

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# ENVIRONMENTAL AUDITING AS A MANAGEMENT TOOL FOR EFFECTIVE MANAGEMENT OF ORGANISATIONS

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## 1. ABSTRACT

Our environment is continuously interacting between its two components i.e., the living or biotic components and the non-living or abiotic components. Economic development is intricately linked to environment. During the last few decades, there has been tremendous economic growth and development. At the same time there has been social and ecological disruptions both in developed as well as in developing countries. Rapid industrialisation besides other economic and social factors are causing great harm to our environment. The concern for deteriorating environment is, however, reflected in the policies of Government of various countries and besides the Government a large number of Non-Governmental Organisations (NGOs) are involved in the process of environmental protection at global, national, regional and local levels. As many as 20,000 or more environmental NGOs in Europe and North America and some 2000 odd in India with quite a large number having popular support and considerable influences on the Governments of those areas are engaged in environmental protection. We are passing through a crucial transition period from the era of environmental neglect to the era of environmental concern. “The climatic uncertainties in sub-Saharan Africa are not unrelated to environmental neglect, and the time has certainly come to reverse that negligence. Environmental changes takes time, but coordinated public efforts in this field can make a difference in the long run” [1].

## 2. SUSTAINABLE DEVELOPMENT

The global concern for the steadily deteriorating state of the environment was first seriously manifested in the United Nations Conference on Human Environment, which was held at Stockholm in June 1972. It focused attention on the dangers posed to the quality of human life by continuous degradation of ecological assets and pollution due to industrial effluents. This conference led to the establishment of United Nations Environmental Programme (UNEP) and the creation of World Commission on Environment and Development in 1983 headed by Madam Brundtland, Prime Minister of Norway.

Economic development without environmental considerations can cause serious environmental damage in turn impairing the quality of life of present and future generations. The old concept of natural resources as plenty and abundantly available as free gift of nature is no longer valid. Natural Resources are not fixed assets. Natural resources are again not unlimited and proper steps must be taken for their replenishment. Moreover, global economic growth has brought a host of undesirable effects like Ozone depletion, global warming, water and soil contamination, air pollution, and deforestation and wastes disposal. The term sustainable development was brought to use by Brundtland Commission in 1987 which indicate “meeting the needs of the present generation without compromising the needs of future generations. The Earth Summit held at Rio de Janerio (Brazil) in June 1992 organised

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by the United Nations Conference on Environmental Development adopted a comprehensive 500 page agenda for the 21st century popularly known as ‘Agenda 21’. Agenda 21 contains a separate chapter devoted to business and industry.

Amongst the major environmental problems, soil erosion, land degradation, deforestation, over exploitation, loss of bio-diversity, atmosphere pollution, water pollution, problem of solid waste management, coastal & marine pollution are more important. And in most of the above cases industrial and business activities are directly responsible. Poverty and population are also responsible for environmental degradation. Business and industries being a part of the society and also directly or indirectly contributing towards environmental degradation cannot remain a silent spectator in such a situation.

## 3. ENVIRONMENTAL LEGISLATION IN INDIA

The growing concern for environment protection is also reflected in the governmental policy of India. The 42nd amendment to the Indian Constitution in 1976, Article 48A was added to the Directive Principles of State Policy and stated that “The State shall endeavour to protect and improve the environment and to safeguard the forests and wild-life of the country”. In the chapter of Fundamental Rights, Article 58(A) provides that “It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”. Moreover, the entries dealing with forests and wildlife were shifted from the State list to concurrent list.

Several pieces of legislation concerning environment were enacted before and after the aforesaid amendment to the constitution. The Major Acts in this regards are:

1. The Factories Act, 1948.
2. The Insecticides Act, 1968.
3. The Wildlife (Protection) Act, 1972.
4. The Water (Prevention and Control of Pollution) Act, 1974. as amended in 1988
5. The Forest (Conservation) Act, 1980.
6. The Motor Vehicles Act, 1939 as amended in 1988
7. The Public Liability Insurance Act, 1991.
8. The Hazardous Waste (Management and Handling) Rules, 1989.
9. The Air (Prevention and Control of Pollution) Act, 1981.
10. The Environment (Protection) Act, 1986.

Attempts are also being made to amend the Indian Companies Act, 1956 to incorporate a statement on Environment to be prepared and included in the Annual Report of the Companies.

The Government of India’s concern for environment is also manifested in recent years in various forums and documents. The Economic Survey 1998-99 has outlined sustainable development as a major economic issue of the environmental policy of the Government of India. The document under the caption “Promoting Sustainable Development, Challenges for Environment Policy” contained 15 specific policy issues on environmental aspects.

## 4. CORPORATE ENVIRONMENT MANAGEMENT

Realising the importance of the sustainable development and management as a long term of global strategy, the corporate houses are expressing their concern in environment management in the organisation. A new area has thus emerged in management popularly known as Corporate Environment Management. The scope of the corporate environment management are:

1. Environmental Impact Assessment
2. Environmental Risk Management
3. Environmental Accounting
4. Compliance of Environmental Legislation
5. Environmental Auditing and
6. Environmental Reporting.

The present paper highlights the different dimensions of Environmental Auditing for sustainable environment management in organisations.

## 5. ENVIRONMENTAL AUDIT DEFINED

We are familiar with the term 'audit' in the sense of examination of financial accounts and records. Environmental Audit (EA) on the other hand refers to verification and assessment of environmental measures in an organisation. Some of the important definitions of Environmental Audit are highlighted here under :

"A management tool comprising a systematic documented, periodic and objective evaluation of the performance of the organisation, management and equipment designed to protect the environment with the aim of:

- Facilitating management control of environmental practices
- Assessing compliance with company policies, including observance of the existing regulatory requirements" (Commission of the European Community's Eco-Management and Audit Regulation)

"A systematic examination of performance to ensure compliance with requirements during the operational phase of industrial activity including the following components viz. full management commitment, audit team objectivity, professional competence, well defined and systematic approach, written reports, quality assurance, follow up (International Chamber of Commerce – Position paper on environmental auditing adopted November 29, 1989).

Environmental auditing is a systematic multidisciplinary method used periodically to assess the environmental performance of a project. In macro sense environmental auditing may be used to assess the performance in the areas of agriculture, forestry, wild life, soil, management of pollution, powers, mineral resources, population and urbanization etc Effective environmental auditing can lead to higher levels of overall compliance and reduced risk to human health and environment. Auditing serves as a quality assurance checks to help improve the effectiveness of basic environmental management by verifying that management practices are in place, functioning and adequate. Audits do not in any way replace regulatory agency inspections.

In micro sense, it refers to organizational environmental performance and hence most of the literature on the subject is used in this sense.

Environmental Auditing as it stands today involves a) monitoring of Environmental management system of the industry, b) checking the status of consent orders c) compliance against consent orders d) water Cess, e) other necessary legal documents etc. f) Industrial data collection regarding product, process, electric consumption, water consumption, raw material to prepare material and energy balances. The present paper, discusses how environmental audit is useful in effective management of organizations.

## 6. OBJECTIVES

The objectives of the present paper is to highlight the importance of Environmental Audit and to review the status of Environmental Audit practices in India.

The paper has been prepared on the basis of secondary data.

**The objectives of Environmental Audit** are:

1. To examine the compliance of environmental norms of the regulatory bodies.
2. To assess and verify the environmental compliance with the corporate requirements.
3. Evaluation and Reporting of key environmental performance like pollution control measures, waste management etc.
4. Ensuring quality improvement in every sphere of corporate life.
5. To minimise wastage, losses and thereby resulting in cost reduction.
6. To generate awareness and consciousness about environmental issues amongst all level of employees in the organisation.
7. To examine the efficient utilisation of materials and reduction in consumption on energy and above all developing a basis for utilising environmental resources.
8. To protect the corporation from potential liabilities [2].

## 7. SCOPE OF ENVIRONMENTAL AUDIT

The concept of environmental audit has wide scope covering the principal areas such as :

1) Material Audit
2) Energy Audit
3) Ground Water Audit
4) Air Pollution Audit
5) Solid Waste Management Audit
6) Liquid Sediment and Sludge Audit
7) Noise decibel levels audit
8) Health of workers audit
9) Health of communities audit
10) Effects of animals and plants species audit
11) Engineering audit
12) Soil quality audit
13) Chemicals discharged and their toxicity audit etc.
14) Surface Water Audit
15) Compliance audit

## 8. STAGES IN ENVIRONMENTAL AUDITING

Mainly there are three stages in Environmental Auditing :

1. **Pre-audit activities**-Planning and Preparations for Environmental Audit such as imparting education, review of organisational background information, composition of audit team, time frame and preparing the questionnaire.

2. **On-site activities** such as interviewing the site personnels, inspecting the site, operations and equipments, collecting data relating to air quality, water quality, materials usages, safety measures etc.

3. **Post-audit activities** such as identifying and evaluating waste reduction option, determination of potential solution, preparing the audit report, assigning responsibility for corrective measures etc.

## 9. ENVIRONMENTAL AUDIT –AS A MANAGEMENT TOOL

i Management is assured of compliance with environmental regulations, standards etc.and thereby reduces the chances of potential legal action from law enforcing agencies.

ii. Facilitates the development of environmental management systems and improvement in environmental performance leading to improved managerial efficiency.

iii. Increases management and employee awareness of environmental issues.

iv. Increases sharing of information.

v. Reduces the potential for liability with potential.

vi. Cost savings and improved efficiency.

vii. Promotes "Good Practice".

viii. Providing better PR and Public Image and "Security" to Top Management.

## 10. ENVIRONMENTAL AUDIT PRACTICE IN INDIA

The development of Environmental Audit can be traced back to early 1970s. Oil spill off the British South Coast, Bhopal gas leak, Chernobyl disaster (1986), pollution of various rivers etc. has led to increased concern in industrial Environment Management. The United States Environmental Protection Agency published their environmental audit policy in 1986 followed by International Chamber of Commerce booklet on Environmental Auditing (1988), UNEP published their technical report on EA (1990), British Standards Institute published BS 7750 specifications for Environmental Management System (1992). The Environmental Protection Agency (EPA) of USA has actively encouraged and participated in the development of environmental auditing and improved environmental management practices since mid 1980s.

The auditing standards of ISO-14000 series provide general principles for environmental audits, guidelines for auditing environmental management systems (EMSs) and qualification criteria for environmental auditors. The environmental audit is viewed as a critical component of an effective EMS and it will need to be performed on a regular basis to measure the conformance of an EMS to an organisation's environmental policy.

The ISO 14000 series consists of the following documents:

14001: Environmental Management System Specification
14004: General Guidelines on Systems, Principles and Supporting Techniques.
14010: General Principles on Environmental Auditing.
14011: Auditing of Environmental Management Systems.
14012: Qualification Criteria for Environmental Auditors.
14013: Management of Environmental Audit Programs.
14014: Initial Reviews.

14015: Environmental Site Assessments.
14021: Environmental Labeling Series.
14031: Evaluation of Environmental Performance.
14041: Life Cycle Assessment Series.
14050: Terms and Definitions.
14060: Guide for the Inclusion of Environmental Aspects in Product Standards.

Of late, ISO 19000 family is under preparation ISO 19011:2002 provides guidance on the principles of auditing, managing audit programmes, conducting quality management system audits and environmental management system audits, as well as guidance on the competence of quality and environmental management system auditors. ISO 19000 also provides for detailed guidelines for Audit team formation with persons of sufficient expertise in activities to be audited and environmental legislation. It is applicable to all organizations needing to conduct internal or external audits of quality and/or environmental management systems or to manage an audit programme.

ISO-14000 is a methodology for environmental management. It provides necessary requirements and recommendations for any organisation to develop and implement a cost effective system of management by introducing environmental auditing. ISO-14000 series covers environmental audit, audit procedure, auditor criteria, audit management and environmental reviews, site assessment, labeling performance evaluations and life cycle analysis. Hence, ISO-14000 is a concerted international attempt to improve the quality of life with minimum effect on the environment to transform with minimum alteration and distortion.

In India, recognising the importance of EA, procedure for EA was first notified under the Environment (Protection) Act, 1986 by the Ministry of Environment of Forests (vide their notification No. GSR 329(E) on 13$^{th}$ March, 1992). Under this every person carrying on an industry, operation or process requiring consent under section 25 of the Water (Prevention and Control of Pollution) Act, 1974 or under section 21 of the Air (Prevention and Control of Pollution) Act, 1981 or both or authorisation under the Hazardous Wastes (Management and Handling) Rule of 1989 issued under the Environment (Protection) Act, 1986 is required to submit environment audit report. The Environmental Audit has been renamed as Environmental Statement (ES) in 1993. The statement is required to be submitted to the concerned Pollution Control Boards. The prescribed proforma has nine parts (Part A to Part I). The economic survey (1998-99) indicated the mandatory submission of annual environmental statement which could be extended into environmental audit amongst others as an environmental policy of the Govt. of India.

The Environmental Statement should not be treated as a substitute for EA. The ES may be considered as a database for EA. The analysis of the data and necessary suggestions for improvement in the environment and efficiency is not outlined in the ES. Most of the developed countries like USA, UK, Canada, California, Commonwealth Australia has already taken up EA for their corporate sector. In India we are yet to popularise EA in our corporate sector. As of now, any disclosures on the environmental matters in the Annual Report of an Indian Company voluntary in nature. According to a study [3] on 144 Indian companies 50% and 22.2% companies in public and private sector respectively disclosed information on their environmental impact through their Annual Reports. Moreover, the practice of preparing stand alone environmental reports is yet to take roots in India. EA is conducted by a very limited number of companies in India.

Good Corporate Governance includes socially responsible business practices. A socially responsible approach to business would involve sensitivity to social, environmental and ethical issues by corporate entities. The high levels of public accountability attached to Public Sector Undertakings (PSUs) as a result of their public ownership makes socially responsible reporting by PSUs particularly important. The issue relating to social obligations of Central Public Enterprises was examined by the Committee on Public Undertakings (COPU) in 1992. It was stated by COPU that “Being part of the ‘State’, every public undertaking has a moral responsibility to play an active role in discharging the social obligations endowed on a welfare state, subject to the financial health of the enterprise." Based on the recommendations of COPU, Department of Public Enterprises (DPE) issued general guidelines in November, 1994. These guidelines basically left it to the Boards of Directors of the PSUs to devise socially responsible business practices in accordance with their Articles of Association, under the general guidance of their respective administrative Ministry/Department. A limited survey of socially responsible reporting by central PSUs in India was conducted by audit in 2006-07 and it was seen that central PSUs were yet to adopt a systematic approach towards socially responsible reporting.

Environmental auditing is an area of specialised auditing. The Comptroller and Auditor General of India is in the process of establishing an international centre which would provide training on environment audit and conduct research on environmental issues and sustainable development.

Earlier the CAG report 'Management of Waste' had raised questions about flawed waste policy in India directed only at waste disposal and ignored waste recycling and waste re-use. CAG had recommended incorporating recycling and re-use in waste management strategies.

As per recently published guidelines on auditing on environment and climate change by CAG, areas such as biological diversity including forests and forest management, wetlands and mangroves, air pollution, water pollution, waste management, climate change and coastal zone management would be covered

## 11. SOME SUGGESTIONS

In order to popularise environmental auditing in India, to serve as management tool for effective corporate management some suggestions are offered as follows:

1. As a first step environmental reporting by Indian corporate sector should be made mandatory as a part of corporate Social Reporting. The proposal of requiring disclosure about particulars of compliance with environment laws, steps taken or proposed to be taken towards adoption of clean technologies for prevention of pollution, waste minimisation, waste recycling and utilisation, pollution control measures, investment on waste reduction, water and other resources conservation etc. should be materialised. Environmental reporting should be published as a part of Annual Report of Companies.
2. Considering the complexities and expertise involved in environmental audit, doubts have been expressed regarding the involvement of accountants and accounting profession in such audit. Audit team should comprise of professionals drawn from different areas as mentioned earlier and Indian Association for Environment Management (IAEM) and National Environmental Engineering Research Institute (NEERI) can play a very positive role in this regard. An institution of environmental auditors may be founded by professionals interested and adequately experienced in the techniques employed in environmental audit [4].
3. The communication gap between the public and the industries can be minimised by publishing environmental audit report. The wrong notion of public that industries are the major pollutants can be minimized if industries are transparent in this regard.
4. Efficiency or inefficiency of the various departments of a unit can also be judged by environment audit and incentives should provided to the efficient departments and penalising the inefficient one.
5. The savings in money because of the measures undertaken on the basis of environment audit report should be invested for better environment management.

6. Environmental audit should be included in the curricula for Production Management, Industrial Management, Environmental Engineering and also in commerce and Business Administration.
7. In major polluting industries, Environmental Audit should be made compulsory and phase wise, this should be extended to other industries, if not annually, at least in every two to three years.
8. The form V of the environmental statement notification needs to be modified.
9. The Environmental Statement should continue to be submitted to the state PCBs and they may also be made available for public.

## 12. CONCLUSION

"There is a saying that a witness can't be more active than plaintiff. In the matter of environmental audit, the society may demand, government may exert pressure, the academic and research institutions may assist, and the professional may be ready to serve, but environmental audit will go into practice only when corporate management appreciates the role of environmental audit as a management tool" [4].

Inaugurating a training programme on pollution control in the distillery industry in August 1993, Mr. Kamal Nath, the then Minister for Environment and Forests [1993] observed that "environmental auditing is a strong management tool and should be used by industry for their own self-assessment". He also exhorted the industry to resort to transparent environmental auditing which ought to be subjected to monitoring and public scrutiny (Hindustan Times, 5.8.93). Increasing awareness for environment should be translated into reality by practising environmental audit by the Indian corporate sector and thereby making the next millennium green millennium.

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# LONGSHORE CURRENT ESTIMATION USING REMOTE SENSING DATA SET

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## ABSTRACT

Longshore current field induced by wave breaking is analyzed using ETM+/LANDSAT and ASTER/TERRA remote sensing data. Sattelites LANDSAT and TERRA fly on the same orbit with an interval of approximately 30 minutes; i.e. LANDSAT gets the first image and ASTER the second after half an hour. Suspended solids (SS) at water surface move along the coast during this period, and a similar method to particle image velocimetry (PIV) was applied to estimate the migration speeds of the SS clouds. The estimation was verified with wave refraction computation showing correlation partially with wave ray spacing and angle in the shallow water.

**Key Words:** Longshore current; LANDSAT; ASTER; image analysis; refraction; longshore wave energy flux.

## 1. INTRODUCTION

It is widely accepted that longshore current is responsible for diffusion of substances along the shore, which is driven by oblique wave breaking. Local imbalances in current field and sediment flux result erosion and deposition of longshore sediments accompanied with re- and processions of shoreline positions.

Longshore currents are usually measured by deploying current meters in the field, which is laborious and expensive work. Current meters provide accurate records at the stations, however, number of the deployment is mostly limited and to gather a detailed understanding of spatial structure of the field is not easy. Remote sensing techniques provide a feasible alternative since they allow sampling over large spatial extents and temporal scales.

This work shows the use of pair of remote sensing data to assess distribution of longshore current over a stretch of approximately 30 km along northern Kashima Coast, Japan. Image data captured by sensors ETM+ on satellite LANDSAT (NASA, [4]) and ASTER (ERSDAC, [3]) on satellite TERRA are used. LANDSAT and TERRA fly on the same orbit, so called formation flying, with an interval of approximately 30 minutes; i.e. LANDSAT gets the first image and ASTER the second after half an hour. Suspended solids (SS) on the water surface move along the coast during this period. A method similar to particle image velocimetry (PIV) was applied to brightness data of the images to estimate the migration speeds of the SS clouds. The estimation was verified then with wave refraction computation.

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## 2. NORTHERN KASHIMA COAST

The study area of this research, shown in Fig. 1, is the northern part of the Kashima Coast, Ibaraki, Japan, facing Pacific Ocean and stretching from north to south. The image in the figure is processed from ASTER data (green) which will be explained later.

Kashima Coast is located on a shelf whose edge in this area is at a depth of 160 to 170 m and the width is approximately 25 km. The well-developed sandy shorelines of these coasts had been preserved as nearly natural until the early 1960s. The construction of the Kashima industrial port, approximately 80 km east of Tokyo, began in the late 1960s on the nearly middle part of Kashima Coast. With the completion of Kashima Port in the beginning of the 1970s, the Kashima Coast was divided into 38 km-long northern and 15 km-long southern parts with respect to littoral sediments since the main breakwater of the port extends to a depth of 20 m.

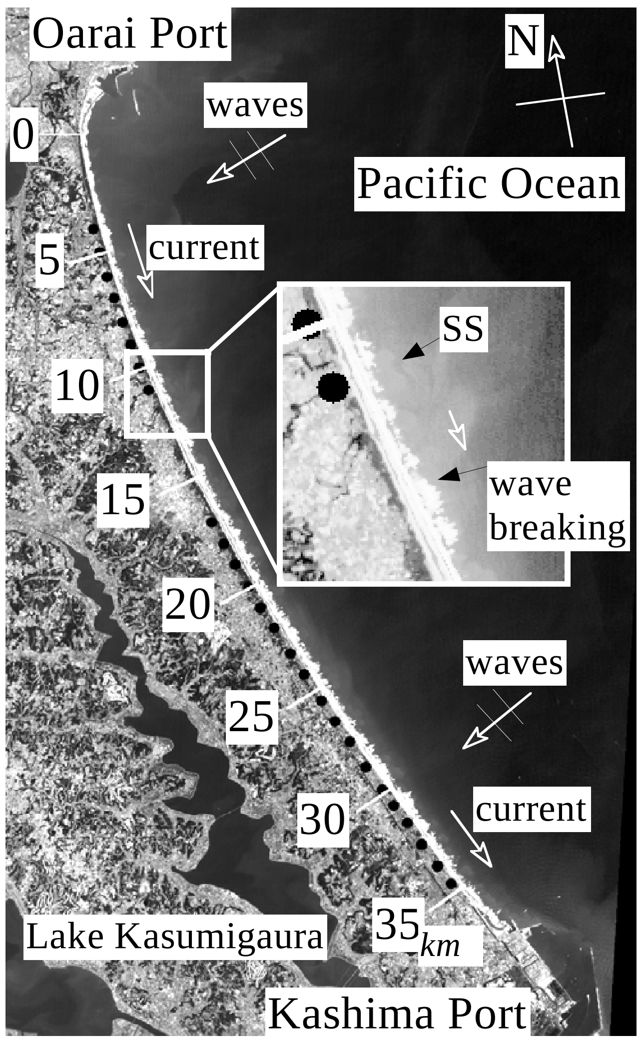


Figure 1 Area of interest: northern Kashima Coast, Japan. Digits denote longshore distance used in the study. Black dots indicate the location of the artificial headlands (HL). The image is processed from green band of ASTER data.

Table-1 Data specification (Observation date: 2001 March 16)

| Satellite<br>Sensor<br>Product | LANDSAT<br>ETM+<br>Level 1G | TERRA<br>ASTER-VNIR<br>ASTL1B |
|---|---|---|
| Local observation time (JST) | 10:06:06 | 10:43:21 |
| Spatial resolution | 28.5 *m* | 15 *m* |
| Wave length<br>(Band: Green) | 0.53 – 0.61 $\mu m$ | 0.52 – 0.60 $\mu m$ |
| Wave length<br>(Band: Red) | 0.63 – 0.69 $\mu m$ | 0.63 – 0.69 $\mu m$ |
| Wave length<br>(Band: Near infrared) | 0.75 – 0.90 $\mu m$ | 0.76 – 0.86 $\mu m$ |

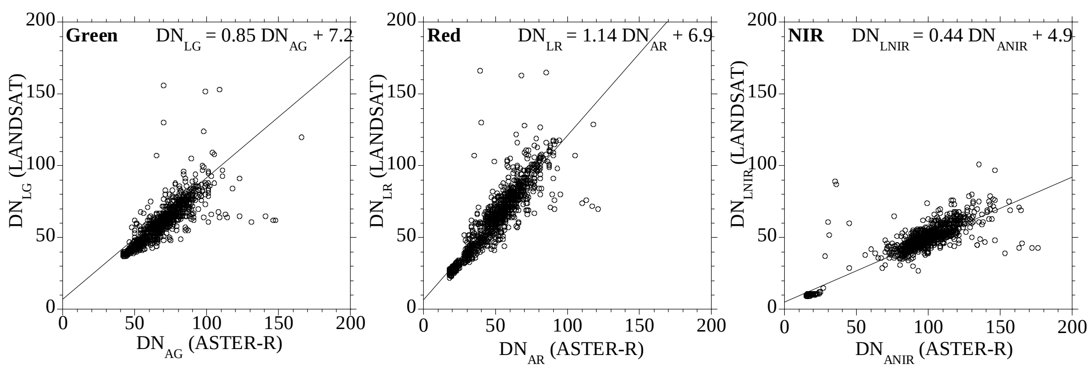


Figure 2 Comparisons of brightness data of green, red and infrared bands observed by ETM+/LANDSAT and ASTER-R/TERRA. DN is abbreviation for Digital Number which represents radiant intensities of the satellite observation.

Coastal erosion has been a serious problem since the 1980s. Oarai Port at the north was extended in the 1980s and trapped sediments in its vicinities. To protect and to stabilize the coast, the construction of artificial headlands (hereafter abbreviated as HL), jetty-like rubble mound structures extending approximately 180 m to the offshore, was begun in 1985 along the coast at intervals of approximately 1 km. Twenty six of them had been completed by 2001 shown in Fig. 1 with solid circles.

## 3. SATTELITE DATA

Satellites LANDSAT and TERRA orbit the earth along the same path with an interval of approximately 30 minutes. This operation is called formation flying, which allows use of data for various scientific purposes. The altitude of the orbit is 710 km which has a return period of 16 days in average.

Sensors ETM+ (on LANDSAT) and ASTER (on TERRA) share several observational wave lengths in visible and infrared bands as shown in Table 1. Since the spatial resolutions of the sensors are different, ASTER data (spatial resolution: 15 m) were resized to the resolution of ETM+ (28.5 m) by nearest neighbor method which will be

Table-2 Wave data measured at offshore of Port of Kashima
2001 March 16, 10h (JST)

| | |
|---|---|
| Significant wave height $H_{1/3}$ | 2 $m$ |
| Significant wave period $T_{1/3}$ | 9 $s$ |
| Mean wave direction $\alpha$ | 63 deg.<br>(incident from ENE) |

referred as ASTER-R hereafter. After this resizing, position of the images was matched using landmarks like corner of artificial structures, roads, water lines etc.

Figure 2 is the comparisons of brightness data observed by the two sensors which showing good linear relationships. Since the analyses in the work described later on are based on correlation analyses, differences in mean of the brightness distribution doesn't affect the results, and therefore no further data processing have been done like atmospheric correction. In the followings, brightness data along coast lines are analyzed to estimate the longshore current speed.

## 4. ESTIMATION OF LONGSHORE CURRENT

### 4.1 Image interpretation

Wave data measured offshore of Port of Kashima is shown in Table 2. Waves were obliquely incident to the shore, which should have driven longshore current to the south. The wave condition was almost calm for this area. Followings are the interpretation results of the set of pseudo-color displayed images of ETM+ and ASTER-R data:

i) Foams were observed close to the HLs, which should have vanished in the next 30 minutes,
ii) Clouds of SS in the offshore of the bright breaker zone migrated to the south,
iii) SS clouds distributed almost regularly along the coast with intervals of several 100 m,
iv) Green data were most suitable to trace the migration of SS clouds. In the next, green data was processed to estimate the longshore current.

### 4.2 Data processing

A baseline was set along the coast by connecting the locations of the tip of HLs, which is shown in Fig. 1 with distance ticks. Since the HLs were entirely immersed in the breaker zone, longshore baseline is not visible in the figure. Another 10 lines parallel to the base line were set in the offshore of the baseline from 430 m to 680 m apart.

Figure 3 shows the distributions of breaker intensities along the base line, beach slopes in the breaker zone estimated from survey data and locations of the HLs. Breaker zone appears as bright areas in the images and breaker intensities were estimated from the pixel intensities between the base line and parallel lines described above. Variation of the breaker intensity suggests that the wave heights and corresponding wave energies had an uneven distribution along the coast.

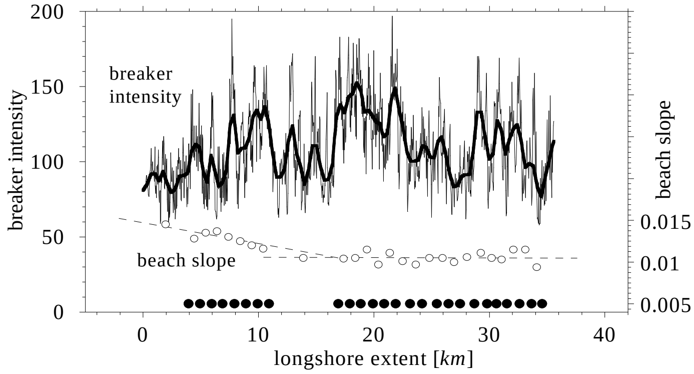


Figure 3 Longshore distributions of breaker intensity, beach slope (open circle) and locations of the headlands (solid circle).

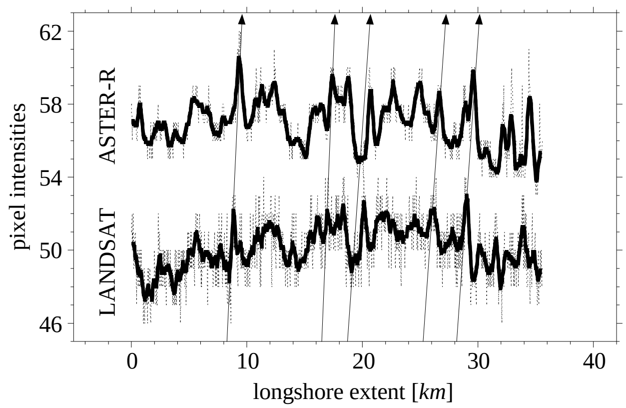


Figure 4 Longshore distributions of pixel intensities of green data along the line 570 m offshore. Oblique arrows indicate migrations of characteristic points tracked manually.

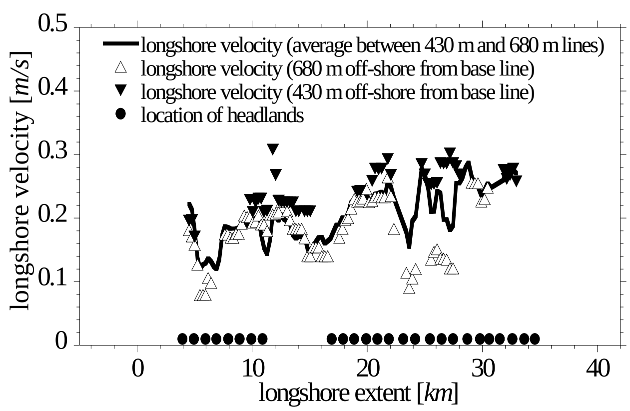


Figure 5 Distributions of longshore velocities (solid line, open and solid triangle) and locations of the headlands (solid circle).

The main interest is to know the longshore velocities in the breaker zone, however, the breaker zone is brightly saturated and we try here to estimate the velocities outside this zone. Figure 4 shows the distributions of brightness data of green band extracted along

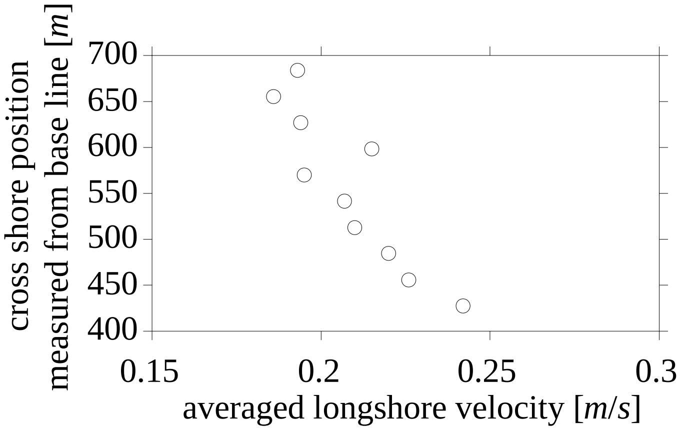


Figure 6 Cross shore distribution of longshore velocity averaged in the longshore.

the line which is 570 m offshore from the baseline. The display shows original data and their moving averages. The wavy variations in the intensity distribution correspond to the patchy SS clouds, which has wavelengths of several hundred meters. Oblique arrows indicate the migrations of characteristic points in the wavy distributions tracked manually. The figure suggests local movements of the SS clouds can be assessed by analyzing the set of brightness data distribution.

Cross correlation analyses were applied to the set of brightness distributions to estimate local migration speeds of SS clouds. Length of local templates were set to 2,580 m. Local velocity was determined from the distance which gave maximum correlation, and time interval of the data acquisitions, 38 minutes 15 seconds. Estimations were approved when the correlation factor exceeded 0.7. The analysis described here is kind of PIV which fixes the flow direction a priori.

Figure 5 shows the result of velocities estimated with the method described above. The velocities fluctuate between 0.1 m/s and 0.3 m/s with wave lengths of several kilometers which is generally consistent with the breaker intensity distribution shown in Fig. 3. The overall distribution of the velocity is increasing from north with local fluctuation in lengths of several kilometers overlapped. The estimated velocities are larger for the line closer to the baseline (at 430 m, solid triangle) compared to that of further offshore (at 680 m, open triangle) which is a reasonable result. The results shown here are for the section from the edge of the breaker zone to the offshore zone and we may expect therefore a stronger current was in the surf zone. There is no obvious flow retardation in the regions protected with HLs and dependence on the bottom slope.

Cross shore distribution of velocities averaged in the longshore for the whole area is displayed in Figure 6. The velocities become smaller in the offshore region, which is quite reasonable and implies a maximum should exist in the breaker zone. The distribution shown here is a part of cross shore distribution of longshore current field.

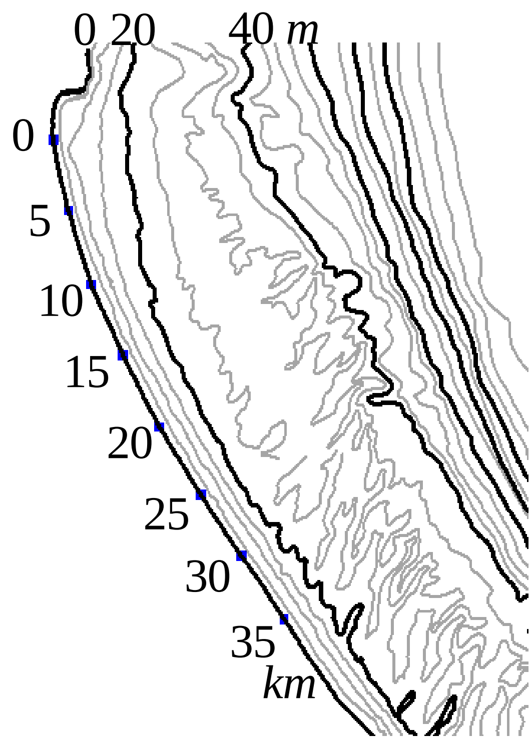


Figure 7 Bathymetry of the northern Kashima Coast.

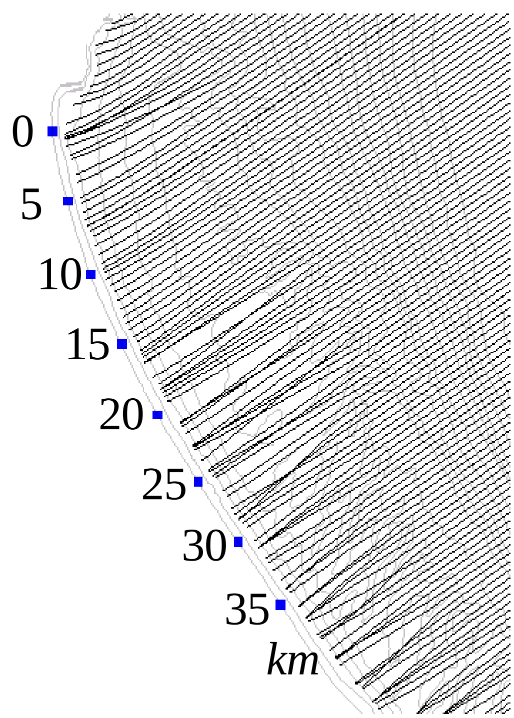


Figure 8 Wave rays.

### 4.3 Refraction computation

Simple wave refraction computation (Dean and Dalrymple, 1991, [2]) was done to know the wave field close to the breaker zone. Deformation of wave rays from the deep to

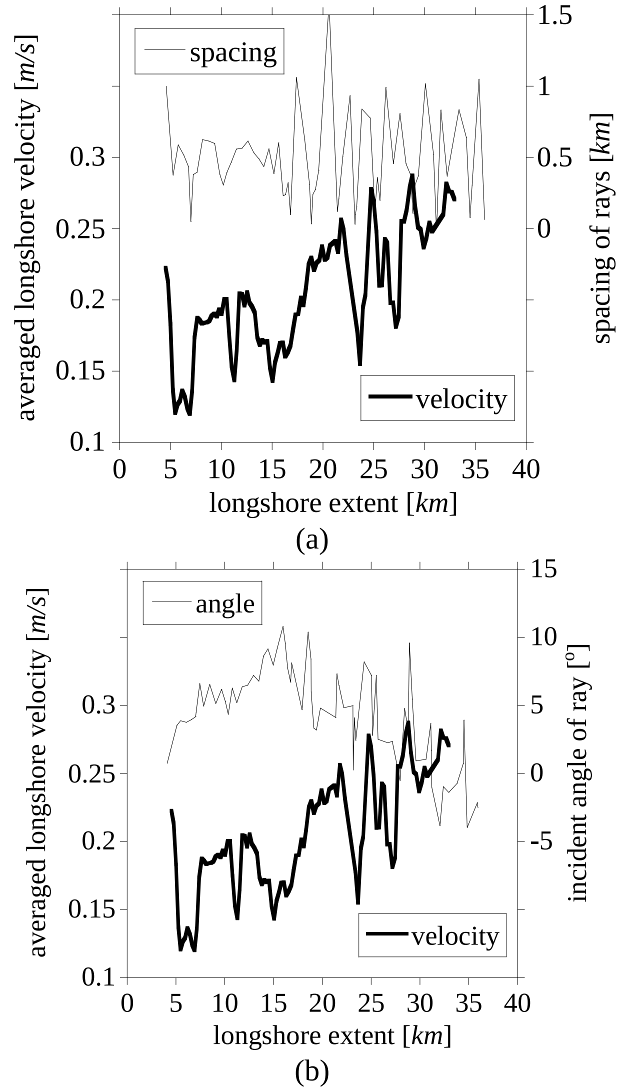


Figure 9 Distributions of longshore current and wave ray spacing and angle.

shallow water was computed which gives wave angles and amplification rates at the breaker zone. Refraction computation has the problem of ray crossing; however, it gives clear insight to the wave field showing convergence and divergence of the waves and corresponding wave energy distribution. Since the velocity estimation from the satellite remote sensing data provides a macroscopic view of the current field, a qualitative refraction computation matches well for that purpose and a more sophisticated phase averaged model like SWAN (Booij et al, 1999, [1]) is not necessary.

Figure 7 shows the bathymetry of the area with the depth contours at intervals of 5 m. The bathymetric data show that the deeper areas are characterized by relatively smooth and concave contours, while the contours of the shallower areas, in the depths from 30 m to 20 m, are characterized by the presence of many ridges which may affect the wave propagation. Angles between the ridge crests and the coastline directions are 50 to 70 degrees. Ridge intervals are approximately 2 km, ranging from 1 to 3 km, and ridge height is 6 to 10 m.

Refraction computation was done with following steps: First, a backwards propagation computation to the offshore was done from the location of wave station of Port of Kashima to determine the offshore wave direction at the deep water. Then, forward wave ray computations started from the offshore with wave ray spacing of 500 m. Computations were terminated when the ray reached at depth of 6 m.

Figure 8 displays the computed wave rays. Some rays cross with the neighboring ray, which is a limitation of wave ray computation. Offshore ridges within the shallow water area are causing wave ray convergences and divergences with intervals of 2 to 3 kilometers.

Figure 9 shows wave ray spacing, local wave propagation direction relative to the shore (normal incidence = 0 degree, wave incidence from the northern: positive) at depth of 6 m and the longshore velocity. Reduction in ray spacing is an indicator of local wave amplifications: At some locations, longshore velocity shows local acceleration where spacing becomes smaller. The incident wave angle is increasing from 5 to 15 km and decreasing for the rest of the area. The macroscopic distribution of longshore velocity is increasing from north to south: The increase of the northern half can be explained from the increase of the incident wave angle. To explain consistently the increase of the remaining part, however, is difficult and needs further consideration.

## 5. CONCLUDING REMARKS

A pair of remote sensing data was analyzed to assess distribution of longshore current over a stretch of approximately 30 km along northern Kashima Coast, Japan. Image data captured by sensors ETM+ on satellite LANDSAT (NASA) and ASTER (ERSDAC) on satellite TERRA are used. LANDSAT and TERRA fly on the same orbit, so called formation flying, with an interval of approximately 30 minutes, where LANDSAT gets the first image and ASTER the second after half an hour. SS on the water surface moved along the coast during the imaging. A PIV-like method was applied to the distribution of brightness data to estimate the migration speeds of the SS clouds. The distribution of the estimated velocity showed a macroscopic increase over the area with local fluctuation of several kilometers. The estimation was verified then with wave refraction computation: Local fluctuations may be explained from the local wave amplifications, however, the macroscopic increase could be explained partially from the distribution of incident wave angles.

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# CLIMATOLOGICAL CHARACTERISTICS OF PRE-MONSOON RAINFALL AND ASSOCIATED WITH ATMOSPHERIC CIRCULATIONS IN BANGLADESH

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## ABSTRACT

The Climatological Characteristics of monsoon rainfall is very important parameter. In order to describing monsoon circulation, the climatological characteristics of heavy monsoon rainfall, onset and withdrawal phases in Bangladesh are examined using pentad 5-day mean annual cycle of monsoon rainfall data between 1948-2008. Pre-monsoon rainfall is very interesting rainfall phenomena, which is occurs over the northeaster part of Bangladesh in April. The result implies that the climatological pre-monsoon onset and summer rainy season is early around the northeast region at Sylhet station in pentad 24 (April 26-30). The mean annual total precipitation at Sylhet was the highest in Bangladesh. The amount of rainfall is found to be 3963.0 mm. The withdrawal of summer rainy season is delay around northeast region at Sylhet station in pentad 57 (October 8-12). The pre-monsoon period, rainfall found significantly low, but during monsoon, amount of rainfall is extremely high around southeast region at Teknaf station. The Teknaf is second highest rainfall station, the amount of rainfall was found to be 3884.5 mm. The withdrawal of summer rainy season is early around southeast region at Teknaf station, on 25th September, pentad 54 (September 23-27).

The monitoring of trace species such as the horizontal wind 850hPa, column total of vapor flux and precipitable water is of great significance for understanding the atmospheric circulation. This study examined the 5-day mean values: of [1] the horizontal wind at 850hPa, [2] the column total of vapour flux, and [3] the precipitable water. The Japanese 25-year re-analysis data from 1979 to 2003 was used. During the pre-monsoon, the horizontal wind speed, the vapour flux, and precipitable water were found to greatly increase in value. In contrast, during the post-monsoon period the values eventually decreased.

Large water vapor area and maximum wind zone is observed both side of equator roughly around EQ-10°N and 70-105°E in middle of April. This result implies that April is the most favorable month for increasing pre-monsoon rainfall through the orographic rainfall processes. In the pre-monsoon period, the maximum horizontal wind zone at 850hPa, the high value of water vapour flux, and the large amount of precipitable water are observed over the Bay of Bengal (BoB). In the pre-monsoon period, P24 (April 26-30) peculiar features of the horizontal wind at 850hPa, the water vapour flux, and the precipitable water activity were found to be extensively increasing over the BoB and their direction was found to be toward the northeast region at Sylhet station of Bangladesh. This is consistent with the area of large amount of rainfall at the northeast region. At the time, strong horizontal wind at 850, the

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water vapour flux, and the precipitable water activity were found less active over the southeast region at Teknaf station. This is consistent with the area is less rainfall at the southeast region. The rainfall distribution map also showed obvious changes in monsoon onset and withdrawal phases. During the pre-monsoon season the rainfall peak was located in northeastern Bangladesh at Sylhet, while it was located in the southeastern tip of Bangladesh at Teknaf after the monsoon onset.

During monsoon, from P31(May 31 to June 1-4) the maximum horizontal wind zone at 850hPa, the high value of water vapour flux, and the large amount of precipitable water are observed over the BoB. The direction of the strong wind, water vapour flux and precipitable water flow found continuously towards in Bangladesh. During the period of P31-32, is defined monsoon onset over Bangladesh.

During post-monsoon, from P57 (October 8-12) the maximum horizontal wind zone at 850hPa, the high value of water vapour flux, and the large amount of precipitable water are found to be gradually decreasing. P56-57 defined as withdrawal of monsoon.

As a result, important changes have occurred in the circulation of the atmosphere, during the period of pre-monsoon, monsoon and post-monsoon. The existence of strong wind, water vapour flux and precipitable water over the BoB, their flowed almost continuously from the BoB towards in Bangladesh, this is consistent with the area of large amount of rainfall, tropical cyclone activity and associated with storm surge over the land and Ocean.

Thus, the seasonal transition of South Asian monsoon is playing an important role in the seasonal transition of rainfall during the monsoon season over the BoB. There is a close relationship between the heavy rainfall and circulation of atmosphere. As the high values of water vapor flux and strong horizontal winds are existent over the BoB, it is the main cause for abundant rainfall over Bangladesh.
**Key words:** Heavy rainfall, pre-monsoon onset, horizontal wind, water vapor flux, precipitable water, Sylhet.

## 1. INTRODUCTION

The word monsoon owes its origin to an Arabic word meaning ‘season’. It was used by sailors, several centuries ago, to describe a system of seasonal alternating winds over the Arabian Sea. These winds appear to blow from the northeast for about six months and from the southwest for the other six months (Das 1968). The South Asian monsoon is well-known as one of the most fascinating phenomena in the world. A number of interesting changes occur in the circulation of the atmosphere, when the summer monsoon takes place over the Indian subcontinent. Matsumoto (1997) noted that the Asian monsoon exhibits an abrupt seasonal transition from winter to summer. The earliest onset of the summer rainy season is in early April in the Assam region over northeast India.

Bangladesh is well-known as one of the heavy rainfall zones in the world, located between 20.67-26.63$^\circ$ N and 88.05-92.74$^\circ$ E (Fig. 1). Climatologically, Bangladesh is situated in the tropical monsoon region. Its climate is characterized by a cool dry season, a hot summer season, and the rainy monsoon season.

Geographically, Bangladesh is very flat, less than 10 m above the sea level. In the southeast, which has a border with Myanmar, the elevation is lower than 200 m. In the northeast, located on the southern slope of the Meghalaya Plateau, approximately 10 km away from the border of north-eastern Bangladesh, elevation is lower than 100 m (Pant and Kumar 1997).

Geologically, a major part of Bangladesh is occupied by one of the largest deltas on the earth. Namely, the Ganges-Brahmaputra-Meghna river basin as a whole is dominated by the Asian monsoon system (Hofer and Messerli 2006). In this region, the Bangladesh Meteorological Department (BMD) divided that the seasons as pre-monsoon: March-May;

monsoon: June-September; and post-monsoon: October-November. Winter is from December-February.

The onset of the Asian summer monsoon is a key indicator characterizing the abrupt transition from the dry season to the rainy season and subsequent seasonal march (Ding and Sikka 2006). Previous studies have been proposed various methods to determine the date of monsoon onset and withdrawal; for example, Das (1968, 1987), Mooley and Shukla (1987), Ananthakrishnan and Soman (1988), Ahmed and Karmaker (1993), Murakami and Matsumoto (1994), Matsumoto (1997), Pant and Kumar (1997), Wang and LinHo (2002), Zhang et al. (2002), Webster (2006), and Htway and Matsumoto (2010).

Ananthakrishnan and Soman (1988) based their approach on daily rainfall data from 1901-1980, from which the monsoon onset dates for the South and North Kerala in South India were determined. Statistics for the mean onset date for South Kerala was found to be on the 30th of May and for North Kerala on the 1st of June. Ahmed and Karmaker (1993) analyzed the mean onset and withdrawal dates of the summer monsoon over Bangladesh. Their statistical analysis, which focused on the summer monsoon, determined that it arrived first in the south-eastern part of the country on 2nd of June and then moves towards the north. The withdrawal of the summer monsoon occurred in the north-western part of Bangladesh on the 30th of September. The Standard deviation (SD) of both the arrival and the withdrawal dates vary from 7 to 10 days.

Matsumoto (1997) determined that the mean onset and withdrawal of the summer rainy season over the Indochina Peninsula and adjacent regions including Bangladesh using 5-day average rainfall data (pentad rainfall). Definition of the onset of summer rainy season is defined such that when the first pentad when exceeds the annual mean pentad precipitation, Pm= (Annual precipitation)/73, in at least three consecutive pentads.

Climatological characteristics of the monsoon onset date are certainly crucial for a tropical monsoon country like Bangladesh. During the pre-monsoon to post-monsoon periods, the large amount of rainfall seriously affects Bangladesh agriculture. Thus, prediction of the dates of the monsoon onset and retreat would help farmers select the most suitable crops to plant as well as determine the time for planting (Das 1987). Indeed, the impact of South Asian monsoon over the Indian Peninsula's economy is very pronounced.

Numerous previous studies have examined monsoon rainfall over Bangladesh. However, there have been very few studies on pre-monsoon rainfall and seasonal transitions in Bangladesh. It is necessary to understand the characteristics of pre-monsoon rainfall and seasonal transitions in Bangladesh. To emphasize the pre-monsoon rainfall phenomena, this study first describes heavy pre-monsoon rainfall associated with atmospheric circulation changes, including the pre-monsoon onset and withdrawal phases in Bangladesh by examining the pentad and 5-day mean horizontal wind at 850 hPa, total column water vapor flux, and precipitable water distribution around Bangladesh. Then, the climatological annual cycle of pentad mean rainfall at each station and regional differences in each season are described.

## 2. DATA

Daily rainfall data at 35 stations in Bangladesh were provided by the BMD (Fig. 1). The data period depended on the station. The station network in Bangladesh has developed gradually. The longest records were for 61 years from 1948 to 2008 at 10 stations, and the shortest records were for 10 years from 1999 to 2008 at one station. The climatological pentad mean amounts of rainfall were calculated from the daily data. When missing data in a particular pentad exceeded 2 days, the data for that pentad were excluded from the calculation of the mean data. The 5-day mean data were calculated from the pentad data.

The space-time structure of the atmospheric circulation field was investigated using Japanese 25-year re-analysis (JRA-25) data with a spatial resolution of 1.25° by 1.25° (latitude-longitude grid) and a time interval of 6 hours (Onogi *et al*. 2007). These data were provided by the Japan Meteorological Agency and the Central Research Institute of Electric Power Industry (http//jra.kishou.go.jp/). This study used climatological pentad mean data of horizontal wind at 850 hPa, precipitable water, and total column water vapor flux over a 25-year period from 1979 to 2003.

## 3. RESULTS

### 3.1. The climatological characteristics of rainfall and seasonal variations

With respect to the climatological characteristics of the rainfall during the pre-monsoon, monsoon, and post-monsoon periods, this study mainly focuses data for five rainfall stations: at Sylhet (24.54°N, 91.53°E), Teknaf (20.52°N, 92.18°E), Satkhira (22.43°N, 89.5°E), Dhaka (23.47°N, 90.23°E), and Rangpur (25.44°N and 89.16°E) indicated by the thick lines in (Fig. 1,2), because they showed characteristic seasonal rainfall variations. Based on the definition used by the BMD, this study used the pre-monsoon onset and withdrawal periods based on Pentad 24 (April 26-30) and Pentad 57 (October 8-12), respectively.

During the pre-monsoon period, in the northeast region at Sylhet station rainfall was found significantly high, from P16 to P30, heavy rainfall was observed. During monsoon to post-monsoon periods; that is, from P31 to P57, extremely heavy rainfall was observed. The highest pentad frequency of heavy rainfall (daily rainfall ≧50mm and exceeding nearly 20%) occurred around P34. From P57 (October 8-12) on the observed rainfall was found gradually decreases. Hoque *et al*. (2008, 2010) investigated heavy rainfall and flood-prone areas around northeastern Bangladesh using rain gauge, discharge, and RADARSAT image data. The high pre-monsoon rainfall in Sylhet seemed to be related to the formation of these flood-prone areas.

During the pre-monsoon period, lasting until P29 in the southeast region at Teknaf station, rainfall was found to be significantly low. During the monsoon, from P33 to P54, extremely heavy rainfall was observed. The highest pentad frequency of heavy rainfall (daily rainfall 50mm and exceeding nearly 40.62 %) was around P35. From P56 on the observed rainfall gradually decreases.

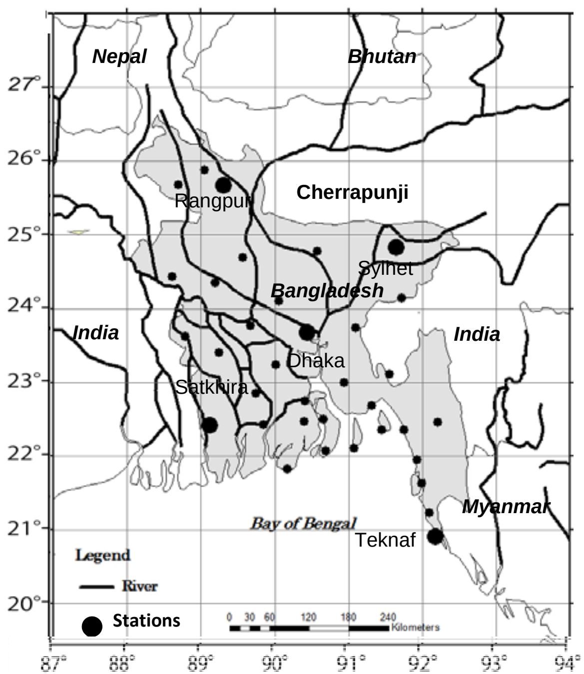



**Fig 1** Geographic location of Bangladesh and the 35 observation stations. Dots denote locations of the 35 BMD rain gauge stations. Larger dots mark stations specifically noted in Fig. 2 with related descriptions.

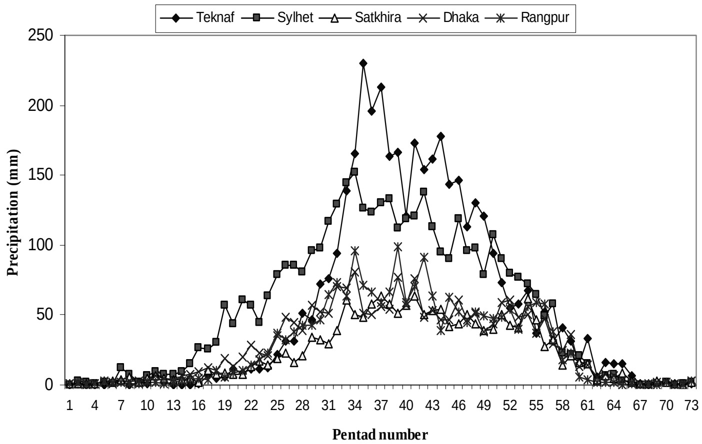



Fig 2. Annual rainfall variations of pentad mean at selected five rain gauge stations, Teknaf, Sylhet, Satkhira, Dhaka and Rangpur.

During pre-monsoon period in the southwest region at Satkhira station, rainfall was found to be very low. During the monsoon to post-monsoon periods; that is, from P32 to P57, rainfall was shown to be high. The highest pentad frequency of heavy rainfall (daily rainfall 50mm and exceeding nearly 6.66 %) was around P37. From P58 on the observed rainfall gradually decreases.

During the pre-monsoon period in the northwest region at Rangpur station, rainfall found to be very low until P24. From P25 to P30, rainfall was shown to be quite high. During the monsoon to post-monsoon periods, P31 to P57, rainfall was high. The highest pentad frequency of heavy rainfall (daily rainfall ≧50mm and exceeding nearly 13.46 %) was around P39. From P58 on the observed rainfall gradually decreases.

During the pre-monsoon period in the central region at Dhaka station, from P19 to P30, the rainfall was shown high. During the monsoon to post-monsoon periods; that is, from P31 to P59, rainfall was shown to be high. The highest pentad frequency of heavy rainfall (daily rainfall ≧50mm and exceeding nearly 9.09 %) was around P34, P39 and P40. From P57 the observed rainfall gradually decreases.

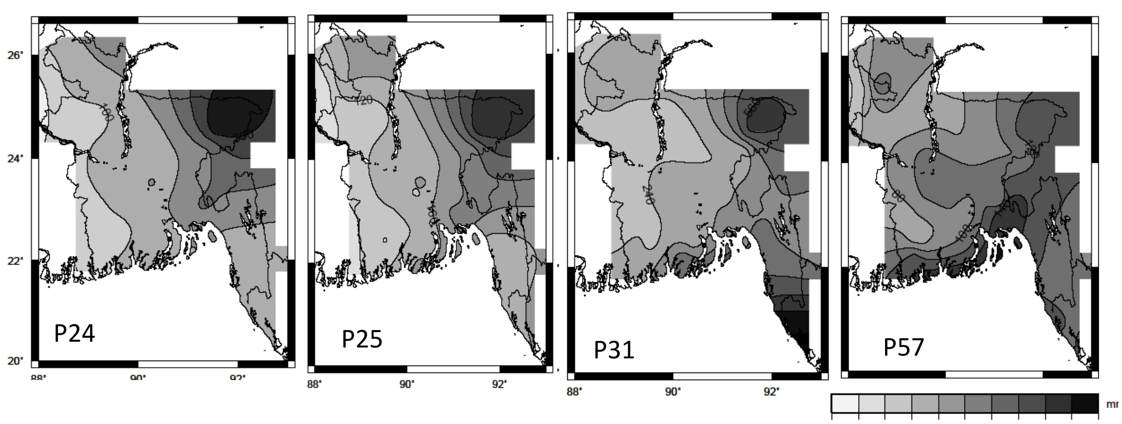



**Fig 3** Spatial distribution of 5-day mean rainfall over Bangladesh, during pre-monsoon periods, P24, P25, and monsoon period P31 and post monsoon period P57

### 3.2 Spatial distribution of the pentad 5-day rainfall maps

During the pre-monsoon period, Bangladesh experiences severe thunderstorms, known as

“*Kal Boishakhi”* meaning a mass of dark clouds in a month of “*Boishak*” (the first month of Bengali year). The rainfall associated with these thunderstorms is of a transient nature. Spatial distribution of the pentad rainfall map in pre-monsoon periods (P24-25) (Fig 3) illustrates that there is significant rainfall only around the northeast region, with very less rainfall shown around the northwest, southwest southeast part of Bangladesh. In P24, is found very unique point, when rainfall greatly increasing. Important changes have occurred from P24. This study defined that P24 is pre-monsoon onset over the northeast region. Patterns of pre-monsoon onset could be located only around northeast region. Until P-30, there is less rainfall around southeast region.

During the monsoon period, from P31 (Fig 3) heavy rainfall is evident around the northeast, the southeast and the whole country. P31-32 is defined as monsoon onset over the country. However, some parts of northwest and southwest regions have less rainfall. Perhaps the most well-known feature of orographic rainfall in northeast India is the extremely large amount of rainfall at Cherrapunji (25.18°N, 91.42°E). The Sylhet district is located approximately 50 km south of Cherrapunji, Murata *et al.* (2008). Thus, Cherrapunji region plays a major role in the heavy rainfall and early flood around the northeastern region (Hoque *et al*. 2010). During post-monsoon, in P56-67 illustrates there is rainfall around northeast, central and southeast region (Fig. 3).

### 3.3. Seasonal transitions of atmospheric circulation field during pre-monsoon, monsoon and post-monsoon

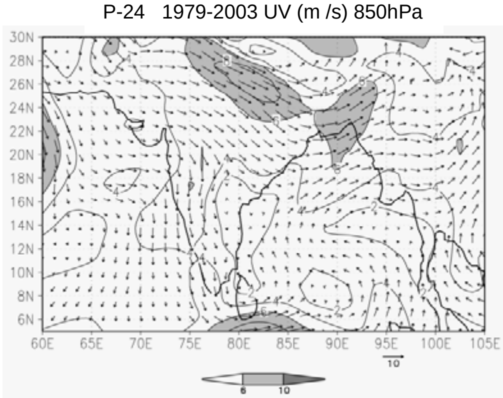
In order to investigate the seasonal transitions of the atmospheric circulation field at the 850hPa level associated with rainfall; this study focuses on the three periods: (1) pre-monsoon, (2) monsoon and (3) post-monsoon. Figure 4 illustrates the climatological 5-day mean value of the horizontal wind at 850hPa, the water vapour flux, and the precipitable water.

In the pre-monsoon period, in P24 and 27 the maximum horizontal wind zone at 850hPa was observed around 5-10°N and 80-115°E (Fig 4a, top). The strong westerly wind is enhanced over the BoB and direction of strong wind seems to the northeastern part of Bangladesh. In P24 and P27, the high value of vapour flux (about 200 to 400 $kgm^{-1}s^{-1}$) and strong westerly wind is well established over the BoB (Fig 4a, middle). The direction of the vapour flux and the wind was shown to move toward the north-eastern part of Bangladesh. At the same time, in P24 and 27, there is a large amount of precipitable water (about 40 to 50 $kgm^{-2}$) over the Arabian Sea, the BoB, and the South China Sea (Fig 4a, bottom). This is consistent with the area of large amount of rainfall over the land and ocean. These results are corresponded well with rainfall distribution map (Fig 3). In the pre-monsoon period, it was found that the maximum horizontal wind, the high value of vapour flux and large amount of precipitable water activity is less strong over the southeastern part of Bangladesh. These results suggest that the pre-monsoon rainfall phenomenon is significant over the northeastern part, than in southeastern part of Bangladesh. During the monsoon period, P31 (May 31 to June 1-4) the maximum horizontal westerly wind zone at 850hPa increased abruptly around 5 to 20°N over the BoB. In P31 is also very unique point, when rainfall greatly increasing.

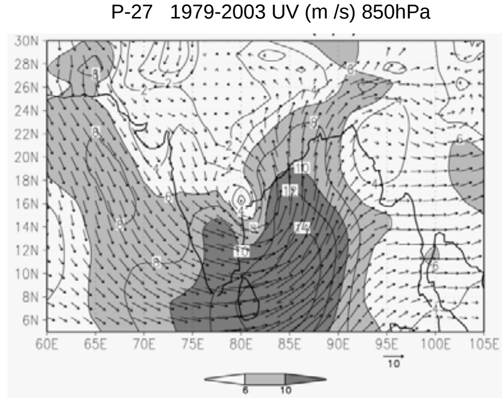
Pre-monsoon period

**Fig 4 (a)** Five-day mean distribution of horizontal wind at 850 hPa (top), water vapor flux (middle), and precipitable water (bottom) in the pre-monsoon periods. Top: contour interval is 2 ms $^{-1}$. Light and dark shading indicate winds stronger than 6 and 10 ms $^{-1}$, respectively. Middle: contour interval is 100 kg m $^{-1}$ S $^{-1}$. Light and dark shading indicate values higher than 200 and 400 kg m $^{-1}$ S $^{-1}$, respectively. Bottom: contour interval is 5 kg m $^{-2}$. Light and dark shading indicate values higher than 40 kg m $^{-2}$ and 50 kg m $^{-2}$, respectively.

P-24 1979-2003 UV (m /s) 850hPa

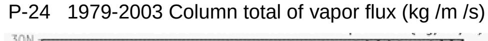



P-27 1979-2003 UV (m /s) 850hPa

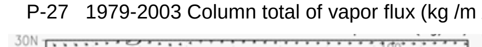





P-24 1979-2003 Column total of vapor flux (kg /m /s)



P-27 1979-2003 Column total of vapor flux (kg /m /s)



From P31-56 the strong westerly wind flow blows in from the Arabian Sea and BoB towards the South China Sea around 5 to 27°N and 60 to 120°E. The strongest westerly winds are circling over the land of India and Bangladesh. Also during the monsoon, P31-55, high values of vapour flux and strong winds exist over the Arabian Sea, BoB and South China Sea, around 5 to 27°N and 60 to 120°E. Because of water vapor flux is strongest over the BoB, it is the main cause for abundant rainfall over the country during monsoon. From P31-55, there are large amounts of precipitable water observed over the BoB, the Arabian Sea and the South China Sea. Such conditions indicate that active monsoon conditions provide copious rainfall over the land and ocean (Fig 4b).

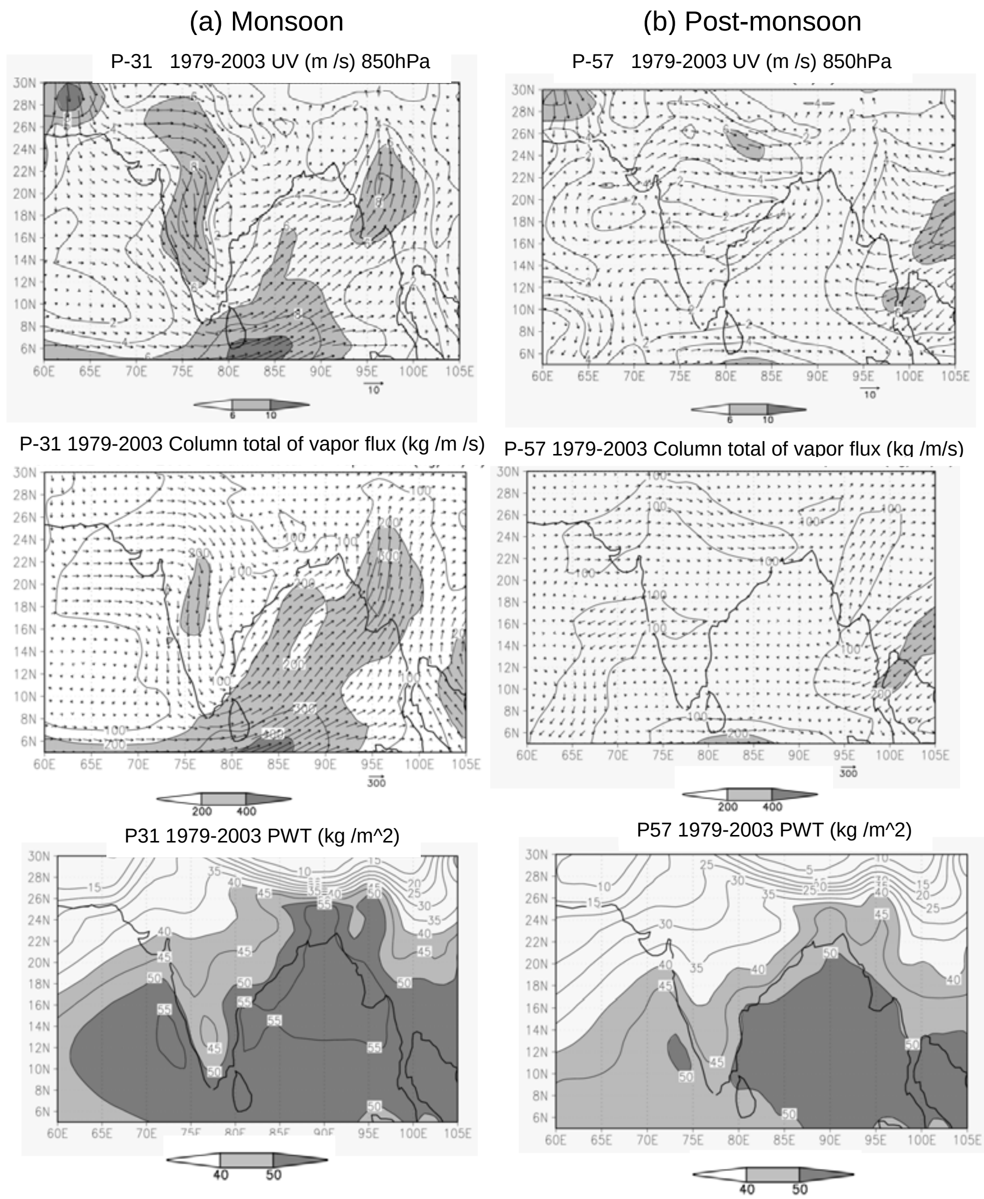



**Fig 4 (b)** (continued) for monsoon (a) and post-monsoon (b) periods.

At the beginning of post-monsoon period, in P56 (October 3-7) the horizontal wind at 850hPa, the water vapour flux and precipitable water are observed to be still active around 5 to 6°N and 75 to 100°E (not shown). In P57(October 8-12) the westerly wind at 850 hPa levels, the water vapour flux and precipitable water was observed to drastically decrease and in the BoB as it begins to receive the north-easterly wind from the South China Sea the water vapour flux and precipitable water (Fig 4b).

## 4. CONCLUSION

The results obtained clearly show the increase of heavy rainfall, during the pre-monsoon period over Bangladesh. This arises because the maximum horizontal wind zone at 850hPa, the high value of water vapour flux, and the large amount of precipitable water are exists over the BoB. In the pre-monsoon period, from P24 peculiar features of the horizontal wind, the water vapour flux, and the precipitable water activity were observed over the BoB. As a result, pre-monsoon period important changes have occurred in the circulation of the atmosphere. In the monsoon period, that is from P31-55, the maximum horizontal westerly wind speed at 850hPa, the high value of the vapour flux and the precipitable water content, are extensively increased over the Arabian Sea, the BoB and the South China Sea. The southerly 850 hPa wind and northward total column water vapor flux flowed almost continuously from the BoB towards in Bangladesh during the pre-monsoon to monsoon season. In the post-monsoon period, the horizontal wind and water vapor flux were found to eventually decrease from P57. The seasonal transition of the South Asian monsoon plays an important role in the seasonal transition of rainfall during the monsoon season over the BoB. There is, thus, a close relationship between the heavy rainfall and the circulation of the atmosphere. As the high values of the water vapour flux and the strong horizontal winds exist over the BoB, they represent the main cause for the abundant rainfall seen over Bangladesh.

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# CREATING SYNERGY FOR BIODIVERSITY CONSERVATION THROUGH COMMUNITY BASED CLIMATE CHANGE ADAPTATION MEASURES: A CASE STUDY OF CHARNAWATI WATERSHED IN DOLAKHA DISTRICT

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## ABSTRACT

Although climate change has become a burning issue of the 21st century, the underlying debates are revolving more on economic and social challenges; and less on those related to conserving biodiversity. Studies have indicated that biodiversity loss would be one of the greatest challenges in the coming years when temperatures, rainfall patterns, and their consecutive impacts would be more pronounced. Mountains are known as barometer for monitoring climatic impacts, as their ecosystems are more sensitive to changes. Monitoring of these changes and conserving biodiversity effectively involve substantial efforts and resources, which are rarely available. However, studies have also revealed that community based approach to management local forests linking them with their livelihoods have brought significant changes not only to contribute in livelihoods but also conserving biodiversity while minimizing climate change impacts.

Taking the case of Charnawati Watershed (Dolakha District), this case study has explored climate change impacts in terms of hazards, vulnerability and analysed them against effectiveness of community level activities in conserving biodiversity. Key findings include remarkable increase in climate hazards and vulnerability across watershed with more seriously on lower and upper parts. Consequences have been increased forest fires, changes in species dominance and losses of local livelihoods. Major climate hazards comprise longer and intense drought, increased frequency and intensity of hailstorms, accelerated landslides and erosion. However, counter measures of the local communities like rainwater management, application of bioengineering and various measure of forest conservation have produced desirable results. Building partnership with research organizations, Charnawati community has successfully convinced potential investors of carbon stored in community forests, thus, has created synergy to

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achieve the goal of climate change adaptation as well as mitigation along with biodiversity conservation.

**Key words:** Adaptation, Climate change, Vulnerability, Hazards, Biodiversity

## INTRODUCTION

The Millennium Ecosystem Assessment (MEA) identified climate change as one of the major drivers having adverse affects on biodiversity and associated goods and services (MEA 2005) and there is already a global consensus that climate change is real, rapidly advancing and widespread (Dahal et. al, 2009). Acclaimed scientists including those in the network of IPCC have presented adequate evidence and tested models to substantiate this alarming fact. In the context of climate change, mountains could suffer wide-ranging environmental and socioeconomic impacts, for example on the hydrological cycle, and this in turn would alter the distribution, seasonality, and amount of precipitation and result in changes in river runoff, ultimately affecting not only mountain watersheds but also the lowlands below (Beniston 2003). In addition, Mountains have been recognised as important ecosystems by the Convention on Biological Diversity (CBD) and its special programme on 'mountain biodiversity' which aims to reduce the loss of biological diversity in the mountains at global, regional, and national levels by 2010.

Nepal, the mountainous country has been experiencing wide range of climatic variation in the forms of hazards, altered temperatures, precipitation especially in ecosystem processes and services. Several studies (Nepal's Initial National Communication Report, 2004, Human Development Report of Nepal (UNDP, 2006), Melting Glaciers of the Himalaya, ICIMOD 2007) confirm that Nepal is among the most vulnerable countries to climate change for two major reasons. Firstly, its mountain regions have already exhibited signs of serious impacts through alarmingly high rates of temperature increases. Secondly, as a least developed country, the majority of the population of Nepal lacks capacity to adapt to climate change. The National Adaptation Plan of Action (NAPA; 2010) has been identified agriculture, forestry, water and energy, health, urban and infrastructure, tourism, industry and all livelihoods and economy as the climate change sensitive sectors.

However, more than 65% (Population census 2001) of Nepalese people depend on agriculture for their subsistence is more vulnerable. Poor economic condition adds the severity because of less possibility of adaptation until some intervention from government and other agencies working in the same sector. Posed serious climate change risks for countries, vital ecosystems, and sectors including agriculture, forestry, health, local economic activities and biodiversity in conjunction with other pressures, they could also exacerbate other serious local and regional challenges, such as poverty, poor healthcare, inequitable distribution of resources, diminishing ecological resiliency and energy insecurity (UNEP 2009). It is also true that, the main sufferer are poorest of poor, who are unable to adapt according to changing environment and even does not have knowledge to understand it as well further step.

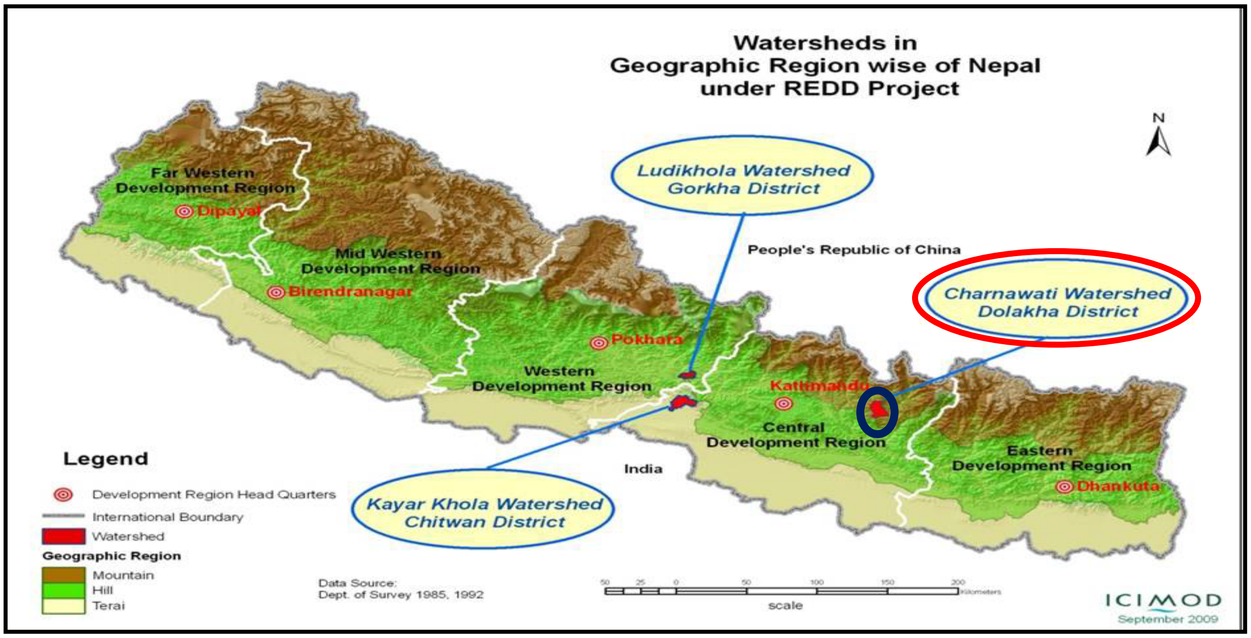
Nonetheless, with compulsion or innocence people are gradually changing their livelihood activities for the survival. Unknowingly different coping strategies for adaptation are applying as their level of understanding locally which become essential to adapt. Scientifically, adaptation signifies as a response to climate change that seeks to reduce the vulnerability of natural and human systems to climate change effects (UNFCCC). In the adaptation process local people are changing agricultural species, adoption of water management, using bio-energy, together with mitigation measures namely, conserving forest resources, plantation of trees ultimately helps for the biodiversity conservation. All these activities are to minimize the adverse impact of climate change on top of local, endangered, endemic species conservation. In one hand livelihood opportunities are increased to improve quality of life, in other hand species conservation leads towards sound and sustainable environment.

This study aims to understand community based biodiversity conservation practices through adaptation measures which can synergize the goal of livelihood enhancement and climate change adaptation as well as mitigation.

## 1. STUDY AREA

This study focuses in *Charnwati* Watershed of *Dolakha* District where recently established Gaurishanker Conservation Area is located. The Watershed is located at an elevation of 820 m-3549 m and covers area of 14037 ha with latitude $27^0$35’16.12’’-$27^0$44’47.92’’ and Longitude $85^0$56’18.41’’-$86^0$03’56.92’’. Facing to the southeast aspect, the entire watershed has high to moderate slope. The upper and lower sections of the landscapes are high gradients and thinly populated compared to the middle section where the slope is moderate and densely populated

(Dahal, 2010). The mean maximum and minimum annual temperatures of *Dolakha* are 19.9 and 8.3 0C respectively. The mean annual precipitation is 2232.1 mm. Of the total, 1791.9 mm falls in 4 months of monsoon between June and September. Diverse population on economical, cultural, religious basis living in the watershed comprises mainly *Tamang*, *Chhetri*, *Brahmin*, *Thami* and *Dalit.*




Source: REDD+ Pilot project (REDD office-ICIMOD, ANSAB and FECOFUN)

**Figure 1** : Location map of *Charnawati* watershed with other REDD+ piloted watersheds of ICIMOD, ANSAB and FECOFUN

## 2. METHODOLOGY

Available literatures of climate change adaptation relevant to Nepal were reviewed especially from ICIMOD publications and internet surfing. During the study period different methods of information gathering strategies were applied to reach on depth of local initiatives and their activities. Primarily three tasks namely expert interviews, focus group discussions (FGD) with community forest user groups (CFUGs) in the watershed and a multi-criteria analysis again with relevant stakeholders of the watershed. FGD revealed the real climatic hazards, risks and their local approaches to adapt from present changing environmental condition. Experts' interview and stakeholders' consultation added the consistency on the findings of the group discussions. Multi-criteria analysis techniques were employed to assess and prioritized the recommended options. Assessments of climate risks and vulnerabilities were undertaken at watershed level through community consultations August 20 to 24, 2010. Finally, information gathered through interviews with the chiefs of district-level government offices mainly from Forest, Agriculture, Watershed Conservation, Livestock Services, and District Development Committee proved useful to verify the prioritized adaptation needs and options of the respective communities in each of the watershed (Dahal 2010).

## 3. RESULT AND DISCUSSION

As National Adaptation Plan of Action (NAPA; 2010) ranked different vulnerable districts based upon the overall climate change vulnerability mapping, *Dolakha* lies on top position of vulnerability with highest value between 0.787 to 1.000. The same is reflected through discussions with the people of *Charnawati* watershed who shared their experiences of different climate hazards and risks depending on their livelihood conditions and geographical locations.

Table 1: Climate change vulnerability/Risk assessment *Charnawati* Watershed, *Dolakha*

| Key climate hazards/Livelihood | Draught | Flash floods; Landslides, Erosion, River bank cutting | Hailstorms, cold waves | Heat waves | Fire Incidents |
|---|---|---|---|---|---|
| Agricultural Production | 2 | 2 | 3 | 0 | 1 |
| Livestock | 1 | 1 | 3 | 1 | 1 |
| Drinking water, Irrigation, Water source | 3 | 2 | 1 | 0 | 1 |
| Biodiversity, Forest | 2 | 1 | 1 | 0 | 3 |
| Road, bridge and other infrastructure | 0 | 2 | 0 | 0 | 2 |
| Local enterprises/ Employment, Education | 1 | 1 | 2 | 0 | 1 |
| Human Health | 3 | 2 | 1 | 3 | 2 |
| Social network and cultural practices | 0 | 1 | 0 | 0 | 1 |
| **Total** | **12** | **12** | **11** | **4** | **12** |

Source: Dahal, 2010

Table 1 elaborates the condition of climate change risk and vulnerability in *Charnawati* watershed. It insists based on number given by local people during FGD where climate hazards and livelihood options were analysed. It is true that most of them have agriculture the main occupation therefore more emphasis was given on the same.

Majority populations of lower part of the *Charnawati* watershed are more vulnerable followed by upper part than middle one. The major hazards illustrated by the local people are draught in number one position followed by flashfloods, Landslides, Erosion, River bank cutting, Fire Incidents, Hailstorms, cold waves, and Heat waves based upon frequency, coverage or intensity and likelihood with occurrence. The findings of the community consultations are in agreements with the general review of literatures[1] and climate data as the majority of climate change related studies have hinted of more intense rainfall in shorter in the recent past. It signifies that the immediate actions are imperative to adapt on local level.

People of *Charnawati* watershed adopted various measures of adaptation that eventually helps for biodiversity conservation which signifies the rational utilization of biotic resources through effective means of sustainability to protect genes, species, and whole ecosystem. As a result synergized output is achieved through local adaptation measures. In the same align people and different stakeholder organizations are working on their own level to minimize the adverse impacts of climate change. Also, some significant works are running in cooperation with other agencies and institutions; however there is lack of concrete future plan and coordination.

Photo plate 1: Settlement with dense vegetation

Photo plate 2: water storage pond in Boch VDC

Diversification on adaptation practices is prevalent basically from the ecological, geographical, and topographical perspectives. Lower part of watershed is warmer than upper part which reflects the need of different adaptation measures such as plantation of semi-desert species, Jatropha for live hedge system in lower part as well as terrace farming, higher altitude favoured medicinal herbs plantation on upper area. Rainwater management, water source conservation, cultivation of stress tolerant species are some of the adaptation measures against draught. In the long run these activities are beneficial to reduce landslide, and erosion, groundwater recharge, increase offseason vegetables etc. Important adaptation measures with their benefits are listed below in tabular form (Table 2).

Table 2: Adaptation Measures and benefits

| S.N | Climate Hazards | Adaptation Measures | Benefits of Adaptation Measures |
|---|---|---|---|
| **1.** | Drought | ≈ Rainwater management<br>≈ Use of hybrid seed with the capacity to grow in less water<br>≈ Cultivation of semi-desert species on lower part of watershed such as Anaar, banana etc.<br>≈ Water source protection | ≈ Enhanced groundwater recharge, prolonged spring flow after rainy season. Water availability in dry season.<br>≈ Reduced landslide and erosion<br>≈ Increased production of off-season vegetables<br>≈ More ponds for livestock and home garden<br>≈ Increased livelihood opportunities |
| **2.** | Flood, landslides, Soil-erosion | ≈ Application of bioengineering<br>≈ Agro-forestry<br>≈ Live hedge system (Jatropha plantation)<br>≈ Multi storey forest management (herb, shrub and trees) | ≈ Rural road, farmland protection from erosion, landslide and slope stabilization<br>≈ Income maximization by selling Bamboo, Amriso, medicinal herbs, fruits i.e. NTFPs<br>≈ Fodder for livestock<br>≈ Habitat for fauna<br>≈ Carbon sequestration |
| **3.** | Forest Fire | ≈ Multi storey forest management<br>≈ Agro-forestry<br>≈ Live hedge system (Jatropha plantation)<br>≈ Make fire lines and collect litter before dry season | ≈ Enhance economic level by selling NTFPs such as medicinal herbs, plant seedlings, saplings etc.<br>≈ Fodder for livestock<br>≈ Habitat for wild animals<br>≈ Carbon sequestration<br>≈ Protect soil erosion<br>≈ Fencing of farmland from livestock and wild animals |
| **4.** | Hailstorms, Lightening, and Storm | ≈ Rice species like Taichin to cope with hailstorm and storm<br>≈ Large shade trees plantation on lower part of watershed | ≈ Carbon sequestration<br>≈ Reduced soil erosion<br>≈ Habitat for birds and insects<br>≈ Increased crops production and Timber from large trees |

The counter measures of the local communities like rainwater management, application of bioengineering and various measure of forest conservation have produced desirable results. Building partnership with research organizations, *Charnawati* community has successfully convinced potential investors of carbon stored in community forests, thus, has created synergy to achieve the goal of climate change adaptation as well as mitigation along with biodiversity conservation.

## 4. CONCLUSION

The Key findings of this study include remarkable increase in climate hazards and vulnerability across watershed with more seriously on lower and upper parts that have affected both local livelihoods and biodiversity richness. Consequences have been increased forest fires, changes in species dominance and losses of local livelihoods. Although local communities have adopted measures to addresses these new challenges, they suffer with inadequate information and knowledge, which is essential to build their capacity for planning and management of their resources. It is important to note that climate change adaptation measures such as building fire lines, enhancing forest density, promoting species diversity and protecting of endangered plant and wildlife species have been also effective to protect biodiversity. They actually have created synergy through these measures though their sustainability and effectiveness depend on a number of external and internal factors such as economic returns of the resources to support local livelihoods, opportunity costs, market and recognition to local communities as a major stakeholder.

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## DISCLAIMER

The view presented on this study does not reflect the institution's view which are implementing REDD+ pilot project in *Charnawati*. It is based on the field visit and the conclusion is author’s personal analysis.

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# STUDY ON THE STATUS OF INDUSTRIAL WASTE POLLUTING THE RIVERS OF KATHMANDU VALLEY AND ITS BEST MANAGEMENT PRACTICES (BMP)

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## ABSTRACT

Rivers play a major role in the economy of a country by sustaining agriculture, industry, energy generation and providing biological resources. However, humans have grossly abused the rivers worldwide by extensive regulation of flows, habitat alteration and disposal of all kinds of wastes into them. Kathmandu, the capital city of Nepal is situated on the bank of Bagmati River. Bagmati river system is supported by many tributaries and mostly overloaded with the pollutants discharged from both industries and domestic sources. The impacts of these activities are already appearing in declining aquatic animals, increasing incidence of floods, lowered groundwater tables and growing incidence of water-borne diseases taking away hundreds of lives every year. Rapid growth of population, urbanization, industrialization, unplanned development, land degradation, and lack of infrastructure for waste disposal are common reasons for the rapid deterioration of the rivers of Kathmandu. In the year 2000, the number of industries established in Kathmandu Valley totaled to 2200 (CBS, 2000). In 1986/87 the numbers of industries in Kathmandu valley were 1504. Besides, nearly 40% of the manufacturing industrial establishments in Nepal are water polluting. The total yearly BOD load from industry sector is 5741 ton of which nearly 20% is released in the river systems of Kathmandu valley. Also total TSS load from the industrial wastewater amounts to 9591 tons annually. Hence, the present study focuses on the status of industrial wastes polluting the rivers of Kathmandu Valley and its Best Management Practices (BMP) together with putting emphasis on the conservation and restoration of rivers for the overall sustainable development of the region.

**Keywords:** Industrial Waste, BMP, Urbanization, BOD, Sustainability, Conservation, Disease

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## 1 INTRODUCTION

Water is very important for all living beings and is consumed by all and as such it is essential that all should get pure and clean drinking water. Only 27% of the population has access to a form of sanitation (such as latrines, septic systems, wastewater treatment plants) in Nepal. Hence, the problem of water pollution is serious environmental and health issues in Nepal. It is rather more problematic in Kathmandu, the capital city. Kathmandu Valley continues to develop industrially and as the city grows in population and expands into outlying areas, the Bagmati River and other urban surface waters are becoming more and more polluted. Quality of life in Kathmandu has not advanced proportionately with industrial development. One reason among others is that Kathmandu lacks adequate solid waste and wastewater collection and treatment systems. The February 2000 ADB Report of Urban Water Supply Reforms in the Kathmandu Valley maintains that the current wastewater collection system covers only 35 percent of households in the Valley (Metcalf & Eddy, 2000). Kathmandu also does not have proper drinking water treatment and supply systems. Those without other resources rely on local surface water, namely the Bagmati River, for bathing, washing clothes and food, and even for drinking and as a public toilet. Furthermore, the River has become a sewage discharge site for municipal wastewater and an industrial dumping ground for local businesses with no other means of disposal.

The poor water quality of rivers of Kathmandu valley has tremendous economic costs associated with it, including degradation of ecosystem services; health-related costs; impact on economic activities such as agriculture, industrial production, and tourism; increased water treatment costs; and reduced property values. The major contributors of water pollution of Kathmandu River include sources like sewage, industrial effluents and agricultural discharges. Sewage contributes 90% of water pollution and remaining 10% is contributed by the industrial sector. The contribution by industrial sector seems insignificant but it has a greater impact because it increases the heavy metal load in the river water. Katmandu's largest manufacturing industry is the carpet industry. Many people have moved to Nepal to work in this industry (Schrier & Shah, 1996). This has caused an increase in the sewage produced due to the increased population in Kathmandu Valley and also an increase in industrial Wastewater.

There are approximately 50 wool dyeing companies in Kathmandu Valley approximately 20-25 of them are located along the Bagmati River, the largest river that runs through Kathmandu Valley (Karanjit, 2003). They lack waste water treatment facilities and discharge their untreated waste directly into the open rivers of Valley (Shrestha, 2005). It is likely that the carpet manufacturing industry may contribute significantly to water quality deterioration. The study was therefore aimed to find out status of carpet industry waste and its contribution in River pollution of Kathmandu valley. It also aimed to know the waste management practices adopted by the industries to manage their industrial waste for conservation and restoration of rivers for the overall sustainable development of the region.

## 1. Materials and Methods

### *2.1 Study Area and Sampling Source*

The present study was carried out at Bagmati River. The Bagmati River with its tributaries- the Vishnumati, Manohara, Dhobikhola, Icchumati (Tukucha), Nakkhu, Hanumante, Karmanasa, and Godavari-is the main river in Kathmandu Valley. The river system has been the valley's main sources of water for drinking and irrigation, and an important component of its ecosystem. It has also tremendous religious, cultural and social significance- the river is worshiped by millions of Hindus in Nepal and India. The famous temple Pashupatinath with many other Ghats and Matths are located on the bank of Bagmati River. It lies between the latitudes 27º 32' 13" and 27º 49' 10" north and longitudes 85º 11' 31" and 85º 31' 38" east and is located at a mean elevation of about 1,300 meters (4,265feet) above sea level.

### *2.2 Water Sampling*

Five points were indentified for the sample collection. They were selected purposely to cover all the tributaries as far as possible. The sites identified were Sundarijal, Pahsupatinath, Tilganga, Shankhmool and Sundarigaht. They were coded as S1, S2, S3, S4 and S5 respectively. All together five representative water samples were collected from Bagmati River Course at different locations from 10 am to 5 pm. The respective bottles and preservatives like Nitric Acid, Sulphuric Acid, Alkali iodide and Manganous Sulphate were used during sample collection to have the accurate data. The samples were collected and analyzed in the month of December 2010.

### *2.3 Analysis of Water Samples*

The collected samples were brought to the laboratory of Water Engineering and Training Center Pvt. Ltd, Kathmandu, Nepal. They were analyzed for the parameters like $P^H$, Temperature, Electrical Conductivity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Chromium (Cr) with best available methods. The parameter like the Temperature and $P^H$ were measured at site while the other parameters were determined in the laboratory. The parameters were determined as per the following methods/instruments.

Table 1: Parameters and method used

| Parameters | Instruments/ Methods Used |
|---|---|
| **E. Conductivity** | Conductivity meter |
| **Temperature** | Thermometer |
| **$P^H$** | $P^H$ Meter |
| **DO** | Iodometric Titration |
| **BOD** | Azide Modification/ 5 days Incubation |
| **COD** | Open Reflux |
| **Cr** | AAS |

## 2. RESULT AND DISCUSSION

The present study was carried out to know the status of industrial waste in connection with the Carpet/dyeing industry polluting the rivers of Kathmandu valley. Kathmandu is very famous for the Carpet industry since past. But very few studies have been performed to know its waste characteristics and its effects on the nearby river. In this study, the DO, COD, BOD and Chromium were taken as major parameters for revealing industrial pollution. The table below shows the result of the study-

Table 2: Water Quality Status of Bagamati River

| Parameters | Units | Result | | | | |
|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | S4 | S5 |
| **Electrical conductivity** | μS/cm | 30 | 188 | 956 | 760 | 1087 |
| **Temperature** | $^0$C | 8.9 | 11.8 | 12.1 | 14.2 | 14.2 |
| **P$^H$** | - | 6.8 | 7.2 | 7.5 | 7.8 | 7.8 |
| **DO** | mg/l | 9.7 | 6.0 | 0.06 | 0.06 | 0.06 |
| **BOD** | mg/l | 0.86 | 3.6 | 386 | 73.5 | 117 |
| **COD** | mg/l | 2.0 | 13.0 | 1040 | 340 | 420 |
| **Chromium** | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

The study shows the water is loaded with both organic and inorganic pollutant and is unfit for any kind of work. Total chromium (chromium in all oxidation states) was measured in an atomic absorption spectrophotometer (AAS) for all of the samples. Most of the water samples tested contained negligible amounts of chromium (less than 0.01 mg/L. A study done by Hillary (2003) revealed similar level of chromium in water for most of the samples but high level of chromium in the dyes used. One could come to the conclusion that because the chromium content of dyes is high and the content in the water is low, not much dye reaches the water, that it is all used in the dyeing process and that the dye that does eventually reach the water is of low chromium content.
Chromium levels in the Bagamati were lower than the WHO's guideline for drinking water but this does not necessarily mean that there is not a problem with chromium in the Bagmati River. It is possible that levels are this low because dyeing is in an off-season during the winter season, dilution of industrial waste with the household waste or sewage in Bagamati River Course, current practices of using heavy metal free chemicals in the carpet/dying industryas stated by the industries and decreased number of Carpet/dying industry in the area due to multiple reasons. Also, more chromium may enter the Bagmati than indicated by chromium measurements. Since dye has an affinity for sticking to particles, those particles filtered out from the water samples before chromium measurements were taken may have contained a significant amount of chromium. Chromium could also be removed by settling to the river sediments. Therefore, broad conclusions cannot be drawn from this result and this study opens a door for sediment analysis for chromium content by researchers in near future.

COD is quite low at Sundarijal and Pashupatinath, but increases sharply at Tilganga. The abrupt increase of COD at this place is due to collective discharge of sewage and industrial waste collected from the Boudha and Jorpati area which are well known for the Carpet/Dyeing industries. These increases and decreases in COD along the Bagmati River can be the result of a variety of substances in the water. One study conducted by the Environment and Public Health Organization (ENPHO) showed that the Chemical Oxygen Demand (COD) is in excess of 400 mg/l within the city and immediate downstream areas where the normal COD level is 40 mg/l for the river (Dhakal 2003).

The result shows the lower value of DO because of increase of COD and BOD values. Except the first two values, the other DO values are below the EPA standard of no less than 5.0 mg/l in order to maintain stable fish populations (Lutz et. Al., 1998).

Currently, there are no large industrial wastewater plants in Kathmandu Valley, though some industries have made an effort to treat their effluent by building small treatment plants, such as one in Hetuada, south of Kathmandu. But the only industrial wastewater treatment plant, at Heatuda, often encounters operational difficulties (ADB 2000; IUCN 1992). None of the carpet/dye company in Kathmandu has treatment facilities and do not have any plan for it immediately. So, over the past years, the rivers of Kathmandu Valley are experiencing large industrial waste, a practice that may need to be stopped. The effluent from some industries goes to the municipal wastewater treatment plant. This may not be a great disposal method either since municipal wastewater treatment plant is not often designed to deal with some of the components of industrial waste, such as heavy metals. These components could actually be detrimental to the plant and decrease efficiency. On the other hand such municipal waste water treatment plants are also not in function or suffer from disruption due to power shortage and politics on pollution. The biological lagoons have the similar stories and have not maintained for years. Thus, the rivers have become major places for disposal of untreated sewage and industrial effluents, as well as urban solid waste dumping in Nepal.

Because of the degradation of the Bagmati, the river is losing some of its religious significance among believers. The tradition of drinking the water of the Bagmati is no longer commonly practiced. The River is not used for fishing because freshwater fish have been completely wiped out. Due to the condition of the rivers in Kathmandu Valley it is not recommended for recreational use, drinking water, or industrial purposes, though it is used for all of the above.

## 3. CONCLUSION

The present research has confirmed the Bagamati River is highly polluted. It is at the state of not supporting any aquatic life. Unfortunately, this research cannot present a concrete conclusion that carpet dyeing effluent significantly decreases the water quality of the Bagmati River, though its contribution on the water quality cannot be underestimated. Hence, it recommends for further research by taking the sediment sample from Bagamati River to accurately justify the role of carpet/dye industry on the effects of river pollution of valley. Also, this research was carried out with limited budget and time frame. So, it might not depict the whole picture of problem stated.

But it gives empirical data that could be helpful in designing new researches and strategic planning for conservation of rivers of Kathmandu valley for the sustainability of the region.

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# DEVELOPMENT OF STREAMFLOW AND RESERVOIR INFLOW PREDICTION MODELS WITH FUZZY LOGIC A CASE STUDY OF LAM TAKHONG DAM, THAILAND

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## ABSTRACT

For the purpose of reservoir management and planning, the fuzzy streamflow and reservoir inflow prediction models were developed for predicting the streamflow at station M.89 located on the upstream side of Lam Takhong Dam and the reservoir inflow. The measured daily streamflow at time t, t-1, and two variables representing the cyclical effect components; $\cos\frac{(2\pi i)}{12}$ and $\sin\frac{(2\pi i)}{12}$ were specified as the major inputs to predict the streamflow values at time t+1. Whereas the predicted daily streamflow of station M.89 at time t+1, t together with, $\cos\frac{(2\pi i)}{12}$ and $\sin\frac{(2\pi i)}{12}$ also used as inputs for the reservoir inflow prediction model to predict reservoir inflow at time t+1. The fuzzy logic approach was applied to develop these two prediction models, and tested the predicted accuracy by R-Square and MSE. The results of model calibration from 1970-2008 for streamflow prediction and from 1987-2008 for reservoir inflow prediction showed a reasonable level of R-Square; 0.60 and 0.61, respectively and MSE which was equal to 56.09 cms and 0.006 mcm, respectively. Additionally, it could predict at a higher level of accuracy for the model validation which R-Square and MSE ranged between 0.63-0.78 and 1.89-2.99 cms, respectively for the streamflow prediction when the data since 2006-2008 and in 1972 were used. While the short-term data from 2006-2008 and peak flow data occurred in 1990 were employed for the reservoir inflow prediction, it found that the results varied between 0.62-0.78 and 0.002-0.041 mcm, respectively. Moreover, the predicted patterns of streamflow and reservoir inflow were similar to the observed values for both low and high flow periods.

**Key Words:** Streamflow, Reservoir Inflow, Prediction Model, Fuzzy Logic, Reservoir Operation, Reservoir Management and Planning, Lam Takhong Dam.

## 1. INTRODUCTION

The effects of global warming crisis have been often occurred and became more severe since the past decade apparently found as the unpredictable rainfall, large variation of streamflow over a year, uncertain water supply, severe flood and drought events. Not only the people and the basic infrastructures were damaged and destroyed but these also made the life living of the people and animals become harder and need to be changed. For the reservoir

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management, the complexity of reservoir operation under the uncertainty of hydrological data caused by the effects of climate change seems to be a serious thing for the reservoir operators especially in the critical operation periods. Consequently, the various research techniques such as artificial neural network (ANN), genetic algorithm (GA), and fuzzy logic approach were used to predict the key parameter data in many ways and new operational strategies were created and applied for the determination of effective reservoir management plan in reducing the risk of failure operation. Fuzzy logic is the famous tool which is mostly applied in many fields such as engineering, computer sciences, information technology and others. It is reported that fuzzy logic is widely used especially for data prediction [1], [2]. Therefore, this study focuses on the development of two fuzzy prediction models to predict the streamflow and reservoir inflow data which are regarded as the major input data for a reservoir operation planning and management. Lam Takhong Dam is selected as a case study in order to compare the predicted results with the fuzzy prediction tools developed by Keskin [3] and ANN technique applied by Vudhivanich [4].

## 2. STUDY AREA

### 2.1 The general characteristics of Lam Takhong Basin

Lam Takhong is a branch of Mun River which is the main river of the Khorat Plateau in the northeast of Thailand and is the largest tributaries of the Mae Kong River. Lam Takhong Dam is located on the upper side of Lam Takhong Basin with the drainage area of 1,430 sq.km. Lam Takhong Dam was constructed in 1964 for mitigating flood and drought problems especially in the lower area of Mun Basin. Therefore, a large number of flow gauging stations was installed over the region to measure the streamflow rate and water stage. The flow gauging station M.89 which is the main station situated on the upstream side of the dam is regarded as the major inflow of the Lam Takhong Reservoir as appeared in Fig 1. Hence, the streamflow data at station M.89 is taken as the major input to develop the reservoir inflow prediction model applied by fuzzy logic.

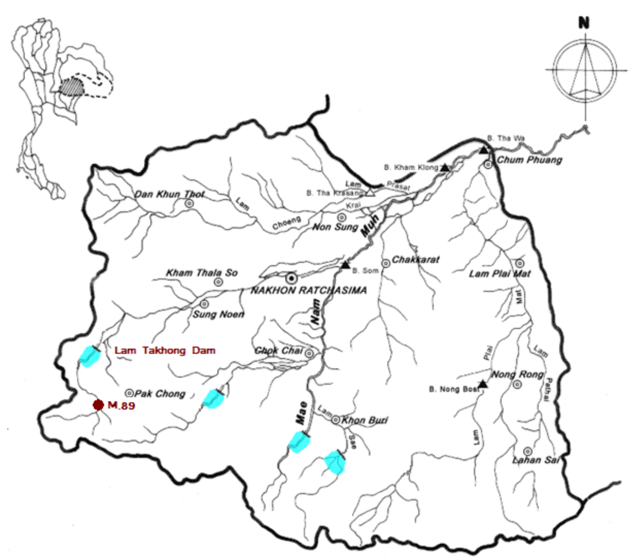



Fig 1 : The location of streamflow gauging station M.89.

### 2.2 The basin meteo-hydrological data

From the preliminary analysis of the daily streamflow data since 1970-2008 at gauging station M.89, it is found that the peak flow occurred in 1972 with 200.95 cms and the lowest flow is only 0.7 cms occurred in 1987. Meanwhile, the average flow is about 8.81 cms as plotted in Fig 2. It is also observed that the large amount of streamflow in this region is gradually increased at the beginning of rainy season. Its magnitude depends on the duration of heavy rainfall. For the water stage, it tends to be higher especially in rainy season since May-December, on the other hands it is very low in drought season since February-June.

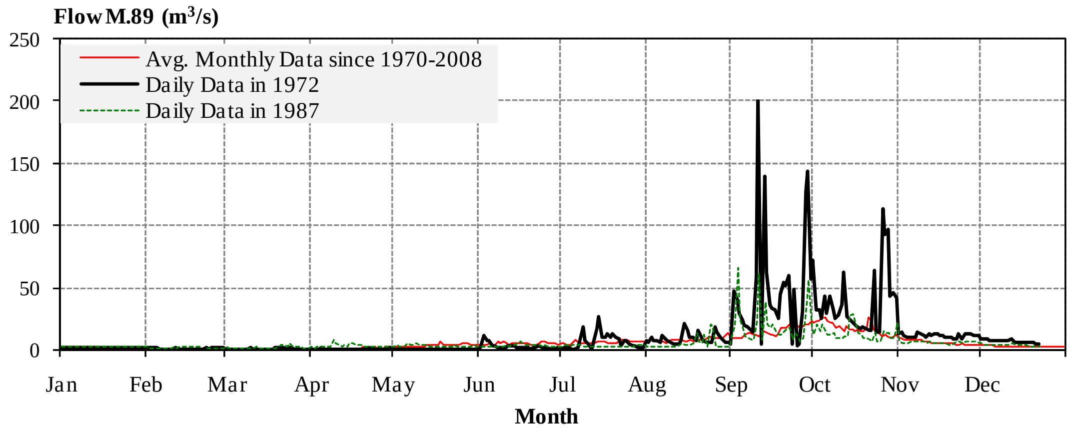



Fig 2 : Daily streamflow at gauging station M.89.

In addition, the investigation of the daily reservoir inflow data of Lam Takhong Dam since 1987-2008 showed that the peak flow is 2.0390 mcm occurred in 1990, the lowest flow is 0 mcm occurred in 2004, and the average flow is 0.0544 mcm. The low flow period starts since December until the end of June, while the high flow period starts since July until November. Besides, the peak flow period is between September and October as shown in the Fig 3.

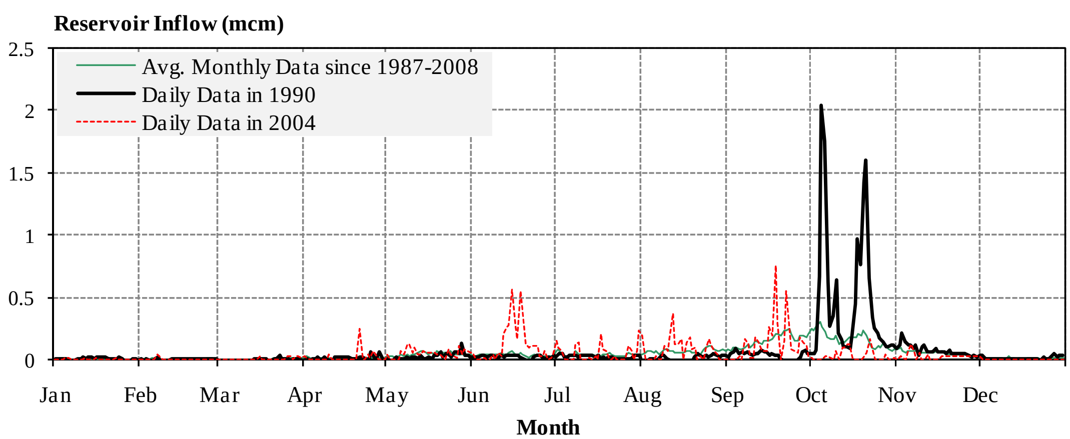



Fig 3 : Daily reservoir inflow of Lam Takhong Dam.

## 3. MATERIALS AND METHOD

### 3.1 Data collection and preliminary analysis

The streamflow data at gauging station M.89 was gathered on the daily basis since 1 May 1970 to 30 March 2008 whereas the reservoir inflow data done by the reservoir water balance concept was collected since 1 January 1987 to 30 March 2008. These collected data were preliminarily checked in parts of the abnormality and inconsistency via time series plots and filled up the missing data by the average value.

### 3.2 The determination of fuzzy prediction models

As mentioned above, the hydrological input data required for the development of fuzzy models was daily streamflow at station M.89 and the reservoir inflow of Lam Takhong Dam. Therefore, the autocorrelation of this streamflow data was analyzed in order to explain the correlation between members of a series of numbers arranged in time (Flow M.89t, t-1, …, t-n) and finally select the number of correlated variable with high correlation for the determination of streamflow prediction models (M.89 t+1) as shown in Fig 4. Meanwhile, the cross correlation between the predicted streamflow data at station M.89 ($M89_{predicted}$t+1, t, …, t-n) from the previous model and reservoir inflow of Lam Takhong Dam (Inflow t+1) was also investigated in order to specify the number of input for the reservoir inflow prediction model as shown in Fig 5. Moreover, in order to explain the periodic effects of the predicted data, $\cos\frac{(2\pi i)}{12}$ and $\sin\frac{(2\pi i)}{12}$ values were taken into account as input variables also [5], [6].

| **Input Variables** | | **Output Variables** |
|---|---|---|
| Flow M.89t, t-1,…, t-n<br>$\cos\frac{(2\pi i)}{12}$, $\sin\frac{(2\pi i)}{12}$ | → | Forecasted Streamflow<br>M.89 (t+1) |

Fig 4 : The model for forecasting streamflow at gauging station M.89.

| **Input Variables** | | **Output Variables** |
|---|---|---|
| Flow $M.89_{Predicted}$t+1, t,…, t-n<br>$\cos\frac{(2\pi i)}{12}$, $\sin\frac{(2\pi i)}{12}$ | → | Forecasted reservoir<br>Inflow (t+1) |

Fig 5 : The model for forecasting reservoir inflow of Lam Takhong Dam.

Setting membership function depended on the number of variables as specified above. The streamflow data in 1972 and the reservoir inflow data in 1990 which gave the highest peak flow were used to set the fuzzy sub-groups made by considering from the relative frequency and cumulative frequency curves of these data. The membership function of variable $\cos\frac{(2\pi i)}{12}$, and $\sin\frac{(2\pi i)}{12}$ were set by referring to the seasonal effects within a yearly cycle.

**3.3 The formulation of fuzzy rule base**

The fuzzy rule base was performed by Fuzzy Inference System or FIS type-Mamdani Model. Firstly, the AND method fuzzy operator was used to set the rule base following the concept of minimum and no weighting were applied, then the implication fuzzy operator was used to find out the result of each rule by minimum function. Aggregation fuzzy operator was used to summarize all the results by maximization operation. Finally, the centroid defuzzification method was used to find the final value of the streamflow at M.89 station and reservoir inflow of Lam Takhong Dam.

**3.3 Model calibration and validation**

To calibrate the accuracy of modeled results, the data since 1970-2008 for the streamflow prediction model and since 1987-2008 for the reservoir inflow prediction model were used. The fuzzy rule base was subsequently modified until the predicted results matched with an observed set of data. For the model validation, the streamflow data since 2006-2008 and in 1972 which gave the highest peak flow were selected for verifying the streamflow prediction model. Meanwhile, the streamflow data since 2006-2008 was also used to validate the reservoir inflow prediction model and in 1990 which gave the highest peak flow was also selected for verifying the reservoir inflow prediction model. The accuracy of model prediction was evaluated by considering the $R^2$ value and Mean Square Error (MSE) [7].

**4. RESULTS**

**4.1 The determination of membership function of input and output variables**

**4.1.1** ***The streamflow at gauging station M.89 and reservoir inflow of Lam Takhong Dam***

The results of autocorrelation and cross correlation analysis revealed that the autocorrelation and cross correlation coefficients of the input and output variables tended to be high especially from lag 1-9 which ranged between 0.41-0.82 and 0.33-0.77 respectively. However, to reduce much information for the model determination, only two previous flow; t, t-1 was selected to formulate the prediction models. For the determination of membership levels of those streamflow input and output variables, the cummulative distribution function fitted to the measured streamflow data was used. The results showed that the streamflow data was fitted to the fatigue life distribution quit well. Consequently, it can set the membership value of the streamflow data at time t, t-1 as illustrated in Fig 6. This cumulative distribution curve was also used to identify the membership levels of target outputs as shown in Fig 7. For the reservoir inflow of Lam Takhong Dam, it was demonstrated that Wakeby distribution with five parameters was fitted to this reservoir inflow data. Therefore, this cumulative distribution curve was brought to set the membership function of reservoir inflow (output) as illustrated in Fig 9. Meanwhile, the membership levels of the predicted streamflow data at station M.89 at time t and t+1 were specified similar to the previous one as shown in Fig 9. It was noticeable that the wide and short range of cumulative probability was set to specify the linguistic terms of those variables by referring to the behavior of actual observed flow data at time t.

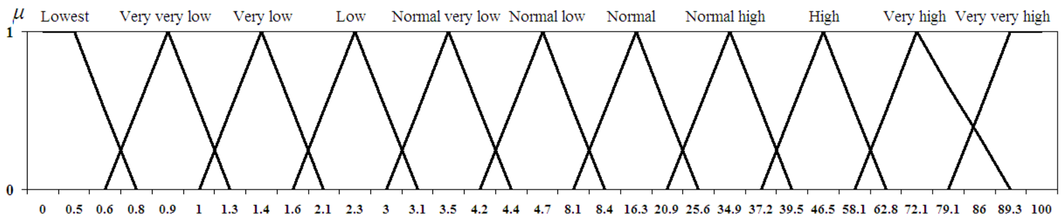



Fig 6 : The membership function of streamflow at time t and t-1.

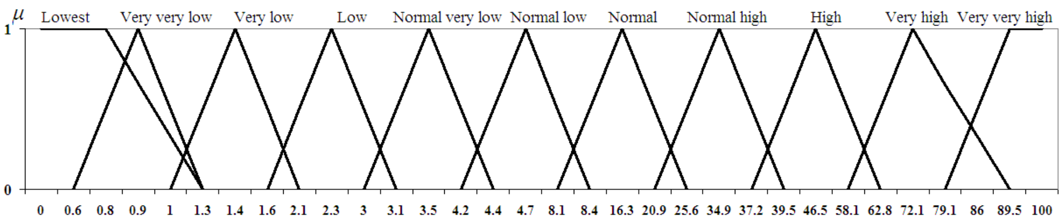



Fig 7 : The membership function of streamflow at time t+1.

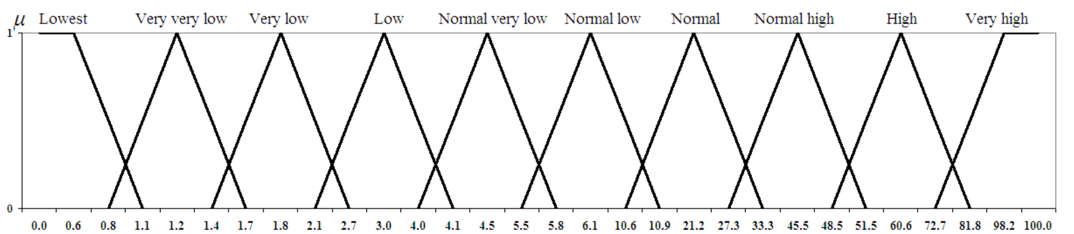



Fig 8 : The membership function of streamflow at time $M.89_{Predicted}t+1$ and $M.89_{Predicted}t$.

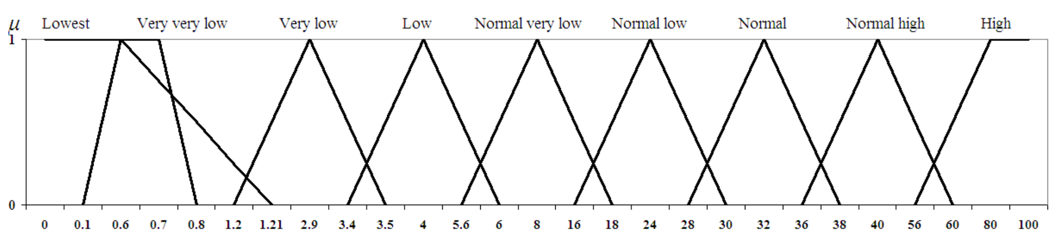



Fig 9 : The membership function of reservoir inflow at time t+1.

### 4.1.2 *The periodicity variables*

To set the membership levels of $\cos\frac{(2\pi i)}{12}$, $\sin\frac{(2\pi i)}{12}$ which refers to the effects of monthly periodicity of streamflow and reservoir inflow data, the following in Fig 10 are the details of how to set the membership values of these variables.

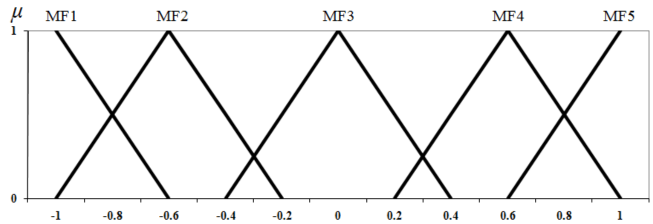



Fig 10 : The membership function of monthly periodicity.

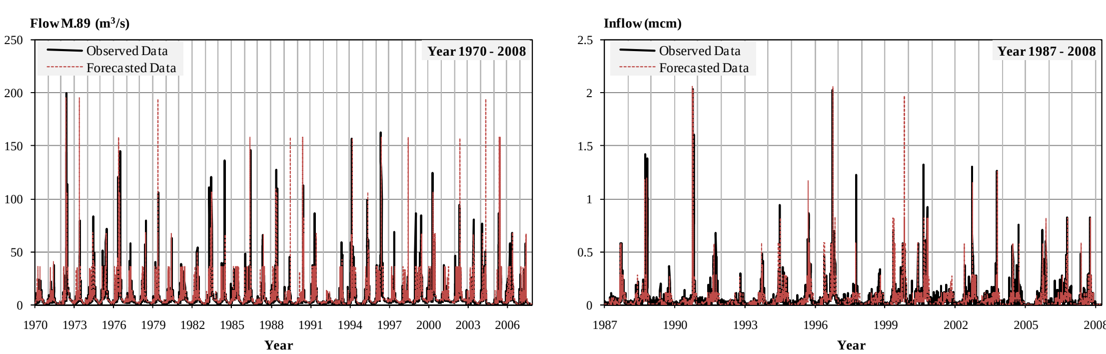
### 4.2 The formulation of fuzzy rule base

Mamdani model was used to set the rule base by if-then law. For example, If (t is lowest) and (t-1 is lowest) and (cos is mf1) and (sin is mf1) then (t+1 is lowest), this means that if streamflow at day t is the lowest and streamflow at day t-1 is the lowest and cosine value of month t is in mf1 function and sine value of month t is in mf1 function then streamflow at day t+1 is the lowest. In this study, the streamflow data during year 1970-2008 was used and the model was set totally 132 base rules and then the model was inferenced. Finally, the model was defuzzificated in order to find the target steamflow at station M.89. The results showed that the predicted accuracy of streamflow was quite low with 0.17 of $R^2$ and the MSE was very high nearly 1,163 cms. For the reservoir inflow prectiction model, the fuzzy model was set with 120 base rules in order to predict the net inflow that flow into the dam. The predicted results showed that the $R^2$ was only 0.199 but the MSE was low merely 0.166 mcm.

### 4.3 The results of model calibration and validation

#### 4.3.1 *Model calibration*

To enhance the prediction accuracy, the author adjusted the rule base of streamflow at station M.89 by increasing the fuzzy rules from 132 rules to 299 rules. The predicted results of new fuzzy rules were shown in Fig 11(a). It was revealed that $R^2$ was increased from 0.17 to 0.60 and the MSE was also reduced from 1,163 to 56. When the rule base of reservoir inflow prediction model was adjusted from 120 rules to 227 rules, the predicted result became more accurate as graphically illustrated in Fig 11(b). The $R^2$ was increased from 0.199 to 0.61 and the MSE was reduced from 0.166 to 0.006.




(a) (b)

Fig 11 : (a) Comparison of the observed and predicted streamflow data after calibration.
(b) Comparison of the observed and predicted reservoir inflow after calibration

### 4.3.2 *Model validation*

Both prediction models were validated by using the daily streamflow data in 2006-2008 as a set of input variables. The validation results showed that the predicted streamflow was more accurate. The $R^2$ of streamflow and reservoir inflow prediction were 0.63 and 0.62 and the MSE were 1.89 cms and 0.002 mcm, respectively as graphically illustrated in Fig 12(a) and Fig 12(b). Moreover, when the short-term streamflow data in 1972 was selected to validate the streamflow prediction model, the $R^2$ was increased to 0.78, however the MSE was increased to 2.99 cms. Besides, it was investigated that the prediction results were not good enough especially during the sudden changes in streamflow from peak flow to low flow period. The validation result of reservoir inflow prediction model with data in 1990 tended to be better. The $R^2$ was increased to 0.78 and MSE was slightly increased to 0.041. Moreover, the predicted results were very close to the observed data both low flow and high flow periods as graphically shown in the Fig 13(c) and Fig 13(d).

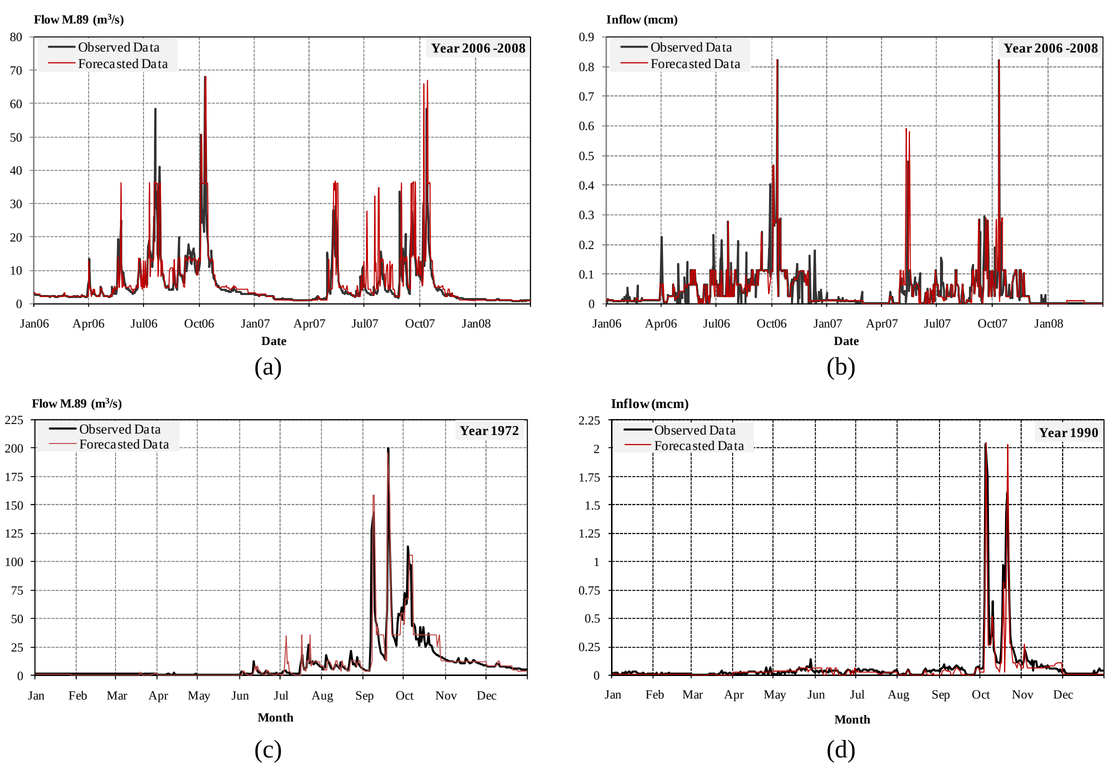



Fig 13 : (a), (c) are comparison of the observed and predicted streamflow data in model validation when the data since 2006-2008 and in 1972 were used.
(b), (d) are comparison of the observed and predicted reservoir inflow when the data since 2006-2008 and in 1990 were used.

### 4.4 Discussion

Similar to the study results by Keskin [3] which developed the fuzzy model to predict the daily streamflow in the Middle Mediterranean in Turkey, it was reported that the accuracy of model prediction was approximately 0.71 which was not much difference by comparison with that obtained from the fuzzy streamflow prediction model of station M.89 which was around 0.78. By comparing with the predicted results using other techniques like artificial neural network models by Vudhivanich [4], two types of ANN prediction models were developed; single reservoir prediction model and multireservoir prediction model, to predict the reservoir inflow of Mun Bon, Lam Chae, Lam Takhong, and Lam Phra Ploeng Reservoirs in Thailand. Consequently, a various form of ANN prediction models was formulated by varying the number of input variables, ANN structures, together with the different types of transfer functions. It was found that the predicted output received from the single reservoir model gave the best result with 0.55 of $R^2$ which was lower than that obtained from the fuzzy prediction model approximately 6%. Moreover, the fuzzy prediction model also gave the better results by comparison with the multireservoir prediction model applied with ANN technique.

## 5. CONCLUSIONS

The fuzzy logic approach was applied to develop the streamflow and reservoir inflow prediction models. The results showed a reasonable level of the modeled prediction accuracy both $R^2$ and MSE. Moreover, the predicted patterns of target outputs were similar to the observed values for both low and high flow periods. In the other words, the fuzzy prediction models are an effective tool in hydrologic data prediction and are very useful especially for the water resource planning and management.

## 6. ACKNOWLEDGEMENT

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# IMPACTS OF NATURAL ENEMIES ON POPULATION OF POD FLY (*Melanagromyza obtusa* Malloch) IN PIGEON PEA [*Cajanus cajan* (L.) Millsp.] - A CASE STUDY

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## ABSTRACT

A study was conducted on incidence of Pod fly (*Melanagromyza obtusa* Malloch, Order:Diptera, Family:Agromyzidae) and its natural enemy population on pigeon pea during 2009-10 in Kalyani, West Bengal. The fly gave its appearance during $2^{nd}$ standard week (January 2010) and continued up to $16^{th}$ standard week (April 2010) with smaller peaks during $7^{th}$, $9^{th}$ and $11^{th}$ standard week during the crop season. Population remained fluctuating in between 0.83 to 3.45 larvae per pod. During study two Hymenopteran larval parasites (*Euderus* sp. and *Ormyrus* sp.) were found to be associated with *M. obtusa*, which appeared almost a week later the pod fly infestation. The parasitization level also exhibited identical fluctuation as that of the host insect. Cumulative rate of parasitization, however, recorded on *M. obtusa* larvae was high during $5^{th}$, $8^{th}$ and $10^{th}$ standard weeks in 2010 showing 8.3%, 11.6% and 17.8% parasitization respectively.

## 1. INTRODUCTION

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is an important pulse or grain legume in semi-arid tropical and subtropical areas of the world. Approximately 90% of world production of this crop comes from Asian countries, where pigeon pea is the third most important pulse crop. India, Myanmar, and Nepal are the largest producers of this pulse crop [14]. In India it is one of the most important pulse crops in terms of area, production and consumption. Nitrogen fixing potential of red gram makes it an ideal intercrop in organic management. Insect pests are the most important yield constraint in most of the areas and the greatest cause of yield variation. More than 200 species of insects have been found feeding on pigeon pea, although only a few of these cause significant and consistent damage to the crop [9]. A generalized review of pigeon pea pests and control strategies was presented by Reed & Lateef [17]. The most serious pests, and the primary focus of pigeon pea pest management research, are those that attack reproductive structures, including buds, flowers, and pods. Pod fly, *Melanagromyza obtusa* (Diptera: Agromyzidae) is mainly a pest of eastern and southern Africa [11] and also occupies a similar ecological niche [12,13]. It causes a large percentage of seed damage in pigeon pea which is considered as one of the most destructive insect pest

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and a cause behind yield loss of this crop. This fly feed only on pigeon pea and closely related species within the subtribe Cajaninae [18]. Some of the workers studying the bio-ecology of *M. obtusa,* recorded various hymenopteran parasites attacking its immature stages [2, 19]. Effective management of insect pests by natural enemies is becoming an integral part of sustainable agriculture. This research work emphasizes the incidence of pigeon pea pod fly, their natural enemy population and effect of natural enemy complex on pest population fluctuations. The purpose of the study is to provide specific pest-natural enemy interactions and management as an easy reference for further work with flexibility for accommodating new information.

## 2. THE PEST

*Melanagromyza obtusa* (Diptera: Agromyzidae) larvae feed on the seed, consuming its starchy portions and the embryo. They leave a trail of excreta which renders the seed inedible, and damaged embryos will not germinate.

### 2.1 Morphology

Both sexes are 2-3 mm long, and may appear black to the naked eye, but the thorax and abdomen have a distinct, green metallic sheen if examined under magnification (Fig. 1). The head has a prominent ocular triangle (Fig. 2), also metallic green that extends to the lunule (recessed crescent above the antennae). The wings are clear. The female has an unusually long, black ovipositor sheath. The male is similar to the female but lacks an ovipositor.

**Fig. 1:** Dorsal view of *Melanagromyza obtusa*

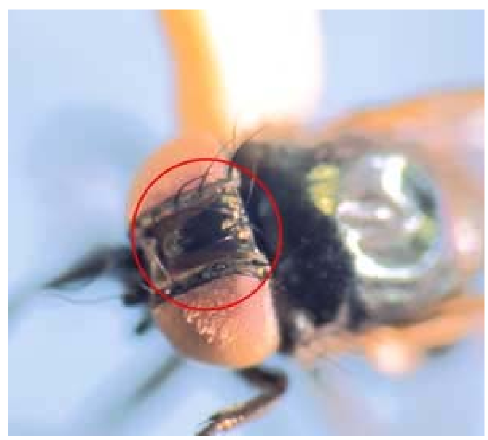

**Fig. 2:** Ocellar triangle indicated by circle

### 2.2 Biology and ecology

*M. obtusa* females produce up to 80 eggs and lay them individually into developing pigeon pea pods. Development of the immature stages under field conditions includes 3–5 days for the egg stage, 6–11 days for the three larval instars, and 9–23 days for the pupal stage. Adults live up to 12 days when fed with honey and about half as long without food [1]. The population dynamics of *M. obtusa* are governed by its narrow host range and feeding niche. In India, pigeon pea pods are available in the field from approximately October to April, and infestations increase rapidly over a relatively short period [16]. Fewer eggs are laid in December and January when temperatures are low, and populations increase as temperatures rise. Long-duration pigeon pea crops mature in March or April and can be heavily damaged [7]. *M. obtusa* may survive the offseason on alternate hosts such as *Rhyncosia minima*, which have been found to be infested with eggs, larvae, and/or pupae between April and November [6].

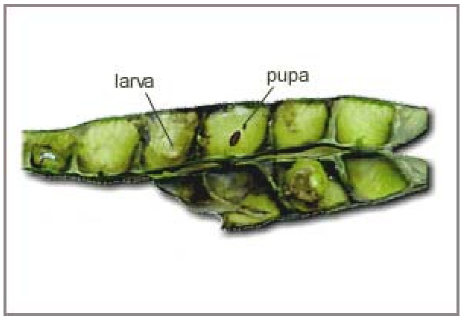


**Fig. 3:** Immature stages inside pod

**Fig. 4:** Puparium of *Melanagromyza obtusa*, dorsal view; posterior spiracles indicated by circle.

### 2.3 damage

Pod fly damage has been reported from several countries. In India, the pod fly is a more serious pest in northern and central areas than in other parts of the country [10]. Damage levels in farmers' fields range from 10 to 50% [8, 15, 22]. In Vietnam, *M. obtusa* is the key pest of pigeon pea, causing seed losses of more than 90% [5], while damage of 43% is reported from Taiwan [23]. Seed damage of less than 1% was observed in Malawi and Tanzania, 3–5% in Uganda, and up to 15% in Kenya [12].

## 3. MATERIALS AND METHODS

Biological survey was conducted in experimental plots in 'C' Block Farm, BCKV, Kalyani, West Bengal during 2009-10. Observations on incidence of pod fly and its natural enemies were done by studying 10 sample plants per plot. Observation data were taken at 8 a.m. on every scheduled day. Meteorological parameters were observed during whole study for simple co-relation with pest and natural enemy population. Pod fly larvae feed on the seed, consuming its starchy portions and the embryo. They leave a trail of excreta on the seed. By identifying specific damage symptoms, damaged pods were collected from sample plants for further study. In laboratory those damaged pods were opened under microscope with strong light to observe the presence of immature stages of pod fly. Simultaneously the presence of eggs and larval stages of parasites feeding on immature stages of host were also studied. Parasitized pod fly larvae were counted to get percent parasitization data.

Parasitized immature stages of *M. obtusa* were closed in pod and placed in Petri dishes containing puffs of moist cotton, which prevented the drying up of pods. Pod surface was treated with absolute alcohol, preventing the fungal attack. Observation revealed the parasitized pupae, which was transparent, allowing us to see the parasite act within the host puparium. Adults were preserved in 70% alcohol. Some of them were mounted on slides in Canada balsam for further taxonomic study.

### 3.1 Data analysis

Population data of both pod fly and natural enemy complex were recorded on each standard week, starting from 1$^{st}$ to 16$^{th}$. Three sets of data were collected to calculate mean population along with their standard deviations. Important meteorological parameters (i.e. Temperature and Relative Humidity) were collected and tabulated from local Meteorological Observatory (situated at ‘C’ Block Farm, BCKV, Kalyani). Through simple statistical formula in MS-Excel 2007, population fluctuations of pod fly and its parasites were co-related with meteorological parameters and from counted parasitized larvae of pod fly, percentage parasitization were calculated.

## 4. MAJOR FINDINGS

The fly gave its appearance during 2$^{nd}$ standard week (2$^{nd}$ week of January, 2010) and continued up to 16$^{th}$ standard week (April 2010) during the crop season. Weekly observations on the incidence revealed that, within this period of its occurrence, the population increased rhythmically showing smaller peaks during 7$^{th}$, 9$^{th}$ and 11$^{th}$ standard week, which are 2.43, 2.82 and 3.45 larvae per pod, respectively. Pod fly population increased with increasing temperature. Maximum Relative Humidity during that period remains almost same. Population remained fluctuating in between 0.83 to 3.45 larvae per pod.

During study two hymenopteran larval parasites [*Euderus* sp.(Hymenoptera:Eulophidae) and *Ormyrus* sp. (Hymenoptera:Ormyridae)] were found to be associated with *M. obtusa*, which appeared almost a week later of pod fly infestation. Shanower *et. al.,* [18] listed more than 14 hymenopteran species associated with this pest, though several research works focused on specific some. Singh (1994) reared and studied these 2 species in India and found them quite effective as parasites of pigeon pea pod fly [20]. Ahmad (1940) and Singh (1990) studied the bio-ecology of these two parasites [2, 19]. *Euderus* spp. are solitary or facultatively gregarious ectoparasitoids and are found in India [21], Sri Lanka [3], and the Philippines. Parasitism rates of more than 25% have been reported for this group [2, 25]. *Ormyrus orientalis* and *Ormyrus fredricki* are solitary endoparasitoids that parasitize up to 13% of hosts in India (24). Parasitism levels of up to 30% have been reported for *O. orientalis* in Sri Lanka [4]. In our study the population of these 2 species also exhibits fluctuations as that of the host insect. They came up one week later the pod fly and continued with their host. Smaller peaks were observed at 5$^{th}$, 8$^{th}$ and 10$^{th}$ standard week, which were, 1.62, 2.03, 2.42 per pod, respectively. Cumulative rates of parasitization, however, recorded on *M. obtusa* larvae were high during 5$^{th}$, 8$^{th}$ and 10$^{th}$ standard week in 2010 showing 8.3%, 11.6% and 17.8% parasitization respectively.

**Table 1.** Weekly maximum-minimum temperature and relative humidity during pod fly and their natural enemy complex incidence record period at ‘C’-Block Farm, BCKV, Kalyani.

| Standard Week no. | Temperature ($^0$C) | | Relative Humidity (%) | |
|---|---|---|---|---|
| | Max. | Min. | Max. | Min. |
| 1 | 23.1 | 8.8 | 97.3 | 55.3 |
| 2 | 21.9 | 11.0 | 93.9 | 61.7 |
| 3 | 23.2 | 9.0 | 96.5 | 51.9 |
| 4 | 24.5 | 9.1 | 95.4 | 37.6 |
| 5 | 27.7 | 10.2 | 95.6 | 36.9 |
| 6 | 29.3 | 15.2 | 95.7 | 42.0 |
| 7 | 29.1 | 15.7 | 97.0 | 48.4 |
| 8 | 32.3 | 17.3 | 97.3 | 48.1 |
| 9 | 32.8 | 21.2 | 97.9 | 32.9 |
| 10 | 34.3 | 19.4 | 93.4 | 35.9 |
| 11 | 35.9 | 21.9 | 91.9 | 41.6 |
| 12 | 37.2 | 25.3 | 97.1 | 54.9 |
| 13 | 37.1 | 26.6 | 95.1 | 52.6 |
| 14 | 38.2 | 25.3 | 97.4 | 40.4 |
| 15 | 36.7 | 27.1 | 94.1 | 56.1 |
| 16 | 38.3 | 27.2 | 93.7 | 51.4 |

**Table-2:** Average population of pigeon pea pod fly, their natural enemy complex (parasite) population and % parasitization.

| Standard Week | Avg. pod fly population /10 pods (mean±SD) | Avg. parasite population/ 10 pods (mean±SD) | % parasitization |
|---|---|---|---|
| 1 | 0±0 | 0±0 | 0 |
| 2 | 8.33±0.51316 | 0±0 | 0 |
| 3 | 11.23±0.45092 | 7.90±0.26458 | 3.5 |
| 4 | 15.13±0.25166 | 10.97±0.49329 | 5.2 |
| 5 | 17.80±1.17898 | 16.17±0.25166 | 8.3 |
| 6 | 20.40±0.79373 | 14.17±0.45092 | 8.2 |
| 7 | 24.30±0.45826 | 17.47±0.65064 | 9.4 |
| 8 | 22.33±0.60277 | 20.27±0.61101 | 11.6 |
| 9 | 28.27±1.40475 | 18.23±0.30551 | 12.9 |

| | | | |
|---|---|---|---|
| 10 | 26.30±0.55678 | 24.23±0.35119 | 17.8 |
| 11 | 34.53±0.66583 | 19.17±0.40415 | 15.6 |
| 12 | 30.56±0.56862 | 17.63±0.45092 | 14.5 |
| 13 | 28.23±0.70238 | 13.97±0.28868 | 13.8 |
| 14 | 26.73±0.60277 | 12.83±0.35119 | 12.7 |
| 15 | 25.96±0.68069 | 12.57±0.47258 | 11.3 |
| 16 | 23.46±0.75056 | 9.87±0.30551 | 11.1 |

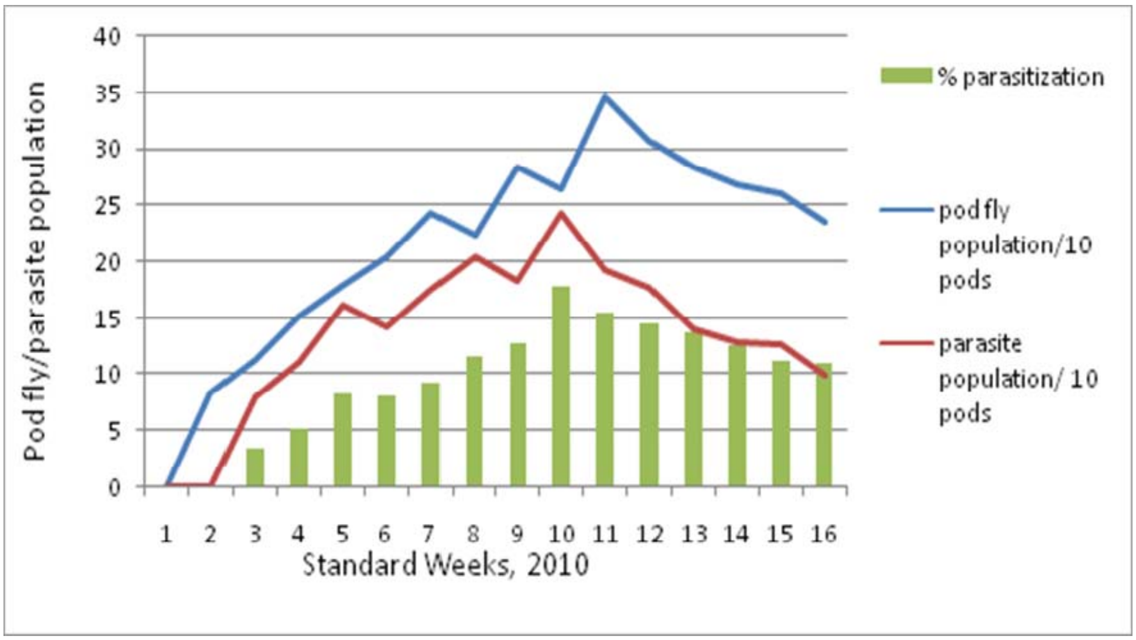


**Fig.5:** Graphical representations of mean pod fly population along with the mean parasite population and % parasitization during different standard weeks.

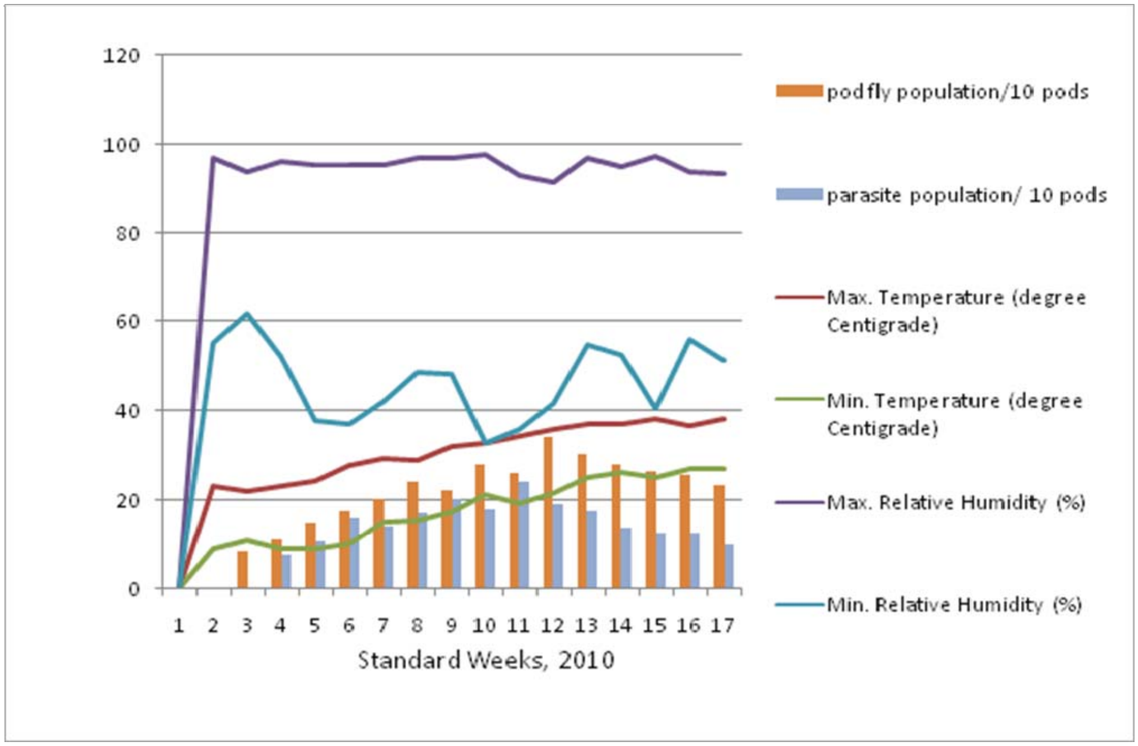


**Fig.6:** Graphical representations of mean pod fly population, mean parasite population fluctuations and % parasitization along with meteorological parameters during different standard weeks.

## 5. CONCLUSION

From this study, we can say that, in absence of pesticides there are some prominent effects of natural enemies on their host. Parasitism is identified as important mortality factor of the larval populations of pigeon pea pod fly. But we found that, only these two hymenopteran larval parasites could not prevent the pest population from causing economic damage to the crop, though the crop was exposed to further high extent of damage by the pod fly infestation, in absence of parasites, under normal condition. So, we can conclude that, for effective management of pigeon pea pod fly, there should be some other compatible sustainable management practices along with conservation of specific natural enemies in the field.

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# A NOVEL CONTROL STRATEGY FOR SMALL WIND ENERGY CONVERSION SYSTEM USING LOAD CONTROL

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## ABSTRACT

Furling control method found to be the most common control method for small wind turbine industry to control the aerodynamic power extraction from the wind. A small wind turbine with furling mechanism and its resulting dynamics is modeled in Matlab/Simulink platform. The model is simulated to regulate the speed of the wind turbine via a load control method. The wind turbine is operated at the optimum tip speed ratio thus ensures the maximum power extraction. A dynamic peak power tracker (PPT) and a novel control strategy using load control is designed and simulated. In this control strategy, the controller uses the current value of $P_{max}$ (corresponding to the current value of rotor rpm) and output power at the load and uses the difference to control the load connected to the system. System modeling and simulation results are presented to validate the approach. It has been found that the system is able to adapt the control strategy and behaves appropriately. The variable of a wind energy conversion system reaches to a stable state after a step change in wind speed and ensures the effectiveness of the control strategy.

**Key Words:** Peak power tracker (PPT), maximum power extraction, life-cycle, greenhouse, aerodynamic power, tip speed ratio (TSR), and wind power generation systems (WPGS).

## 1. INTRODUCTION

The installed wind power capacity in the world has been increasing at more than 30% per year over the past decade [1, 2]. The current surge in wind energy development is driven by multiple forces in favour of wind power including its tremendous environmental, social and economic benefits, the technological maturity, and the deregulation of electricity markets throughout the world, public support, and government incentives. Based on a life-cycle assessment [3], the greenhouse gas emission from worldwide electricity generation with the 2000 fuel mix is 0.572 kg of equivalent per kWh. In 2000, the total world electricity generation was 14617 KWh, emitting about 8364 megatons of equivalent.

Recent developments in wind power generation have provided an economically competitive and technically sound solution to reduce greenhouse gas emissions. The power produced by the wind turbine is directly related to the wind speed. So at high wind speed, when the turbine is generating more power than its rated output, some types of control should be implemented

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to control the aerodynamic power. One of the methods to control of the wind turbine mechanical power is furling control method which is most likely the most useable control method now a day. Furl the wind turbine rotor against the wind is the basic idea of this method. So, scope of the work has been explored in this area. But in the practical situation, along with aerodynamic control we need to meet the load demand of the user. As a whole, a proper strategy should be selected so that it will maintain equilibrium between the user demand as well as power extraction from the wind. The strategy should also ensure the maximum power extraction.

In this work, firstly, an aerodynamic power control via furling as well as a dynamic peak power tracker (PPT) has been designed and simulated. A novel control strategy has been selected using the load control method. The paper is organized as follows: the first section is a short overview of the work to be presented, the second section presents the control strategy followed by the mathematical model of the system components in the third section, the fourth section contains the simulation results and findings are highlighted in the conclusions.

## 2. CONTROL STRATEGY

Variable speed operation and direct drive generators have been the recent developments in wind turbine drive trains. Compared with constant speed operation, variable speed operation of wind turbines provides 10–15% higher energy output, lower mechanical stress and less power fluctuation. In order to fully realize the benefits of variable speed wind power generation systems (WPGS), it is critical to develop advanced control methods to extract maximum power output of wind turbines at variable wind speeds. A variable speed WPGS needs a power electronic converter, often called an inverter, to convert variable-frequency, variable-voltage power from a generator into constant-frequency constant-voltage power, and to regulate the output power of the WPGS. Traditionally a gearbox is used to couple a low speed wind turbine rotor with a high speed generator in a WPGS. Recently much effort has been placed on the use of a low speed direct-drive generator to eliminate the gearbox [4].The mechanical output power at a given wind speed is drastically affected by the turbine's tip speed ratio (TSR), which is defined as the ratio of turbine rotor tip speed to the wind speed. At a given wind speed, the maximum turbine energy conversion efficiency occurs at an optimal TSR [5].Therefore, as wind speed changes, the turbine's rotor speed needs to change accordingly in order to maintain the optimal TSR and thus to extract the maximum power from the available wind resources. Researchers have developed several methods to extract the maximum power from the wind turbine. TSR control regulates the wind turbine rotor speed to maintain an optimal TSR. In TSR control, both the wind speed and turbine speed need to be measured for TSR calculation, and the optimal TSR must be given to the controller. The first barrier to implement TSR control is the wind speed measurement [6], which adds to system cost and presents difficulties in practical implementations. The second barrier is the need to obtain the optimal value of TSR, which is different from one system to another. This dependency on turbine-generator characteristics results in custom-designed control software tailored for individual wind turbines. Another option is to extract the maximum power is the hill-climbing control method. This method is based on the power measurement at the output.

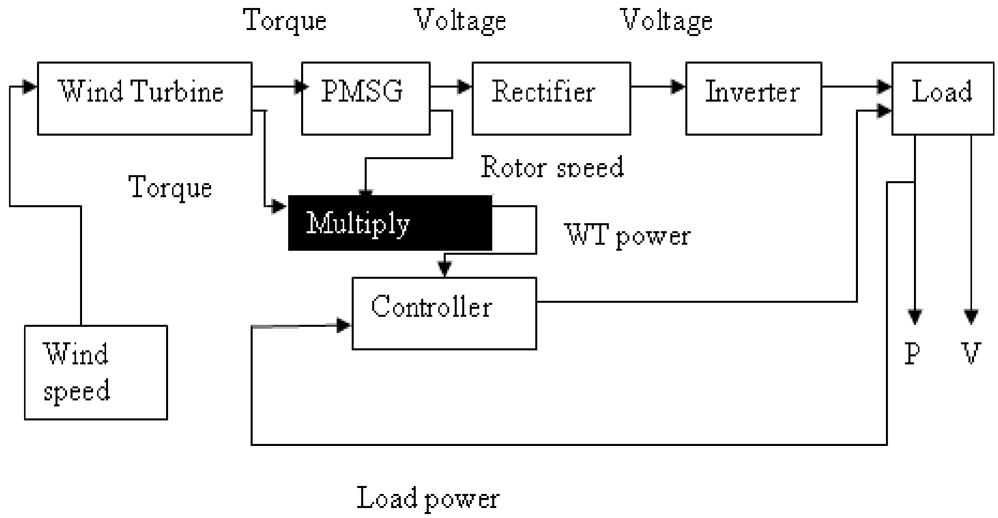


Fig. 1: Block diagram of the proposed control strategy

load and based on this difference increase or decrease the slope of the power curve through the maximum power point. It has also demerits that to find a suitable parameter for the controller is hard to achieve. Besides this, there is no well developed method to determine the controller parameter. So obviously it will be time consuming and also some uncertainty should be involved with this control method. Due to these complexities a simple way to extract the maximum power from the wind turbine has discussed in this paper to model the wind turbine such that at all time it maintains its optimum tip speed ratio. Thus it ensures the maximum power extraction. A dynamic peak power tracker (PPT) and a novel control strategy using dump load is designed and simulated. In this control strategy, the controller uses the current value of $P_{max}$ (corresponding to the current value of rotor rpm) and output power at the load and based on this difference tries to control the load connected to the system through a rectifier and an inverter. Simulation has shown that the output power and voltage has controlled using the suitable parameter value of the PI controller. The block diagram of such a control strategy has been shown in Fig. 1.

## 3. MODELING OF THE SYSTEM COMPONENTS

A stand-alone variable speed wind turbine when connected to a load should be controlled to extract the maximum power. Several works has been done to extract the maximum power out of the turbine [2-5]. Dynamic modeling and simulation is required to determine the suitable controller of the wind turbine connected to a load. The wind turbine and the associated components have modeled by the following equations.

The output power of the wind turbine can be expressed as,

$$P_{aero} = 0.5\, \rho\, A\, Cp\, (\lambda)\, V^3 \qquad (1)$$

The torque produced by the wind turbine is then:

$T_w = P_{aero}/\omega_m$ (2)

Where, $\omega_m$ = Angular velocity of the wind turbine rotor (rad/s). Also, the tip speed ratio $\lambda$ is given in terms of rotor speed, ωm and wind speed, V (m/s) as:

$\lambda = R\ \omega_m / V$ (3)

Where R = the radius of the wind turbine rotor (m).

Therefore, the torque term becomes

$T_w = 0.5\ \rho\ A\ Cp\ (\lambda)\ V^3 /\omega_m = 0.5\ \rho\ A\ R\ Cp\ (\lambda)/\lambda * V^2$ (4)

But, we know, Torque co-efficient = $C_t\ (\lambda) = C_p\ (\lambda)/\lambda$. When the wind speed increases it produces an angle $\theta$ with the horizontal axis. The effective wind velocity at the rotor plane will be $V\cos\theta$ [6]. Putting all these values, we get the final expression of the torque as:

$T_w = 0.5\ \rho\ A\ R\ C_t\,(\lambda) * (V\cos\theta)^2$ (5)

The wind turbine is considered to be of similar to Bergey Excel - S rating and incorporates furling mechanism and is based on permanent magnet synchronous generator (PMSG). The permanent magnet synchronous generator has been modeled in the rotor reference frame. If we assume zero sequence quantities are not present and apply Park's transformation, the terminal voltage of the PMSG in the rotor reference frame can be expressed as [7]:

$V_{gq} = -(R_g + p\ L_{gq})\ i_{gq} - \omega_r\ L_{gq}\ \ i_{gq} + \omega\ \lambda_m$ (6)

$V_{gd} = -(\ R_g + p\ L_{gd})\ i_{gd} + \omega_r\ L_{gq}\ \ i_{gq}$ (7)

Where $R_g$ = stator phase winding resistance ($\Omega$).

$L_{gq}$ = stator inductance in the quadrature axis (H).

$\omega_r$ = rotor angular velocity of the generator (rad/s)

$\lambda_m$ = Flux linkage (V-s/rad)

p = operator d/dt

The electromagnetic torque in the rotor reference frame may be written as

$T_e = (3/2)(P/2)\ [(L_{gd} - L_{gq}\ )\ i_{gq}\ i_{gd}\ - \lambda_m)\ i_{gq}$ (8)

Where P = Number of poles of the PMSG.

The relation between the angular velocity of the generator ωr and mechanical angular velocity of the rotor ωm can be expressed by:

$\omega_r = (P/2)\ \omega_m$ (9)

The rotational speed and the torque produced by the wind turbine can be related as:

$T_w = J\ (2/P)\ p\omega_m - Te + B\ \omega_m$ (10)

A small friction term has been added in the generator for making it more realistic. Tw is the torque produced by the wind turbine and should be the input to the PM.

The stator voltage of the PM can be expressed as

$$V_{sg} = -(R_g + p\,L_g)\,i_{gq} + \lambda_m\,\omega_r \tag{11}$$

As we did not consider the rectifier as a controlled one, so the delay angle $\alpha$ of the rectifier will be zero. As a result the direct axis current $i_{gd} = 0$ [7].

In terms of rotor reference frame quantities and the assumption of non-existence of zero sequence current, we can write:

$$V_R\,I_R = (3/2)\,(V_{gq}\,i_{gq} + V_{gd}\,i_{gd}) \tag{12}$$

Since Vgd is zero and same as igd, we can write:

$$i_{gq} = (V_R\,I_R)/(3/2 * V_{gq}) \tag{13}$$

The simplified dc output voltage of the rectifier can be expressed as

$$V_R = (3*\sqrt{3})\,V_{sg} \tag{14}$$

And the current will be:

$$I_R = P_{load}/\,V_{sg} \tag{15}$$

The power inverter has been modeled by the basic principle of pulse width modulation (PWM) operation. Then a simple series RL load model has been considered as a load.

## 4. SIMULATION RESULTS

The system that that has been described above is simulated using Matlab-SimulinkTM blocks. The load has been considered here is a simple RL load, which is mainly used for home appliances. The main advantage that has been noticed here is that only the self block of the simulink is used to model the total system which greatly enhanced the time to complete the simulation and also simulation can be done for a long time. The model that will describe the system is presented in Fig. 2.

The output of the rectifier has been converted into AC by a simple inverter and the load has been adjusted using the difference in power. A PI controller has been adjusted the load connected to the system. The controller value has been calculated simple Ziegler-Nichols (ZN) method. The suitable controller parameter has been found as; Kp=6; Ki=1; Kd=0. A step input of 11.5 m/s to 12.5 m/s has been applied after a stable condition (7 seconds). The simulation has started from 7 second and within 17 second all the quantities has reached to a steady state value. The furling angle and generator speed (RPM) is increasing with the increase in wind speed and has come in a stable state within 10 second (Fig. 3). Fig. 4 shows the output power and output voltage of the PWM inverter. It is easily notable that after a step wind speed, power and voltage returns to the stable value and system stabilization are achieved. It is observable the proposed control strategy effectively can ensure the system stabilization

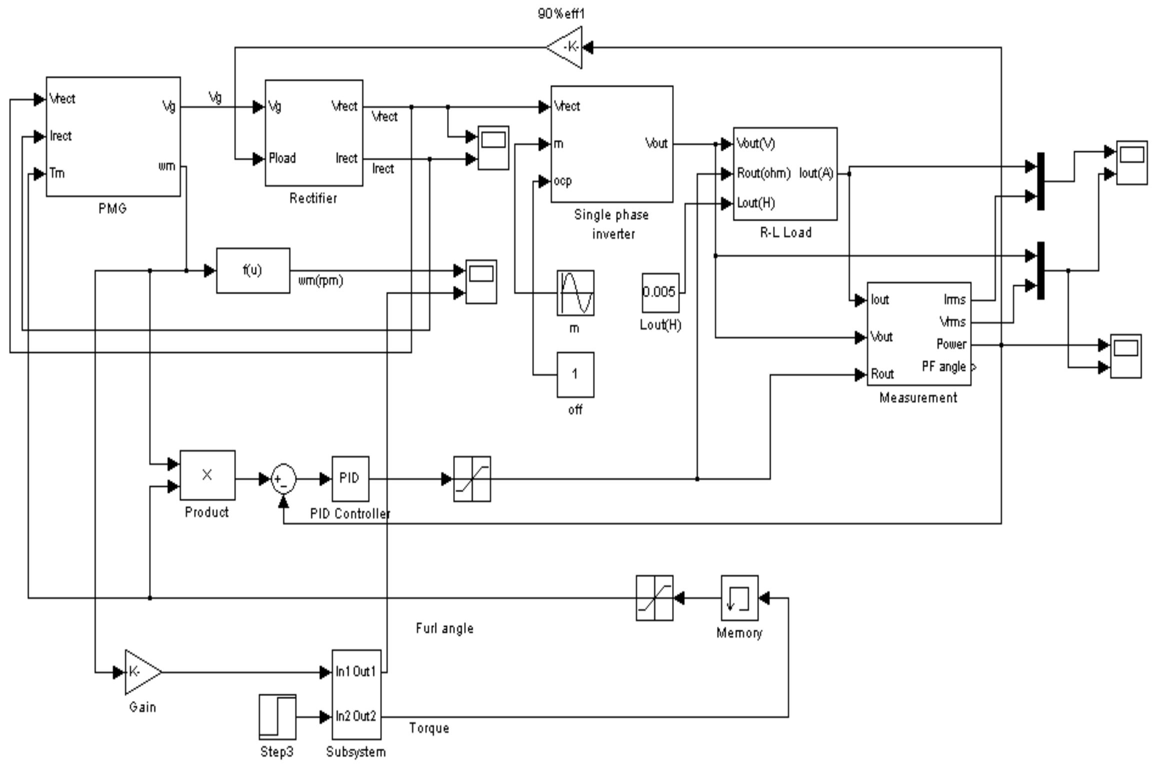


Fig. 2: Simulation model of the wind turbine with PPT

after a drastic change in wind speed. It should be mentioned that a step input is the most drastic change and can able to reflect the worst case of scenario from the control point of view.

To ensure the furling action on the turbines power production model was simulated from 1m/s to 23 m/s and the corresponding curve can be viewed in Fig. 5. It has been found that after 17 m/s wind speed there is a sudden decrease in power which ensures the furling action of this wind turbine. However, the simulated furling speed may not match with the a real wind turbine and is due to the parameter variation of the simulated system.

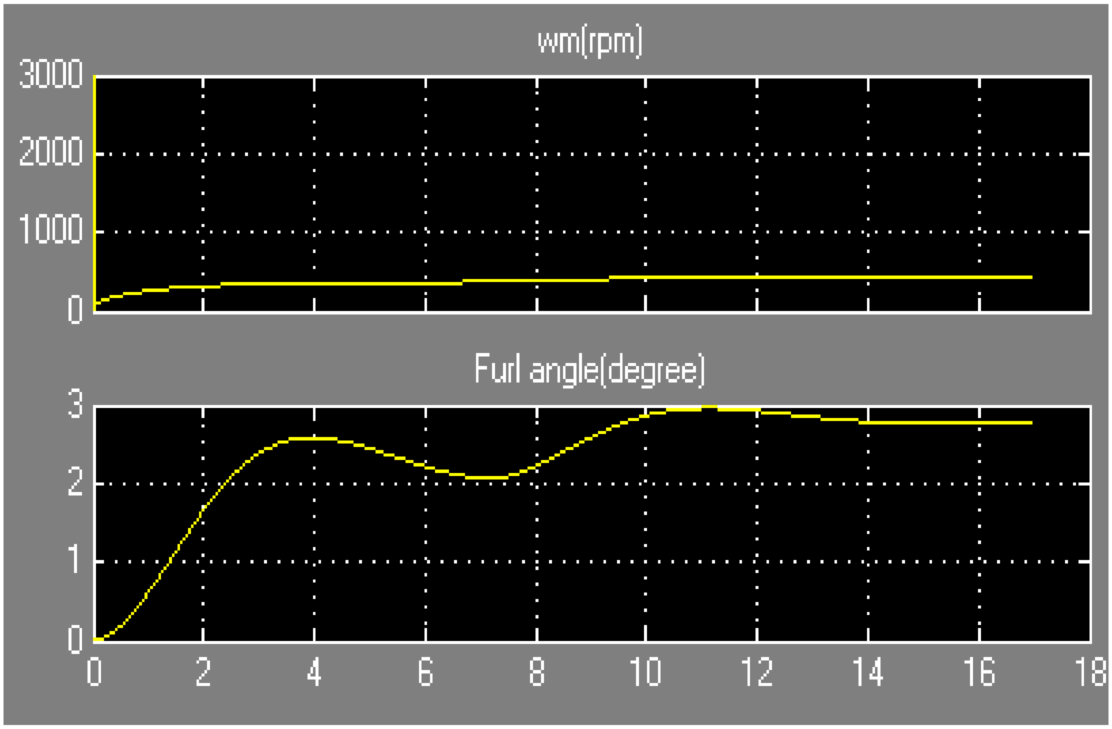


Fig. 3: Step response of the turbine with proposed control.

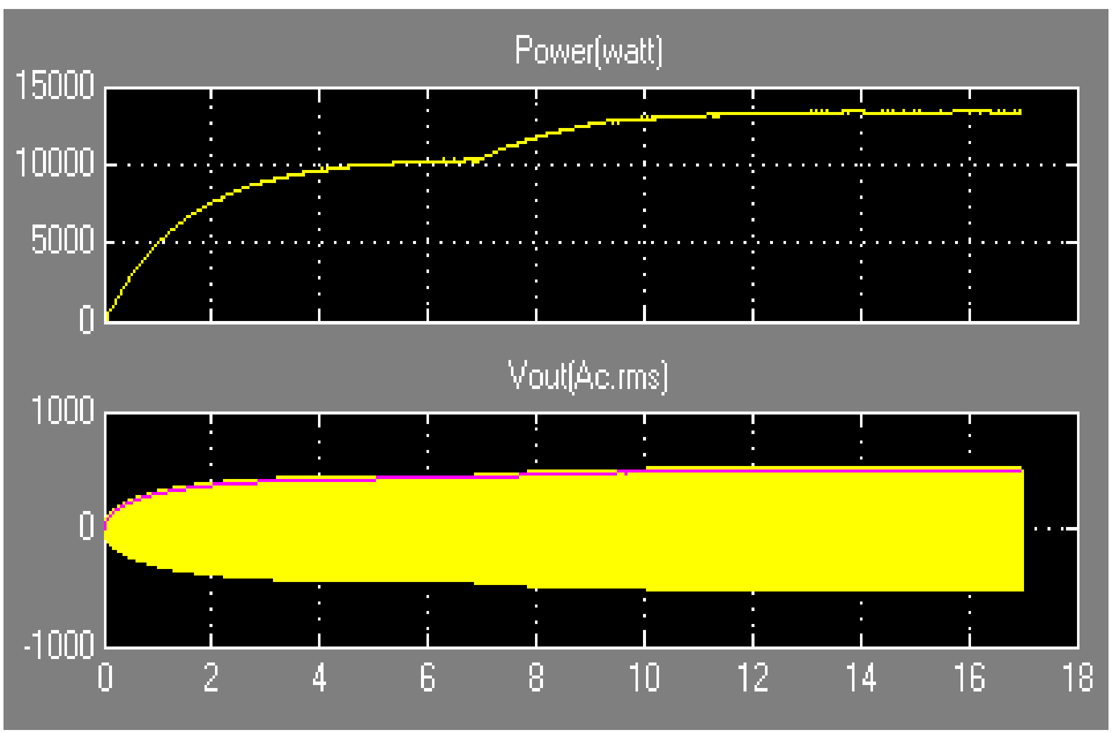


Fig. 4: PWM output of the inverter during proposed control

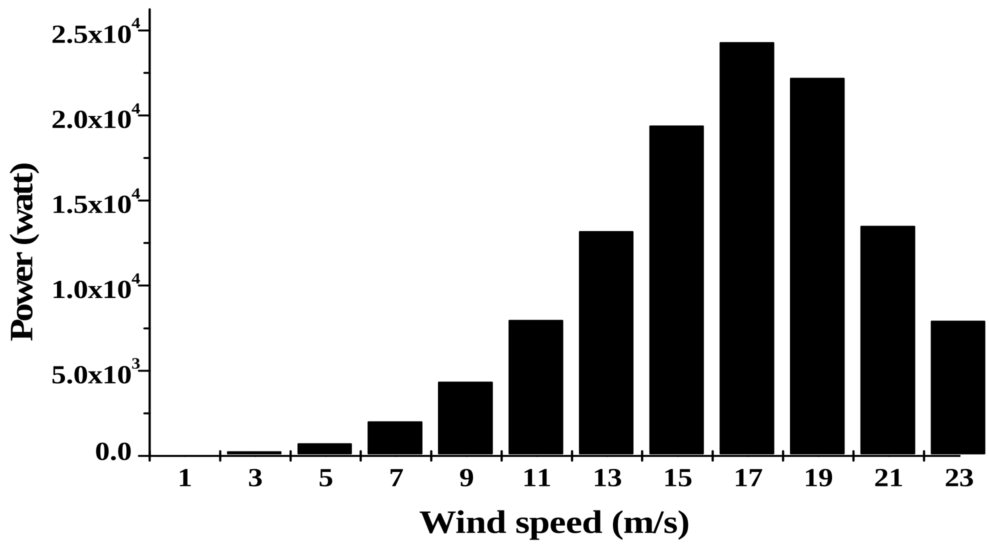


Fig. 5: Power curve of the wind turbine for the proposed control.

## 5. CONCLUSIONS

A short review of wind turbine control and its aspects is described along with the maximum power extraction technique. A small wind turbine along with its furl dynamics has been modeled in Matlab/Simulink platform. Maximum energy production of wind turbine has been confirmed by operating the wind turbine at its optimum TSR and a PPT is used to track the peak power production of the wind turbine. A PI controller has been designed for PPT to control the load connected to the system. Simulation results have been presented to prove the effectiveness of the proposed control strategy.

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# LAND COVER CHANGE DETECTION USING REMOTE SENSING AND GIS TECHNOLOGY- A CASE STUDY IN BANGLADESH

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**Key Words:** Land use change, Forest cover change, Geographic Information System, Remote Sensing, MODIS image, Normalized Difference Vegetation Index (NDVI).

## 1. INTRODUCTION

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use land cover change thus providing an accurate evaluation of the spread and health of the world's forest, grassland, and agricultural resources has become an important priority.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996). Xiaomei Y, and Rong Qing L.Q.Y (1999) noted that information about change is necessary for updating land cover maps and the management of natural resources. The information may be obtained by visiting sites on the ground and/or extracting it from remotely sensed data.

Therefore, an attempt has been made in this study to map out the status of land use/ land cover of three districts Gazipur, Tangail and Mymensing between 2000 and 2008 with a view to detecting the land cover changes that taken place in the study area particularly in the sal forest area based on land use classification from 2000 to 2008 using both Geographic Information System and Remote Sensing data. Gazipur, Tangail and Mymensing are the nearest districts to the capital city of Bangladesh have been witnessing remarkable expansion, growth and developmental activities such as building, road construction, deforestation and many other anthropogenic activities since its inception in 1971 just like many other cities in Bangladesh. This has therefore resulted in increased land consumption and a

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modification and alterations in the status of her land use land cover over time without any detailed and comprehensive attempt (as provided by a Remote Sensing data and GIS) to evaluate this status as it changes over time with a view to detecting the land consumption rate and also make attempt to predict same and the possible changes that may occur in this status. It is therefore necessary for a study such as this to be carried out if these three districts will avoid extreme land cover change which is associated with many problems of a growing and expanding city like many others in the world.

## 2. THE STUDY AREA

The study was conducted in three districts (Gazipur, Tangail and Mymensingh) of Dhaka division. The study area is located within the coordinate of $90^0$ 39' E and $25^0$12' N to $89^0$ 45' E and $23^0$33' N with an area of about 9518 km².

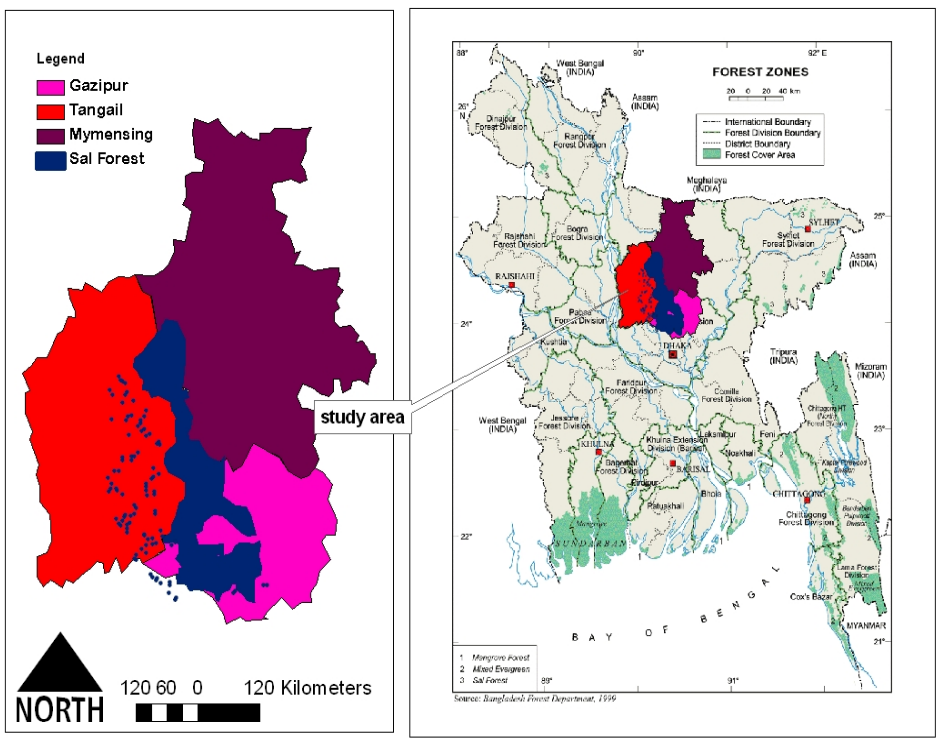


Figure 1.1: Map of Study area

### 2.1 Sal Forest

The sal forest is a slightly elevated tract, extending from the north of Dhaka district into the heart of Mymensingh; its average height is about 60ft above the level of the surrounding country, and it nowhere exceeds 100ft. Total sal forest area was 91`040.18 hectares. The jungle contains abundance of sal, valuable both as timber and charcoal. The only other elevated tract in the district is on the southern border, where the Susang hills rise. They are for the most part covered with thick thorny jungle, but in parts are barren and rocky (BBS, 2007).

## 3. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

It is a measure of the amount and vigour of vegetation at the surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigour and amounts of vegetation. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near infrared part of the spectrum. Previous research suggests the estimation of air temperature extrapolating the best fit line through the NDVI of full vegetation canopy (generally 0.7) and LST correlation. Mathematically it can be written as-

$$NDVI = (NIR-RED) / (NIR+RED) \quad \ldots\ldots (1)$$

Where, NIR and Red are the reflectance in the near infrared and red bands. NDVI is a good indicator of green biomass, leaf area index, and patterns of production (Thenkabail and Gamage, 2004; Wang and Wang, 2004). NDVI is the most commonly used vegetation index. The NDVI values range from -1 to +1 with most values ranging from 0 to 0.6. Healthy green vegetation has a high NDVI value because more near-infrared light is reflected than red light. For bare soil on the other hand, both near-infrared and red light are strongly reflected so the NDVI would be near zero. Water and ice reflect a little more red than near-infrared light so those values tend to be slightly negative. Two characteristics of the NDVI that make it ideal for vegetation monitoring are that no other surface exhibits higher NDVI values than vegetated surfaces and that, when vegetation vigor changes due to the nature of vegetation growth and development or environmental induced stress such as drought, the NDVI also changes (Tucker et al., 1987). Therefore, the NDVI does have potential in drought detection and climate impact assessment.

A case study relating to drought risk evaluation depending on agricultural crop production was carried out by ( Chopra, 2006). It has been shown that there exists a good correlation between NDVI and crop growth. Yuhas and Scuderi (2009) found in Western North America that severity of die-off and/or plant-water stress is measured depending on the fluctuations in NDVI in a semi-arid region. Studies in the Sahel Zone (Tucker et al 2005) and Mediterranean (Vogt et al., 1998), indicate meaningful direct relationships between NDVI derived from NOAA AVHRR satellites, rainfall and vegetation cover and biomass.

### 3.1 Advantages of MODIS for Land Cover Change Detection

MODIS provides a unique opportunity for global assessment and monitoring of vegetation phenology and productivity every eight days at 250 m-1 km spatial resolution. The advantage of MODIS data is to develop a prototype for land cover change at the scale of a country, state, district or pixel with an 8 or 16 day time interval. The results described feed directly into the development of the regional drought monitoring system (Tucker et al. 2005). The objectives of MODIS mission is to improve predictions and characterizations of natural disasters like droughts and as a next generation scientific satellite sensors, MODIS has particular advantages over NOAA-AVHRR for land surface temperature detection and biomass estimation. On the other hand MODIS has more finely defined visible and near infrared bands then NOAA-AVHRR and it has one of the most accurate calibration subsystems ever flown on a remote sensing instrument. The calibration allows the raw brightness values to be converted into true percentage reflectance or radiance measurements. MODIS has a higher radiometric resolution than other sensors. It uses 12 bits for quantization in all bands as compare to AVHRR's 10 bits.

### 3.2 Pre-processing of Satellite Data

**a) Conversion of HDF format to tif format:** The original MODIS data are provided in the Hierarchical Data Format (HDF-EOS). HDF is a multi-object file format for sharing scientific data in multi-platform distributed environments. This HDF-EOS format image is exported to tif format using MRT tool.

**b) Reprojection:** MODIS Land surface temperature and surface reflectance image is in sinusoidal projection and WGS84 datum. This sinusoidal projection is reprojected to albers conical equal area and WGS84 datum.

**c) Subset:** Using district layer of Bangladesh boundary, subset area corresponds to Gazipur, Tangail and Mymensing districts has been done for all the images.

**d) Multification factor:** Multiplication factor is different for land surface temperature as well as for surface reflectance. All the SR images have been multiplied by scale factor 0.0001 in model maker.

**e) NDVI computed from model maker**: Normalised difference vegetation index has been computed using two bands of surface reflectance image. In Surface reflectance image band 1 represents red and band 2 represents near infrared (wavelength).

**f) Inherited cloud problem with NDVI and LST products:** The presence of clouds in satellite images is a significant obstacle to land surface studies. Undetected clouds distort the real reflectivity of the land surface and consequently develop into an additional source of error. Clouds in satellite images must thus be precisely identified prior to any further analysis. The total number of NDVI images processed is about to hundred for the period from 2000 to 2008 and out of these some images are cloudy.

**g) Layer stacking:** After processing above intermediate steps, all the images are stacked.

**h) Area calculation:** after counting NDVI value pixel value was calculated based on NDVI value. Here one pixel represents 0.059 $km^2$. Total area of each land cover was calculated multiplying total pixel by 0.059 $km^2$.

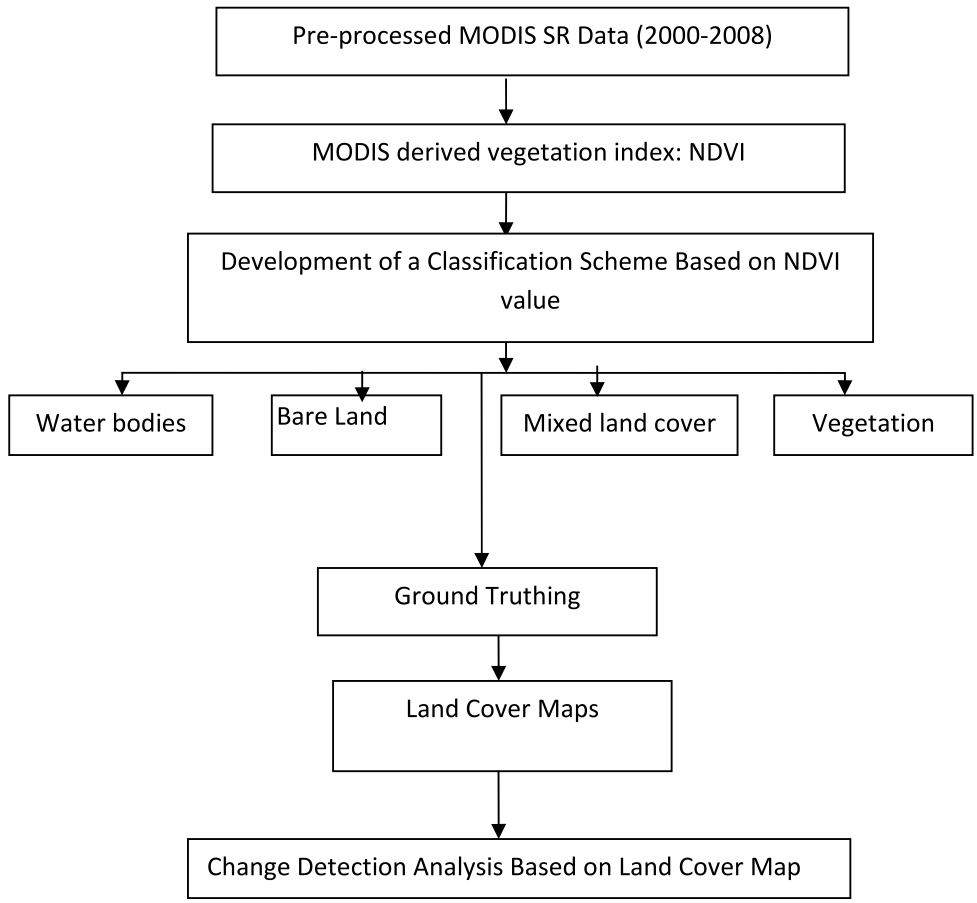


Figure3.1: Schematic presentation of Post-processing of satellite data

Based on the previous knowledge of the study area for over 9 years, a brief reconnaissance survey with additional information from previous research in the study area NDVI (Normalised difference vegetation index), a classification scheme was developed for the study area. The classification scheme developed gives a rather broad classification where the land use land cover was identified by two digits after decimal of NDVI value. The definition of bare land as used in this research work denotes land with scrub, sandy areas, dry grasses, rocky areas and other human induced barren lands.

Table 3.1: Land use land cover classification scheme

| Sl. No. | Land cover categories | NDVI value |
|---|---|---|
| 1 | Water body | <0.35 |
| 2 | Bare land | 0.35-0.45 |
| 3 | Mixed vegetation | 0.45-0.55 |
| 4 | Forest | >0.55 |

## 3.3 Software Used

Basically, four software were used for this project viz;

(a) ArcGIS 9.2– this was used for displaying and subsequent processing and enhancement of the image.

(b) ILWIS 3.6 – This was used for the development of land use land cover classes and subsequently for change detection analysis of the study area.

C) MRT tool for image reprojection

(d) Microsoft Excel - was used in producing the graph.

Based on the satellite information of the study area for over 9 years, a brief reconnaissance survey with additional information from previous research in the study area and with NDVI (Normalized difference vegetation index) value, a classification scheme has developed for the study area. The classification scheme developed gives a rather broad classification where the land use land cover was identified by two decimal of NDVI value.

The definition of bare land was used in this research work denotes land with scrub, sandy areas, dry grasses, rocky areas and other human induced barren lands. Forest cover includes sal forest along with scattered social forestry and agroforestrty.

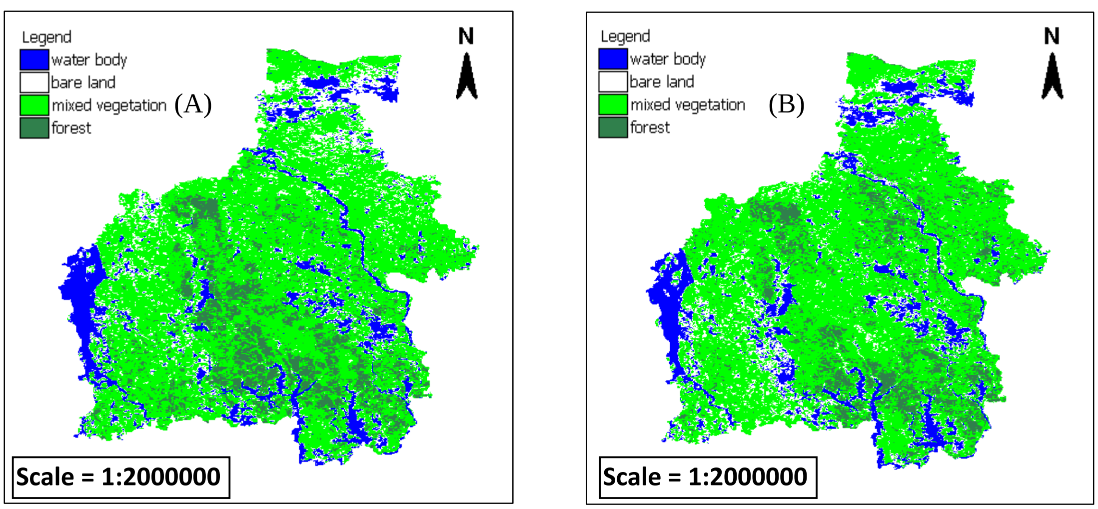


Figure 3.2: Land use\land cover pattern in the year 2000 (A) and 2002 (B)

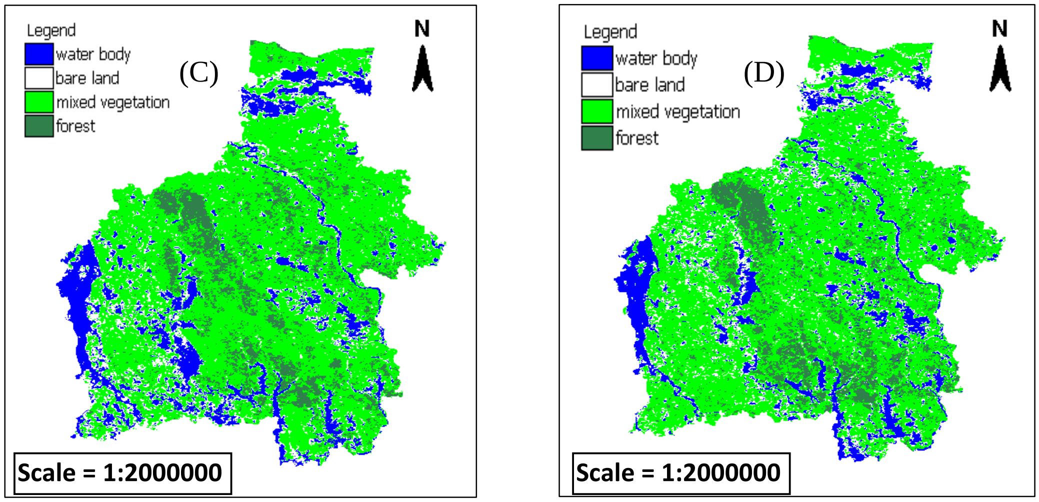


Figure 3.3: Land use\land cover pattern in the year 2004 (C) and 2006 (D)

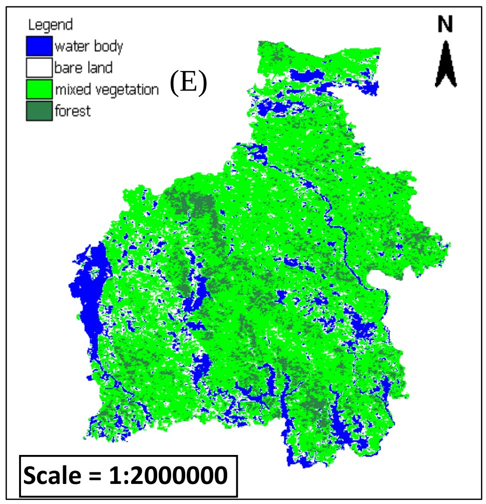


Figure 3.4: Land use\land cover pattern in the year 2008 (E)

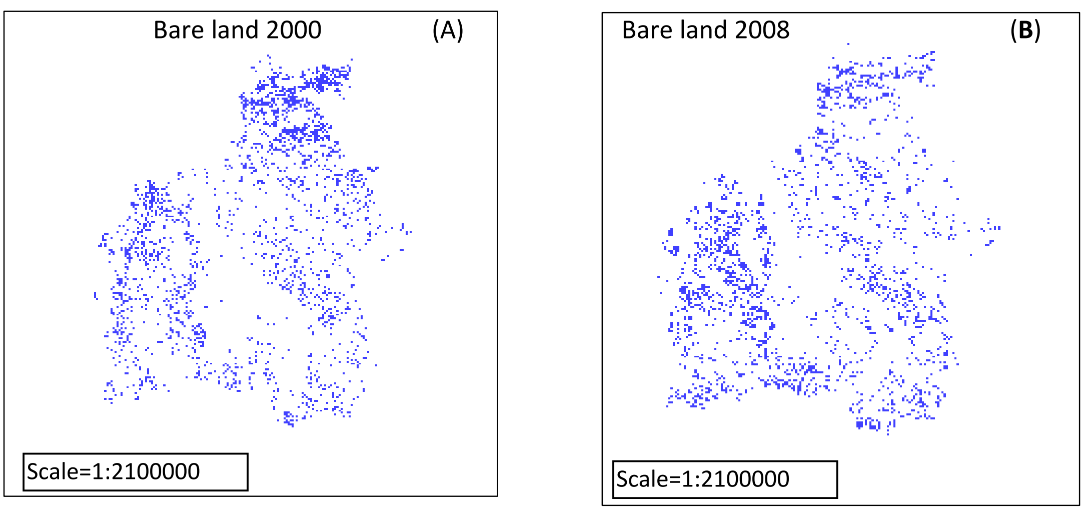


Figure 3.5: Bare land area change in the year 2000 (A) and 2008 (B)

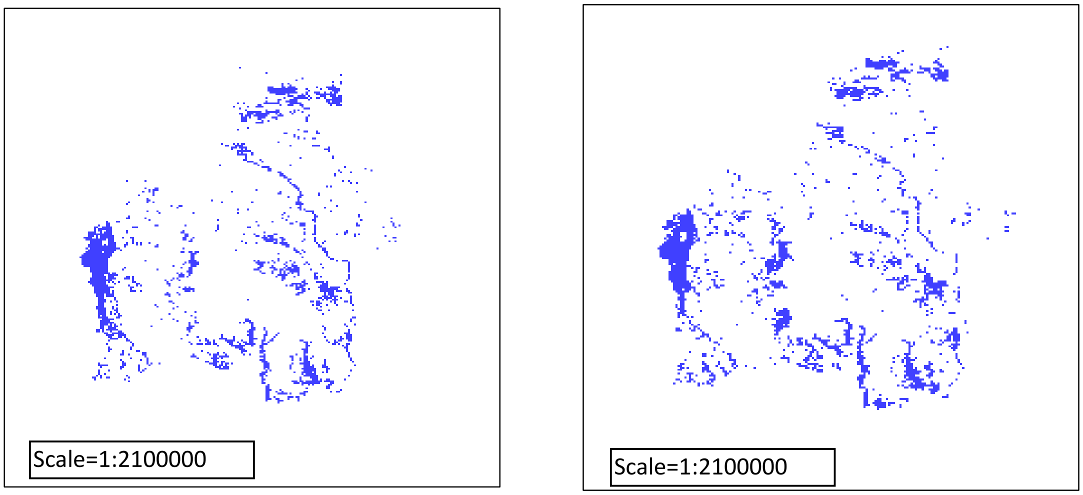


Figure 3.6: Area of water body change in the year 2000 (A) and 2008 (B)

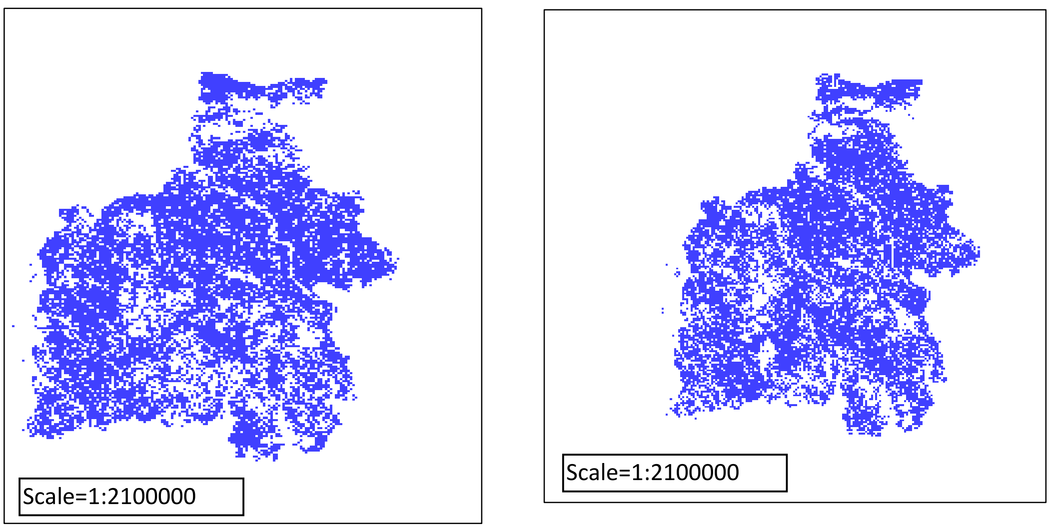


Figure 3.7: Area of mixed vegetation change in the year 2000 (A) and 2008 (B)

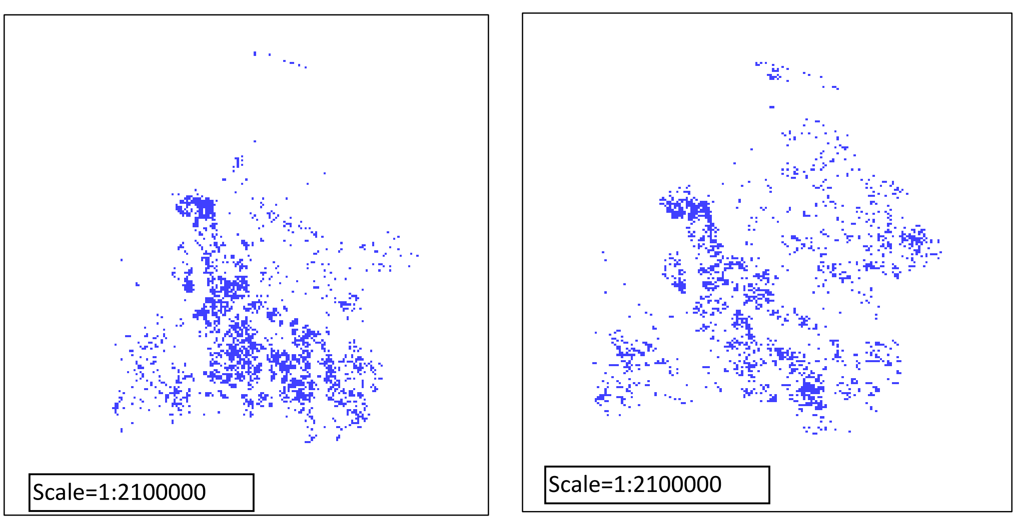


Figure 3.8: Forest cover area change in the year 2000 (A) and 2008 (B)

Table 3.2: Area of different Land use/ land cover classes

| Sl. No. | Land cover categories | Area in km² | |
|---|---|---|---|
| | | 2000 | 2008 |
| 1 | Water body | 1205.01 | 1222.01 |
| 2 | Bare land | 1131.21 | 1044.42 |
| 3 | Mixed vegetation | 6128.33 | 6365.92 |
| 4 | Forest | 1095.45 | 927.83 |

## 4. LAND COVER CHANGE ANALYSIS

It was found that land use/cover in the study area changed significantly from 2000 to 2008. Analysis revealed that the bare land area decreased from 1131.20 km$^2$ to 1014.09 km$^2$ from 2000 to 2004 after that there was a slight increase in 2006 and then it has reached to 1044.41 km$^2$ in the year 2008. So, it was found that there is a moderate decline in bare land from 2000 to 2008 (Figure 3.5).

The water body category had a very slight increment during the study period. It was 1205.01 km$^2$ in 2000 but 1222 km$^2$ in 2008 (Figure 3.6). It was also observed that in 2004 bare land cover had shrinkage where as water body increased almost equal area. So, there is a relationship between increase of water body and decrease of bare land.

On the other hand, mixed vegetation classes increased gradually with slight decrease in the year 2004 when water body increased and reached to 6365.92 km$^2$ in 2008 which was 6128.33 km$^2$ in 2000 (Figure 3.7).

Forest cover Change detection was one of the most important objectives in this research paper. It was observed that there is a drastic change of forest cover from 2000 to 2008 and it is 1095.45 km$^2$ to 976.50 km$^2$ and after 2002 there was a gradual destruction of forest occurred in the study area and in 2008 it reached to 927.83 km$^2$ (Figure 3.8).

In summary, it was found that forest cover/ forest resources have been decreasing constantly during the study period. if necessary measure and actions are not taken this change will continue and in the long run there will be no sal forest in the study area except Modupur national park and Bhawal national park.

## 5. CONCLUSION

This research work demonstrates the ability of GIS and Remote Sensing in capturing spatial-temporal data. Attempt was made to capture as accurate as possible four land use/ land cover classes as they change over the study period. The four classes were distinctly produced for each study year but given more emphasis on forest cover change; and indeed, it is one that affects on other classes in the study area. An attempt was also made to separate social forestry from sal forestry using data available in forest department but lack of exact social forestry data in forest division, it was not possible. Forest land has reduced steadily between 2000 and 2008 and Sal forest is likely going to be significantly decreased in the long run. This situation will have negative implications in the area because of the associated problems of crowdedness like industrialization and easy spread of human habitation. It was also observed that if necessary measures and actions are not taken this change will continue and in the long run there will be no sal forest in the study area except Modupur national park and Bhawal national park. It is therefore suggested that awareness should be given to people not to destruct forest and government should also take necessary action against forest cover destruction.

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# RESERVOIR OPERATION CONSIDERING ENVIRONMENTAL FLOW REQUIREMENTS IN THE HARI ROD RIVER BASIN, AFGHANISTAN

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## ABSTRACT

Growing pressure on the available water in the Hari Rod River basin of Afghanistan requires a better understanding of the river flow systems for effective allocation of the available resources considering water requirement by the riverine ecosystem. This study attempts to quantify environmental flows required for healthy ecosystem as well as to establish appropriate assessment techniques to be applied for basin-wide management in the major basins in Afghanistan. The study is based on collected data and information regarding the Hari Rod River basin in Afghanistan. Indicators of Hydrologic Alteration method considering Range of Variability Analysis were applied for quantifying the environmental flow requirements and compared with other hydrological based approaches (e.g. Tennant Method, Flow duration curve analysis and 7Q10 method) and hydraulic based approaches (e.g. wetted perimeter method). It is found that hydrological based approaches are appropriate to estimate environmental flow requirements in the basin. Maintaining environmental flows of a river means the reducing of water demand from one or more sectors. Keeping this in mind, reservoir simulation technique was applied to operate the proposed reservoir (Salma Dam) in the Hari Rod River basin of Afghanistan. HEC-ResSim model was used for simulating the reservoir operation (proposed Salma Dam) and different alternative scenarios were generated to evaluate the possible impacts of allocating environmental flows on the other demands (e.g. irrigation and hydropower). Different mitigation options were suggested at the same time to reduce the impacts. A new conservation zone rule curve was developed to decrease the water shortages for irrigation caused by the additional demand due to the allocations of the environmental flows. This study estimates that the water shortages can be alleviated substantially by improving existing irrigation efficiency in the basin. The result also shows that there will be no water shortages by irrigation, hydropower and environmental flow demand for a 5% improvement of irrigation efficiency.

Key Words: Afghanistan, Environmental Flow Requirement (EFR), Hari Rod River Basin, HEC-ResSim, Irrigation Efficiency, Reservoir Operation, Salma Dam

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## 1. INTRODUCTION

Increasing water demands are the main cause of degrading river and other aquatic ecosystems in countries across the world. Many of these countries acknowledge that environmental protection must be a component of their management of aquatic resources, but have limited data and understanding of their systems with which to achieve this. Nowhere is the problem more urgent than in developing countries in semi-arid climates, where fast-growing populations are dependent on the very limited water resources [3,12]. This has led the protection of the aquatic environment to take the top position on the world's water resources agenda. Thus, it is recognized that there is a high requirement to allocate water for the rivers itself to meet the ecological demand for preserving the riverine ecosystems and its associated functions. The amount of water from the original river flow regime that needs to flow all the way to the outlet into the sea in order to maintain the specified valued features of the river ecosystem in a desirable condition is known as the environmental flow requirement (EFR) [2,5,8,10,11]. The concept of the river EFR is emerged from the requirement to establish the level to which the flow regime of a river can be altered from the natural condition while preserving the sustainability of the riverine ecosystem [11,12]. Such requirements are determined by means of environmental flows assessment (EFA), which attempt to determine the amount of water that must remain during different times of the year in a regulated river system to maintain the aquatic ecosystem and resources at desirable level [1,9]. The objective of environmental water requirement and its ecological values signify the necessity of EFA in a basin. Such objectives attempt to maintain or improve flora and fauna in a desired status; the higher this status, the more flow regime will need to be allocated for protection of riverine ecosystem [2,8].

Hari Rod River basin in Afghanistan has unstable environment where the ecological flora and fauna have been affected due to the years of civil war, severe drought, growing pressure on available water by irrigation sector within the catchment and lack of attention to environmental impacts. Civil war and years of conflict has created a situation in the country where local people and government officials do not percept the value of endangered species in contrast to pre-conflict period. Dust storms, water pollution and loss of biodiversity are rapidly increasing because of high poverty and high population growth. The available discharge in the Hari Rod River to be used for irrigation purpose is deficit in the summer and excess in the spring. Accordingly, water user groups have adjusted their agricultural and irrigation water supplies to natural regime. But the distribution efficiency is degraded on the main and major sub branches of the Hari Rod River caused by corrupted canal diversions, alignment and devastated bifurcations. The primary focus of water resources development projects in Afghanistan particularly in Hari Rod River Basin has been the irrigation and hydropower aspects. Until now, EFR downstream of these developments have not been considered an important concern. However, the apprehension to minimize the adverse social and environmental consequences of such plans is getting much attention. Therefore, establishment of environmental flows is regarded an essential part of Hari Rod River basin management prior to any water resources developments projects. The primary intention of environmental flow (EF) management for the Hari Rod River basin must be the anticipation of further degradation that may arise from flow regulation intensification, particularly loss of high flood flows, reduced base flows and further alteration in the seasonal inflows. Legislation in Afghanistan depicts that its water resources management plan should reserve that much amount of water to be required for environmental purposes in all its river basins. This issue is also highlighted in the water sector strategy of the country's national development strategy [4,6]. Little is known about the existing environmental and natural circumstances of the river basins in Afghanistan except few reports identifying the possible management plans and development options [6]. This has led to the recognition that environmental flows in each of the river basins in Afghanistan need to be quantified. But there has not been any established guideline yet for this purpose which suggests in developing a slate of methodology to be adaptable for the river basins in Afghanistan. Thus, the present study attempts to assess the environmentally acceptable flow regime for the Hari Rod River basin, which is expected to assist in developing an appropriate operating policy for proposed Salma dam in the basin with a consideration of estimated environmental flows. It is also expected that this study would contribute to the efforts required for managing properly the riverine ecosystem in the Hari Rod River basin of Afghanistan.

## 2. DESCRIPTION OF STUDY AREA

Hari Rod River basin is located in the western part of Afghanistan (Fig 1), which is relatively more developed than other basins in that location. The upper part of the basin is located in Ghor province with an altitude of 4000m above mean sea level (MSL). The location of lower part is in the Herat province with an altitude of 750m above MSL. The basin covers a total area of 3,901,722 hectare having a population of 460,000. Upper reach of the Hari Rod River has narrow valley with gravelly bed, in the middle reach the river valley becomes wide, flat and meanders greatly below the village Obeh. In the lower reaches, the river forms part of the international boundary between Afghanistan and Iran and finally enter into Turkmenistan where it disappears in the sand. Climate is distinguished by cold winters with snow and rainfall increasing with rising altitude. Usually rainfall occurs in spring and the mean annual precipitation is estimated as 236 mm with uneven spatial distribution. Runoff comes from snowmelt which is the major source of surface and ground water of the basin spanning over two months (February/March to April). The river has high flood flows from March to June and very low flows from August to February. Hence, there is sufficient flow in the river from end of February to middle of June or sometimes end of July. Farmers within the basin have adapted their agricultural and irrigation practices to this flow regime. Thus, the river water is mainly used for irrigation purpose. However, groundwater is used as supplement for irrigation throughout the year. Salma Dam is located near the Chisht-e-Sharif in Herat province and was planned as a multi-purpose project to afford both irrigation and power benefits. Presently, it is under active construction which is to be utilized in the upcoming years. Significant lacking is observed in the consideration of environmental and ecological aspects as an important issue for this water resources development project (proposed Salma Dam) in the basin [4]. Thus, there is a requirement for better understanding of the EF in the Hari Rod River in order to establish and allocate water for ecological processes of the riverine ecosystem of the basin.

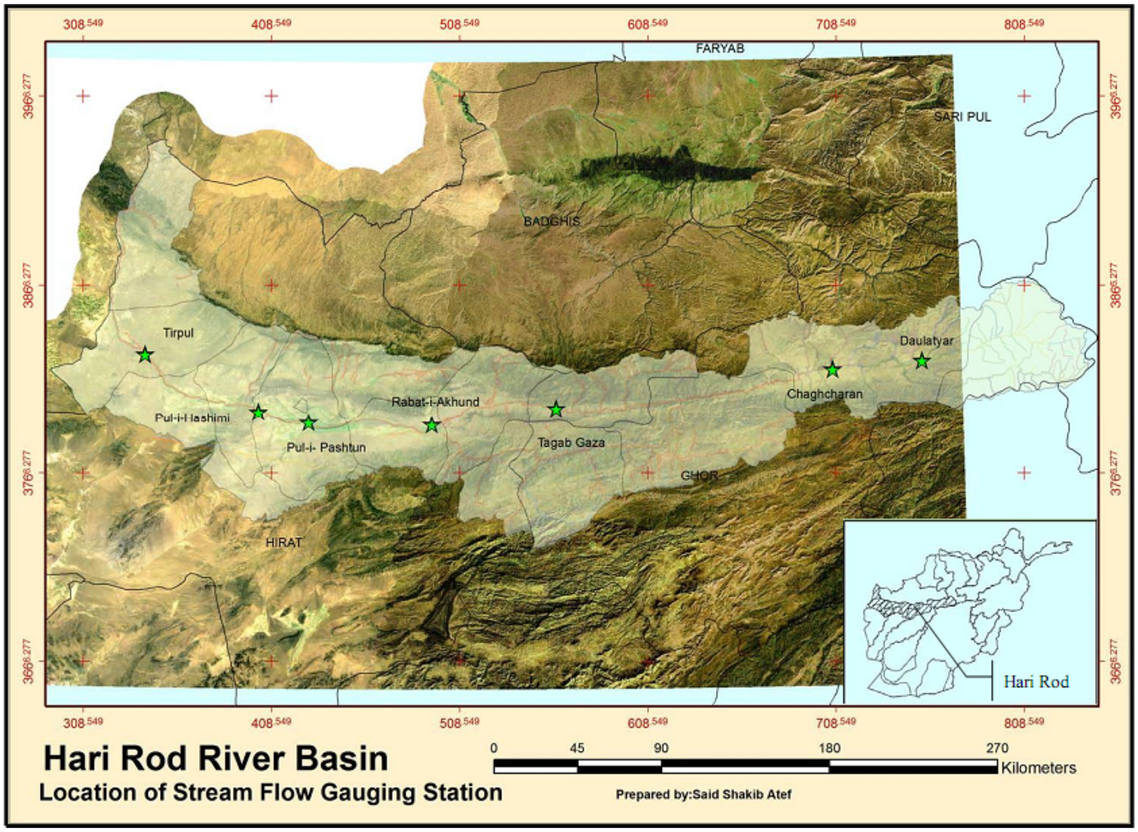


Fig 1: Location Map of the Hari Rod River Basin in Afghanistan

## 3. METHODOLOGY

The methodology for establishing reservoir operation considering environmental flows in the study area is based largely on the observed data and information in the field. Simple approaches have been adopted to use commonly available hydrological data. The framework of methodology mainly consists of two subsets of activities: estimation of environmental flow requirements and establishment of a reservoir operation policy applying simulation technique. Well-known hydrological (e.g. Tessman method, Flow Duration Curve analysis, and 7Q10 method, Indicators of Hydrologic Alteration method, Range of Variability analysis) and hydraulic method (e.g. Wetted Perimeter method) for estimating environmental flows are used [1,2,5,8,11,12] to estimate environmental flows. HEC-ResSim, a model for reservoir system simulation [7], was used for simulating the reservoir (proposed Salma dam) operation. Three alternative scenarios were generated to evaluate the possible impacts of allocating environmental flows on the other (e.g. irrigation and hydropower) demands.

## 4. RESULTS

### 4.1. Estimation of Environmental Flow Requirement (EFR)

Major tributaries of Hari Rod River is located in the lower part of the basin, where there is an impact on EF due to growing pressure on the available water by irrigation demand. Thus, the present study considered the gauging stations which are located in the lower part of the basin for EFR assessment. Tagab Gaza and Tirpul station is located in the middle and lower part of the basin respectively along with three more gauging stations (Pol-i-Pashtun, Pol-i- Hashimi and Rabat-i-Akhund) along the river between these two stations (Fig 1).

#### 4.1.1. Tessman Method

Tessman (modified Tennant) method uses a percentage of the average annual flow (AAF) for a monthly basis rather than two season (six months period) basis (Tennant Method). In this method, EFR is estimated for all stations using 20 years daily flow data considering seasonal variability which is presented in Table 1. As a representative example for Tagab Gaza station, it is observed that the AAF is less than average monthly flows (AMF) from March to end of June, then EFR is equal to 40% of AAF and for the rest of the year, EFR is equal to AAF where AAF is more than AMF. Maximum EFR (15.9 $m^3/s$) is obtained at Tagab Gaza station, which is located very near the reservoir (proposed Salma dam) location.

#### 4.1.2. Flow Duration Curve (FDC) Analysis

This method uses daily discharge data to develop FDC. Then, the percentage of time that values of a specified river discharge is equalled or exceeded 90% during a period of interest was considered as standard for EFR. Usually, $Q_{95}$ and $Q_{90}$ index are used, which indicate the extreme low flow conditions to protect the riverine ecosystem integrity. Table 2 presents the EFR ($Q_{90}$) in various gauging stations, which shows that the estimated EFR for Tagab Gaza stations is tolerable. But for other three stations, it is very less. This is due to increased demand of available water by irrigation in upstream of these stations. The result also shows that there is sufficient flow in the river during spring season due to less irrigation demand. But in summer season, the river discharge doesn't meet the irrigation requirement since the demand is high. So, the groundwater sustains the irrigation and aquatic biota is not protected. Therefore, $Q_{50}$ is estimated, which is used as indicator of aquatic biota protection (Table 2).

#### 4.1.3. The 7Q10 Flow Methodology

This method can be interpreted as the 7-day low flow with a 10-year return period using daily discharge data. At least 10 years observed data is needed to start the analysis and consecutive 7-day average flow for each year as well as frequency of return interval is calculated. This method depicts that the resulted minimum stream flow should be maintained to protect river water quality. The estimated EFR by this method (Table 2) for Tirpul station is very less. This is because that the river flow disappears into sand in the downstream part of the basin.

#### 4.1.4. Indicators of Hydrological Alteration (IHA) Method

IHA method quantifies the hydrologic sequential variability of flow regime into 32 biological parameters based on statistical evaluation. In this method, these parameters were calculated from 20 years daily record (1961 to 1980) at Tagab Gaza station by considering single period analysis with nonparametric statistics. The result shows that there is alteration between recent and pre-settlement period. For specific months the monthly low flow is drastically decreased in the recent period. The monthly low flow median in pre-impact period is 6.4$m^3/s$ which is decreased to 5.3$m^3/s$ in post-impact period. The tabulated view of median flow variation is presented in Table 3. There is a significant variation in April and May median flows of post-impact period compared to pre-impact period.

Table 1: Results of EFR by Tessman method for stations in lower Hari Rod River basin

| Month | Tagab Gaza EFR ($m^3/s$) | Pol-i-Pashtun EFR ($m^3/s$) | Pol-i-Hashimi EFR ($m^3/s$) | Tirpul EFR ($m^3/s$) |
|---|---|---|---|---|
| Jan | 7.9 | 6.99 | 10.62 | 12.44 |
| Feb | 9.2 | 11.2 | 11.48 | 12.48 |
| Mar | 15.7 | 15.6 | 12.49 | 12.48 |
| Apr | 15.9 | 15.31 | 12.49 | 12.48 |
| May | 15.9 | 15.31 | 12.49 | 12.48 |
| Jun | 15.9 | 14.75 | 8.96 | 12.48 |
| Jul | 14 | 0.44 | 1.36 | 0.79 |
| Aug | 7.7 | 0.29 | 0.92 | 0.1 |
| Sep | 7.4 | 0.35 | 1.02 | 0.08 |
| Oct | 7.1 | 0.6 | 1.76 | 0.16 |
| Nov | 7.6 | 1.37 | 3.72 | 2.35 |
| Dec | 7.6 | 2.04 | 7.15 | 5.21 |

Table 2: Results of estimated EFR by FDC and 7Q10 methods

| Code | Name | Elevation (m) | EFR by FDC Method | | EFR by 7Q10 Method |
|---|---|---|---|---|---|
| | | | $Q_{90}$ ($m^3/s$) | $Q_{50}$ ($m^3/s$) | ($m^3/s$) |
| 93 | Tagab Gaza | 1460 | 5.61 | 9.64 | 5.10 |
| 89 | Pol-i-Pashtun | 940 | 0.18 | 1.15 | 0.38 |
| 88 | Pol-i-Hashimi | 850 | 0.86 | 8.31 | 0.90 |
| 86 | Tirpul | 760 | 0.04 | 2.4 | 0.085 |

Table 3: Results of monthly median flow alteration by IHA method

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-Impact | 4.3 | 5.6 | 10.9 | 67.6 | 151.0 | 37.5 | 10.5 | 5.7 | 6.1 | 6.4 | 5.5 | 5.0 |
| Post-Impact | 5.0 | 5.8 | 9.0 | 113.5 | 141.0 | 38.9 | 8.7 | 5.0 | 5.4 | 5.3 | 5.4 | 5.2 |

#### 4.1.5. Range of Variability Analysis (RVA) Method

The results from IHA analysis are used for RVA approach and the management targets are identified. First, the management rules are developed based on the estimated ecological information needed to accomplish the target flows on annual basis. Then biological goals are identified to achieve through generated flow regime. The nonparametric monthly low flow analyze for Tagab Gaza station shows that the post-impact period peak discharge and volume is increased by 4% compared to pre-impact period (Fig 2). The positive and negative changes in water conditions are increased from pre-impacted period than post-impact period.

#### 4.1.6. Wetted Perimeter Method

The Tagab Gaza site is selected based on the availability of daily flow data and surveyed cross-sections. The intention is to compare the estimated EFR with other methods. Since it is difficult to estimate the point of maximum curvature in the wetted perimeter to discharge relation, so EFR are estimated based on the breaks in the slope of wetted perimeter verses the discharge diagram and it is about 7.71$m^3/s$.

## 4.2 Comparison of EFR Methodology

Tessman methodology usually provides good results at initial level of analysis. But it is found that most often this method under or over estimates and gives unexpected results due to seasonal condition. The result by this method is considerable higher than other methods for dry season. However, FDC results are much lower than Tessman method. FDC method concise the entire flow distribution and shows the range of extreme low flow conditions but they do not reveal the detail of the seasonal impacts. Since it is highly necessary to maintain variability for the entire year, this method can be used for primary screening of the complete series of river discharge from low flow to flood events. Therefore the single, minimum, threshold flow can't represent the entire EFR of a river (Fig 3). Results obtained using 7Q10 method is very less in terms of magnitude compared to other methods. But when the question of seasonal variability arises, 7Q10, FDC and wetted perimeter method can't fully include EFR in management level. It is recognised that intra and inter-annual variability of hydrologic regimes are needed to maintain and restore the natural form and function of aquatic ecosystems. That range of variability is the most sophisticated form of hydrological index methodologies. IHA method generally considers the magnitude, duration and frequency of flow regime. Therefore, the estimated EF of IHA method is considered to simulate the reservoir and evaluate the impact of EFR on other demands.

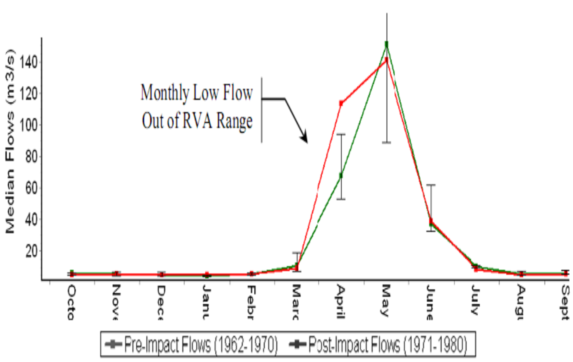


Fig 2: Monthly flow alteration with RVA boundaries in Tagab Gaza station

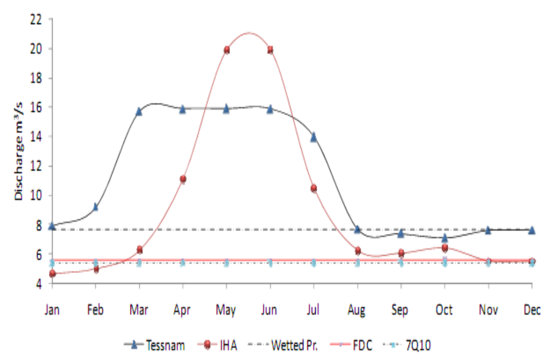


Fig 3: Comparisons of EFR obtained by Different EFR Methodology

## 4.3. Simulation of Reservoir System

During simulation of reservoir system, irrigation and hydropower demands are considered initially. The reservoir (proposed Salma dam) should meet the current irrigation demand of 42000ha and generate an installed capacity of 42MW early after construction and expected to mee the future irrigation demand for 75000ha after development of irrigation facilities. Considering the storage behind Salma dam, there is not shortage for irrigation when reservoir is operating only for hydropower and unintentionally environmental flow is also meet; hence this study evaluates the future impact, when irrigation demand is high and reservoir will be operated in the interest of both irrigation and hydropower including EFR. HEC-ResSim model was used to simulate the reservoir (Proposed Salma dam) operation with 20 year daily time series data. Three different scenarios were developed in order to evaluate the impact of

EFR consideration on irrigation and hydropower demands which are described in subsequent sections.

**4.3.1. Scenario I: Reservoir Simulation without Considering EFR**

Since Salma dam is designed to operate irrigation and hydropower demand, for this reason, the intention of developing this scenario was to elaborate dam status after construction. The evaluation shows that there are about 18 fully satisfied years for irrigation within 20 years analysis period. The simulated time series of the reservoir shows that the irrigation shortage was observed in two dry years in specific moths (dry season). It also shows that the available water from 1970 to 1971 is very less, the same happens in year 1966, therefore both of these years were highlighted in this study. Fig 4 shows the irrigation shortage from August to November in 1971, where the total annual inflow in that specific year was 281Mm$^3$, this is while the average annual irrigation demand and average annual inflow to the river is 584Mm$^3$ and 1217Mm$^3$ respectively. This implies that there is no shortage for irrigation for normal and wet years, if the reservoir inflow is equal or more then estimated average annual inflow. Besides observation shows that total reservoir inflow in year 1969 to 1970 was almost same as year 1971, but there was no shortage observed, this is because of reservoir storage in 1968 to 1969, the reservoir inflow is more then estimated average inflow, therefore, beside meeting the demands, much of the water was stored and were released in year 1970, thus there was no shortage on that specific years. It can be conclude that, reservoir operation policy can meet both irrigation and hydropower demand if the available water is more then average reservoir inflow in addition the storage behind dam is also meeting the next dry year demand. Observation shows that the annual inflow in 1971 was extremely low; it was almost 1/5 of average annual flow. Though there was less inflow to the dam, simulation shows that totally 8 month (Jan to end of Jul) was fully satisfied, but irrigation demand was 20% satisfied in Aug and 45% in Sep and Oct, bearing in mind that there is no irrigation demand on Dec. The resulted average energy generated is reasonably more than the proposed capacity (186.13 MWh). This is because the release for both hydropower and irrigation is from hydropower gate in order to optimize both irrigation and power demand. It is considered as key reference to compare with other scenarios.

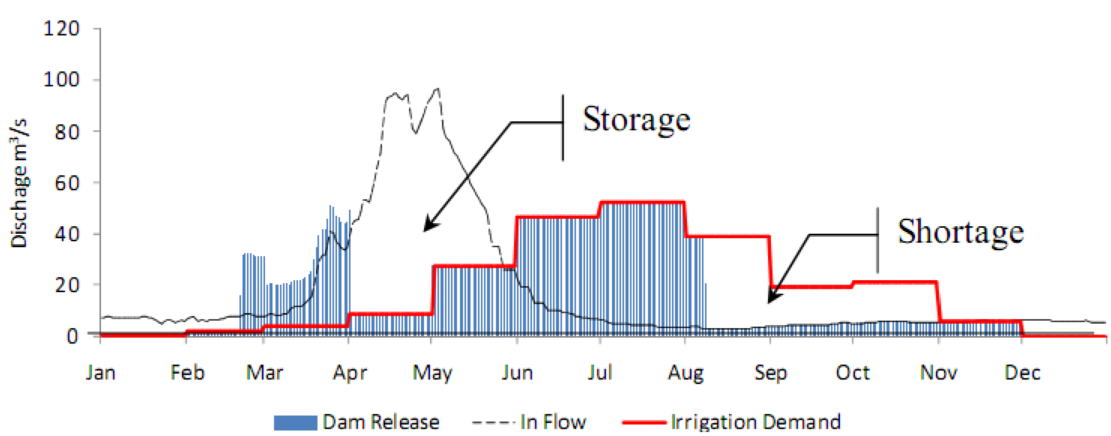


Figure 4: Dam release vs. irrigation demand for the year 1971 without EFR.

Table 4: Irrigation shortage due to EFR consideration (Scenario II)

| Date | Release ($10^6$ $m^3$) | Irrigation Demand ($10^6$ $m^3$) | Percent of Satisfied |
|---|---|---|---|
| Aug-66 | 59.0 | 101.0 | 58% |
| Sep-66 | 14.2 | 49.8 | 29% |
| Oct-66 | 16.5 | 54.8 | 30% |
| Sep-70 | 37.7 | 49.8 | 76% |
| Oct-70 | 19.2 | 54.8 | 35% |
| Aug-71 | 24.3 | 101.0 | 24% |
| Sep-71 | 10.9 | 49.8 | 22% |
| Oct-71 | 13.9 | 54.8 | 25% |

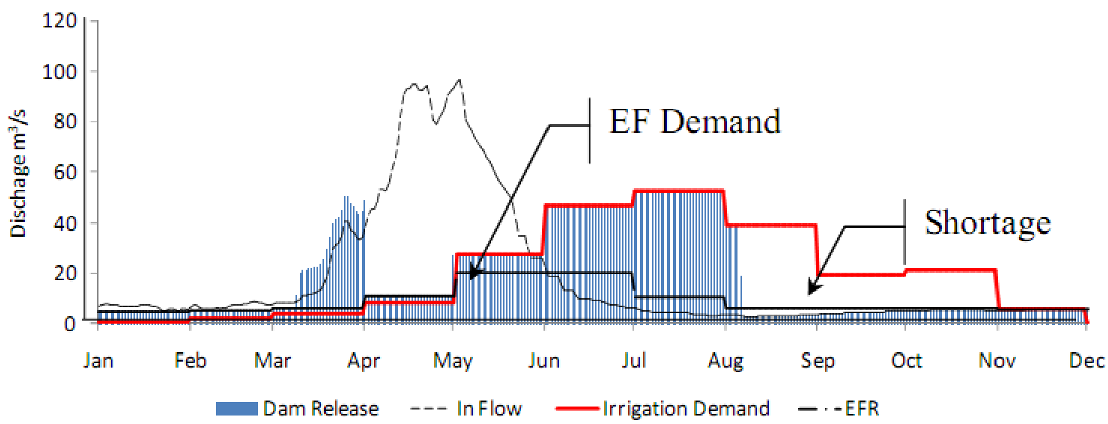


Fig 5: Shortage of Irrigation Demand due to EFR Consideration for the Year 1971

**4.3.2. Scenario II: Reservoir Simulation Considering EFR**

This scenario evaluates the influence of EF consideration on other demands. The simulated result shows that after inclusion of EF in reservoir operating policy, there will be more stress on irrigation demand in the specific dry years (Fig 5). The EF release decision was defined as a minimum reservoir supply on monthly basis. This decision is made in reservoir hydropower gate and then EF is evaluated downstream at Tirpul Station. River routing was carried out to calibrate the estimated EFR downstream of the river. Table 4 presents the EF consideration impact on irrigation demand. The shortage has been noticed from Aug to Oct of 1966, 1970 and 1971 out of 19 years simulation period and sever shortage was noticed in year 1971, where reservoir is meeting almost 22% of the demand. There was not much difference in average energy generated after adding EFR demand in reservoir simulation model.

**4.3.3. Scenario III: Developing Guide Curve for Reservoir Operation**

Evaluation shows that reservoir starts to storing water from April to end of Jun and releases from July to next April. This release decision is applicable in normal and wet years where the dam inflow is almost equal to average annual inflow. This may also help to decrease the level of flooding while meeting the irrigation demand and generating more energy. But during the drought period, when the dam inflow is almost one fifth of the average annual inflow, the existing conservation zone will not fully meet the irrigation, hydropower and environmental demands (Fig 6). So, a new conservation zone is developed based on dry year circumstances to meet irrigation, hydropower and EFR during dry years. The simulation result shows that there will be no shortage for both irrigation and EF after applying the new conservation zone. It is observed that reservoir release is meeting the total demand of irrigation and EFR. Different results are obtained for each scenario (Table 5) and compared to evaluate the impact of EF consideration on the irrigation and hydropower demand. It shows that when reservoir releases for only Irrigation and hydropower, there is shortage for years 1966 and 1971, but when EF is included to reservoir operation in addition to other demands, there is shortage for years 1966, 1970 and 1971. But after applying scenario III, simulation result shows that there is no shortage for irrigation, hydropower and EF demand. In addition, the energy generated for those specific years of scenario III is more then scenario I and II.

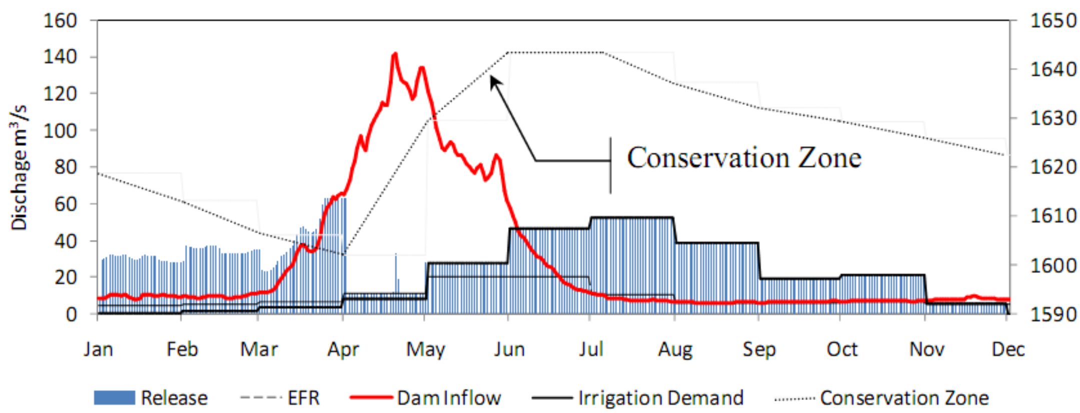


Fig 6: Reservoir release decision when existing conservation zone is applied (1977)

Table 5: Comparison of scenarios I, II and II

| Demand | Unit | Scenario I | | Scenario II | | | Scenario III | |
|---|---|---|---|---|---|---|---|---|
| Irrigation Shortage | Years | 1966 | 1971 | 1966 | 1970 | 1971 | 0 | |
| | Magnitude(MCM) | 114 | 155 | 116 | 86 | 15 | 0 | |
| | Percentage (%) | 54 | 73 | 56 | 54 | 76 | 0 | |
| Average. | (MWh) | 154.5 | 121.6 | 156 | - | 12 | 197.4 | 140.9 |

**4.3.4. Scenario IV: Improvement of Irrigation Efficiency**

Improving the current irrigation efficiency could be another possible solution for minimizing the irrigation shortage. It is reported that currently the overall irrigation efficiency in Hari Rod River basin is 35%. Data analysis shows that there was about 970000 ha cultivated area under the basin before the conflict period. As a result, it has been drastically decreased to almost 42000ha. Consequently, there is a potential and available source to expand current cultivation. Irrigation water requirement (IWR) for each crop was estimated using CropWat model developed by FAO, for Herat province. Mean monthly temperature, rainfall, evaporation, and soil data were used to estimate net depth of irrigation for each crop.

Scenario II shows that there will be shortage in dry years for 75000 irrigable areas if EF demand is considered in Dam operation policy. Therefore improving irrigation efficiency can mitigate this issue. For this purpose, average IWR per ha was estimated to find total demand of future irrigable area. Table 6 shows that by improving 5% of irrigation efficiency, there will not be any shortage for irrigation demands. In dry season, total dam supply is simulated 226 x $10^6$ $m^3$ and in that specific season the demand is 240.26 x $10^6$ $m^3$, the demand is more then maximum supply it means there is shortage having 35% irrigation efficiency, by improving 5% of irrigation efficiency, the demand will decrease by almost 15 x $10^6$ $m^3$, thus the supply is meeting the demand. Besides, additional area can be irrigated during wet years. Usually it is expensive and time consuming issue to improve irrigation distribution efficiency this can be done by canal lining, and constructing the broken bifurcations and canal diversions. In case of the distribution efficiency is not improved then almost 2000 ha out of 75000 ha of land will be impacted.

Table 6: Improving irrigation efficiency to meet demand of 75000ha cultivated area

| No | Description | Wet Season | Dry Season | Total |
|---|---|---|---|---|
| 1 | Total Cultivated Area (ha) | 52402.00 | 22458.00 | 74859 |
| 2 | Estimated Av. CWR per he (l/s/ha) | 2.42 | 4.13 | - |
| 3 | Total Irri. Water Supply. Winter ($10^6$ $m^3$) | 361.01 | 226.00 | 587.01 |
| 4 | IWR Winter ($10^6$ $m^3$), 35% efficiency | 328.44 | 240.26 | 568.70 |
| 5 | IWR Winter ($10^6$ $m^3$), 40% efficiency | 317.24 | 225.09 | 542.33 |
| 6 | IWR Winter ($10^6$ $m^3$), 45% efficiency | 309.59 | 221.09 | 530.68 |
| 7 | IWR Winter ($10^6$ $m^3$), 50% efficiency | 303.11 | 211.54 | 514.65 |

## 5. CONCLUSION

This study attempts to establish EFR in the Hari Rod River basin of Afghanistan using different hydrological and hydraulic methods. It also simulates a proposed reservoir (Salma da) system applying HEC-ResSim model to estimate the impact of EFR inclusion in the reservoir operation policy. It is found that the hydrological based methods are suitable to establish EFR in the Hari Rod River basin which are appropriate for initial reconnaissance level of assessment. Estimated EF using IHA method is preferred as it considers natural flow variability, magnitude, frequency and duration of flow for estimating EFR. Salma Dam is in the process of establishment and this study concludes that there is no severe impact on other demands with the inclusion of EFR in reservoir operation policy. The reservoir simulation result shows that there will be in shortage of water by irrigation demand during dry years if Salma dam operates to satisfy all irrigation, power and EFR demand. Impact of EFR inclusion in the reservoir operation can be reduced by applying proposed conservation zone for dry years. This can save about 2000 ha land which was supposed to be affected. The simulation result also demonstrates that there will be no shortage of water for irrigation, hydropower and EF for 5% improvement of irrigation efficiency in the Hari Rod River basin of Afghanistan.

## 6. ACKNOWLEDGEMENT

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# INVESTIGATING THE DEVELOPMENT OF RECALCITRANT ORGANIC MATTER IN LANDFILL LEACHATES

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## ABSTRACT

The main objectives of the study are to attain a better understanding of the leachate quality of UK landfills which is generally characterized by measurement of chemical oxygen demand (COD), amongst other parameters, which is regarded as being indicative of the recalcitrant organic matter or hard COD. Four untreated and two treated leachate samples were collected from two UK municipal solid waste (MSW) landfills L1 and L2 to characterize and identify variations in leachate quality. Factors investigated in this research included pH, $BOD_{30}$, COD, carbon and solid contents, anions and cations. The results show that the leachate solids content, organic and inorganic components fluctuated considerably between sites; leachate L1 had higher solids, organic and inorganic matter content than those of leachate L2 in all of the untreated and treated leachate samples. A trial study of leachate treatment was also performed in order to evaluate the suitability of aerobic treatment processes for the removal of recalcitrant COD from the untreated and treated leachate samples. The aerobic biodegradation experiments on the collected leachate samples were carried out in glass reactors over a period of 30 days with an air supply arrangement. This laboratory scale aerobic treatment system achieved reductions upto 64% of COD. The presence of significant amounts of remaining recalcitrant organic matter that can be further removed from the untreated and treated leachate samples suggests that leachates could receive further treatment before they are discharged to the receiving water and may reduce the chance of any potential environmental impacts.

**Key words:** Aerobic treatment processes; $BOD_{30}$; Biodegradation; COD; Landfill; Leachate quality; Recalcitrant organic matter

## 1. INTRODUCTION

Leachates are primarily generated from the disposal of municipal solid waste (MSW) in landfills [1]. The chemical composition and characteristics of leachates depend on the waste composition, climate, hydrogeological factors and the age of the landfills [2-4]. Its characteristics also vary over time with regard to the biodegradable compounds present [5]. Leachate is therefore regarded as a continuum of organic compounds including low molecular weight (MW) biodegradable organic compounds such as carbohydrates, amino acids, organic acids and as well non-biodegradable high MW organic compounds [6]. These high MW non-biodegradable organic compounds may consist mostly of humic substances (humic and fulvic type molecules) and are often also termed as recalcitrant organic compounds [6]. These humic substances are heterogeneous mixtures of different organic

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materials such as aromatic, aliphatic and phenolic components [7] and therefore significantly affect the accumulation and migration of some priority substances and hence, play an important role in the natural environment [8]. Leachates are usually treated before being discharged to the receiving water. Although the remaining amount of organic compound after treatment does not necessarily represent non-biodegradable fraction of leachate, it has been generally referred as the 'hard COD' or recalcitrant material in the literatures [3, 4, 9, 10]. In the UK, biological processes are the most commonly used methods of leachate treatment [11]. However, the presence of non-biodegradable and/or recalcitrant compounds such as humic substances and other toxic substances make the leachate less amenable to biological treatment as they are resistant to microbial degradation [12]. These compounds can pass through the biological treatment system in an unchanged form and appear in the resultant effluents [4]. If these leachates are discharged to the receiving water there is a potential that they could damage the local water quality and/or create public health problems. Therefore, proper characterisation of leachates is essential to understand the characteristics of recalcitrant organic compounds for the proper treatment of leachates. Without knowing the nature of the chemical changes in leachate composition, it would be difficult to predict the recalcitrant organic compounds present in them and to design a suitable control system for the proper treatment of leachate.

The main objectives of this study are 1) to study and to compare the chemical composition of untreated and treated leachate samples collected from two municipal solid waste landfills in the UK, different in age, size and waste deposited and 2) to evaluate the suitability of aerobic treatment processes for recalcitrant COD removal from the untreated and treated leachate samples.

## 2. MATERIAL AND METHODS

### 2.1 Landfill sampling sites

Four untreated and two treated leachate samples were collected from two MSW landfills L1 and L2 in the UK. The characteristics of the leachate samples, and details of the treatment carried out on the treated leachate samples, are presented in Table 1. Both sites have been in operation for over 50 years. The L1 landfill received mainly MSW with commercial, industrial, and non-hazardous liquid wastes. The L2 landfill contains old Phases that accepted MSW and industrial wastes, and more recent Phases containing predominantly MSW and commercial wastes. At these sites, a range of hazardous wastes are co-disposed with municipal solid wastes and there is no dedicated hydraulic isolation between different phases. The collected samples may represent mixture of leachates generated from a diverse range of waste composition and age and hence, merit investigation.

### 2.2 Leachate characterization methods

Four untreated and two treated leachate samples were collected in plastic bottles and stored at $4^{o}$C. In the laboratory leachate samples were filtered through a 25 mm glass micro-fibres filter *(Fisher Brand, MF 200)* for BOD analysis.

The leachate samples were analysed for pH, $BOD_{30}$ (30 day biochemical oxygen demand), COD, TC (total carbon), TIC (total inorganic carbon), TOC (total organic carbon), dissolved organic carbon (DOC), TS (totals solids), TVS (total volatile solids), TFS (total fixed solids), TDS (total dissolved solids), TSS (total suspended solids), VSS (volatile suspended solids), and anions ($Cl^-$, $NO_3^-$) and cations ($Na^+$, $NH_4^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$).

Table 1: Characteristics of the landfills and leachate samples (Information provided by landfill operators)

| Sample | Label | Nature of waste from which leachate derived | Nature of treatment |
|---|---|---|---|
| 1 | L1 (LTP)[a] | Landfill L1<br>Mixed MSW, commercial, industrial and hazardous wastes, with hazardous liquid wastes until 2002, non hazardous liquid waste thereafter. | Leachate was passed though a treatment plant consisting of aerobic rotating biological contactors |
| 2 | L1 (P4) | Landfill L1, phase 4<br>Predominantly MSW waste, with some industrial waste, with liquid non-hazardous wastes | Untreated |
| 3 | L2 (LTP)[a] | Landfill L2, yellow phase<br>Predominantly hazardous industrial wastes, over-tipped by recent non hazardous MSW. | Untreated |
| 4 | L2 (FE)[b] | Landfill L2<br>Sample is effluent of leachate treatment plant, treating “red” and “yellow” phase leachate | Treatment primarily consists of oil separation, air stripping and settlement of iron sludge, followed by activated sludge aerobic treatment |
| 5 | L2 (P2) | Landfill L2, phase2<br>Predominantly domestic MSW and non hazardous industrial wastes | Untreated |
| 6 | L2 (LTP Haz)[c] | Landfill L2, red hazardous<br>Predominantly hazardous industrial wastes – elevated concentrations of chlorinated aliphatic and aromatic organic compounds | Untreated |

[a] Leachate Treatment Plant
[b] Final Effluent
[c] Hazardous

$BOD_{30}$ of the leachate samples was determined by WTW OxiTop control system. COD measurements were carried out using the micro-digestion technique [13]. TS, TFS, TVS, TDS, TSS, and VSS analysis were performed according to the standard methods [14]. TC, TIC, TOC and DOC were analysed by a high-temperature total organic carbon analyzer (Dohrman Rosemount DC-190, USA) and anions and cations analysis were carried out using a Dionex-500 ion chromatograph. Leachate samples were repeatedly analysed in order to validate/evaluate the produced results and they were found within acceptable analytical error (± 4%). All chemicals used for the analytical determinations were of analytical grade.

## 2.3 Landfill leachate aeration

Aerobic biodegradation experiments of the untreated and treated leachate samples were carried out in 1 L batch stirred glass reactors over a period of 30 days. Air was supplied by an *AQUATEC* aquarium pump through 5 mm diameter poly-vinyl chloride (PVC) tubing via a 3 cm long airstone at the top of the reactor. The air streams into the reactors were maintained at a flow rate of 100 ml/min. Leachate samples were taken at different days from the reactors, filtered through a 25 mm micro glassfibres filter *(Fisher Brand, MF 200)* for dissolved COD analysis. These assessments were carried out at an average temperature of 20 ± 2$^{o}$C. The removal of recalcitrant organic matter by simple aeration processes was evaluated by measuring COD.

## 3. REAULTS AND DISCUSSION

### 3.1 Chemical characteristics of leachate

Table 2 shows the chemical properties of the untreated and treated leachate samples collected from landfills L1 and L2. The pH of the collected leachates was in the range 7.20-8.42. The pH of leachate usually increases with time due to decrease of the concentration of free volatile fatty acids [15, 16]. The reported pH of acidogenic leachates ranges from 5.6 to 6.9 whereas the pH of methanogenic leachates is in the range 6.8-8.0 [17-19]. The pH values for the untreated samples in this study therefore indicating a methanogenic state although the leachates here may come from a mixture of old and new wastes within the sites.

BOD and COD are used to measure the organic strength in leachates. Table 2 shows that all of the untreated and treated leachate samples had $BOD_{30}$ values in the range of 85-452 mg/l and COD values in the range of 850-4500 mg/l. BOD/COD values are correlated with the age of the landfill. Cho et al. [20], Tatsi et al. [21], Lopez et al. [22] and Cecen and Aktas [23] reported that leachates from young landfills are characterised by high BOD and COD concentrations with values ranged from 2300 to 25000 mg/l and 10540 to 70900 mg/l respectively, whereas in old landfill leachates BOD and COD values ranges from 62 to 800 mg/l and 1409 to 3460 mg/l respectively. Chian and DeWalle [15], Chian [24] and Harmsen [25] also demonstrated that the leachates generated from old landfills consist mainly of high molecular weight recalcitrant organic compounds, which are correlated with low BOD and COD values. Thus the low BOD and COD values of the collected leachate samples in this study implying significant leaching from the old wastes in the sites and hence, considerable amount of recalcitrant organic compounds should be expected to be present. This can also be verified by the corresponding BOD/COD ratio which is commonly known as a measure of biodegradability [17, 26]. The BOD/COD ratios of the collected leachate samples ranged from 0.02 to 0.30. Studies reported in the literature indicate that leachates containing high molecular weight recalcitrant organic compounds had BOD/COD ratios in the range of 0.01-0.40 [20-23, 27, 28].

Table 2 also shows that although L1 (P4) leachate had been collected from the phase where wastes were less than 4 years old (Table 1), it had a high pH and low values of BOD and a low BOD/COD ratio. This may indicate that methanogenic conditions may have been established at an early stage in this phase. The early establishment of methanogenic conditions in this phase may be attributed to a high amount of readily degradable organic waste and the high moisture content (Table 1) allowing fast dissolution of organic compounds and accelerating microbiological decomposition. This may also be due to the fact that older leachates were mixed in with leachates from this phase. The early establishment of methanogenic condition has also been reported in the literature [17, 29]. Kulikowska and Klimiuk [29] showed that in landfills in Poland, methanogenic conditions had been established at an early stage with stable COD values of 610 mg/l after about 4 years. The total carbon content of the untreated leachate L1 (P4) was relatively higher than the untreated leachates collected from L2 implying that organic and inorganic compounds in the L1 landfill was considerably higher than the L2 landfill. However, the treated leachates collected from each of these landfills generally showed lower total carbon content in comparison to the untreated leachates thereby indicating the effect of treatment.

Table 2 Chemical composition of landfill leachate samples

| Parameter (mg/l) (except pH) | Sample 1 (treated) | Sample 2 (untreated) | Sample 3 (untreated) | Sample 4 (treated) | Sample 5 (untreated) | Sample 6 (untreated) |
|---|---|---|---|---|---|---|
| | L1 (LTP) | L1 (P4) | L2 (LTP) | L2 (FE) | L2(P2) | L2 (LTP HAZ) |
| pH | 8.42 | 7.72 | 7.20 | 7.60 | 8.12 | 7.40 |
| $BOD_{30}$[a] | 282 | 85 | 113 | 226 | 452 | 282 |
| COD | 3300 | 4500 | 1100 | 850 | 3700 | 950 |
| $BOD_{30}$/COD | 0.09 | 0.02 | 0.10 | 0.27 | 0.12 | 0.30 |
| TC | 1026 | 2728 | 644 | 243 | 2117 | 854 |
| TIC | 351 | 1477 | 373 | 104 | 1422 | 778 |
| TOC | 675 | 1251 | 271 | 139 | 695 | 76 |
| DOC | 663 | 1191 | 232 | 125 | 680 | 64 |
| TS | 17190 | 32890 | 7170 | 8200 | 10870 | 7400 |
| TVS | 15480 | 18080 | 1120 | 1620 | 2140 | 920 |
| TFS | 1710 | 14810 | 6050 | 6580 | 8730 | 6480 |
| TSS | 475 | 170 | 167 | 230 | 170 | 150 |
| VSS | 100 | 80 | 125 | 110 | 40 | 50 |
| TDS | 16713 | 32710 | 7000 | 7830 | 10490 | 7220 |
| Chloride ($Cl^-$) | 675 | 680 | 701 | 242 | 729 | 759 |
| Nitrate ($NO_3^-$) | 0.63 | 0 | 1.40 | 1.0 | 4.30 | 5.0 |
| Sodium ($Na^+$) | 382 | 306 | 325 | 307 | 295 | 298 |
| Ammonium ($NH4^+$) | 284 | 315 | 343 | 325 | 325 | 341 |
| Potassium ($K^+$) | 565 | 461 | 481 | 449 | 456 | 474 |
| Magnesium ($Mg^{2+}$) | 57 | 59 | 17 | 11 | 10 | 14 |
| Calcium ($Ca^{2+}$) | 696 | 611 | 325 | 254 | 268 | 215 |

[a] 30 days BOD

The concentrations of total solids (TS), total volatile solids (TVS), total fixed solids (TFS), total suspended solids (TSS), volatile suspended solids (VSS) and total dissolved solids (TDS) are presented in Table 2. With the exception of TFS and VSS of L1 (LTP), the leachates from L1 generally had a higher solids content than the leachates from L2. In the L2 leachates the TFS contents were higher than the TVS contents for all of the untreated and treated leachate samples, whereas for the L1 leachates the trend was reversed. This indicates that the leachates from L2 contained higher levels of inorganic solids whereas those from L1 contained higher levels of organic solids. TSS, VSS and TDS contents in all of the untreated and treated leachate samples ranged from 150 to 475 mg/l, 40 to 125 mg/l and 7000 to 32710 mg/l respectively, which are significantly higher than the values reported in the literatures [30, 31]. This reflects a high degree of mineralization during active anaerobic decomposition of the waste in L1 and L2 landfills [30].

The concentrations of chloride ($Cl^-$), $NO_3$- nitrogen, ammonia-nitrogen ($NH_3$-N), sodium ($Na^+$), potassium ($K^+$), magnesium ($Mg^{2+}$) and calcium ($Ca^{2+}$) are presented in Table 2. The values of ammoniacal-nitrogen ($NH_3$-N) observed in all of the untreated and treated leachate samples were at the high end of the concentration range reported in the literature [28, 32]. This might be due to the hydrolysis and fermentation of the nitrogenous fraction of biodegradable substrates [33]. In comparison to ammoniacal-nitrogen ($NH_3$-N), low $NO_3$-nitrogen values were found for all of the leachates, indicating that the majority of the nitrogen was in the form of ammonia. The results also show that the values of $Na^+$, $K^+$, and $Cl^-$ observed in all of these leachate samples were in the high concentration range [5, 30, 31]. The high values of these salt contents are correlated with high conductivities and the high TDS values. The $Mg^{+2}$ and $Ca^{+2}$ contents of the L1 leachates were higher than those of L2 leachates. This might be due to higher industrial wastes disposed in L1 landfill than in L2 landfill (Table 1) [29].

The above results confirm that the chemical composition of leachates may vary significantly from site to site. Differences were found in the concentrations of organic matter, anions and cations and in total and fixed solids contents. Leachates from L1 had higher solids, organic matter, sodium, chloride and magnesium contents than leachates from L2 in all of the untreated and treated samples. Owing to such a variable characteristics of landfill leachates, it is essential to conduct a long term monitoring programme to obtain representative information on leachates and to understand the detailed evolution of the constituent organic matter.

**3.2 Effect of laboratory scale biological treatment in the removal of recalcitrant COD from leachate**

In this phase of the study, the untreated and treated leachate samples from landfills L1 and L2 were treated aerobically for upto a maximum of 30 days to remove the recalcitrant organic compounds in leachates. The removal of recalcitrant organic compounds from leachates was evaluated by measuring COD changes. Fig 1 shows the total and dissolved COD as a function of time for all of the untreated and treated leachate samples.

The results show a gradual decrease of COD with time indicating the reduction of organic compounds by biological processes. However, a slight increase in COD at the beginning of aerobic biodegradation was observed for every leachate sample (Fig 1). Similar results have been reported by Nilsum [34] and Bila et al. [35] and this might be due to a rapid change in the structure of the organic compounds as a consequence of reactions in the formation of short-term intermediates that are easily oxidizable in the COD test. Fig 1 also shows that the COD concentrations were high in the untreated leachates L1 (P4) and L2 (P2), indicating that these two leachates contained significant amounts of organic compounds. The treated leachate L1 (LTP) also had high values of COD. This suggests that the treatment applied prior to aerobic biodegradation in the laboratory and the subsequent aerobic biodegradation were insufficient to remove all of the organic compounds from this particular leachate. These figures and those in table 2 also show that the organic compounds in the leachates contributing COD were mostly in dissolved form.

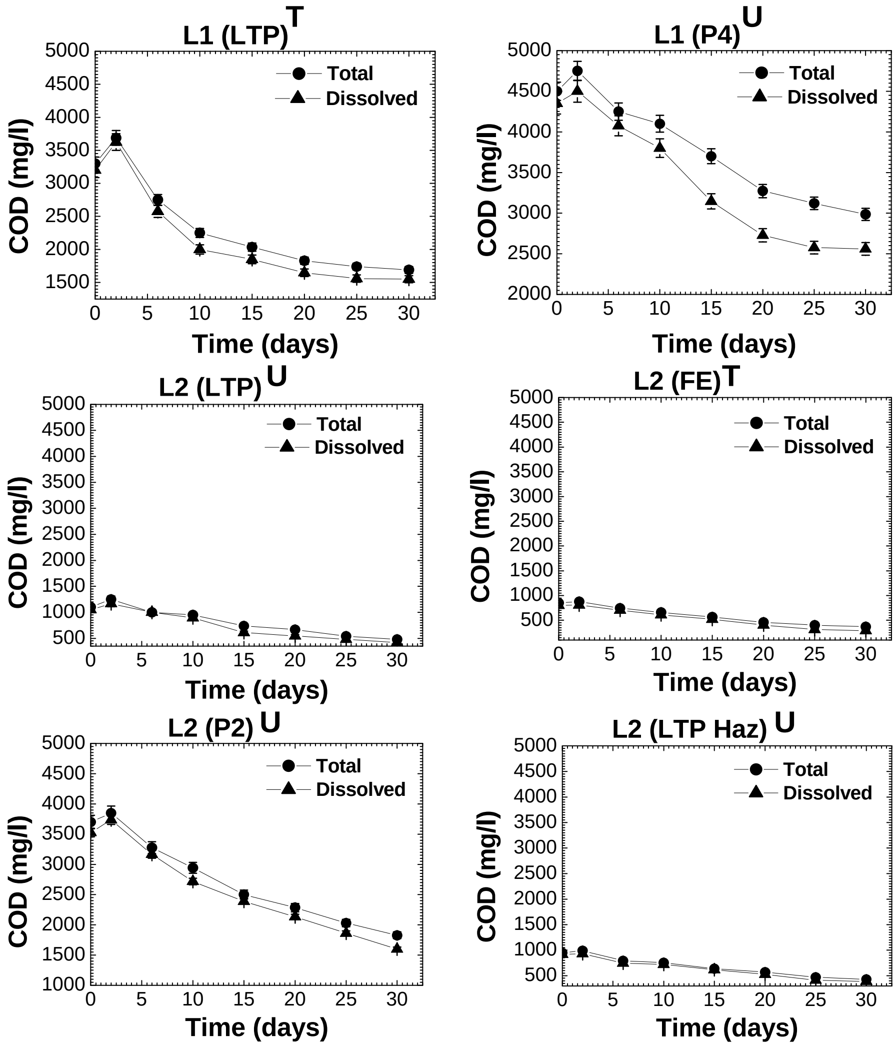


Fig 1: The change in COD over time during aerobic biodegradation for all of the untreated and treated leachate samples (T = treated and U = untreated)

Fig 2 shows the percentage removal of COD in the laboratory scale aerobic biodegradation experiments as a function of time. The %COD trend shows that after 30 days aeration the degradation of different leachates are in the order of L2 (LTP) > L2 (FE) > L2 (LTP Haz) > L1 (LTP) > L2 (P2) > L1 (P4) thereby indicating their biodegradability. However, from the %COD results the leachates can be divided into two groups in terms of their biodegradation after 30 days. The L2 (LTP) and L2 (FE) leachates which have low concentrations of organic compounds could be classed as easily biodegradable leachates whereas the rest of the leachates which have high concentrations of organic compounds could be classed as not easily biodegradable. However, from Fig 2, it can be concluded that the biodegradability of L2 (LTP) leachate is the highest after 30 days of aeration whereas L1 (P4) leachate can be accepted as one of the least biodegradable leachates among the six leachates under consideration.

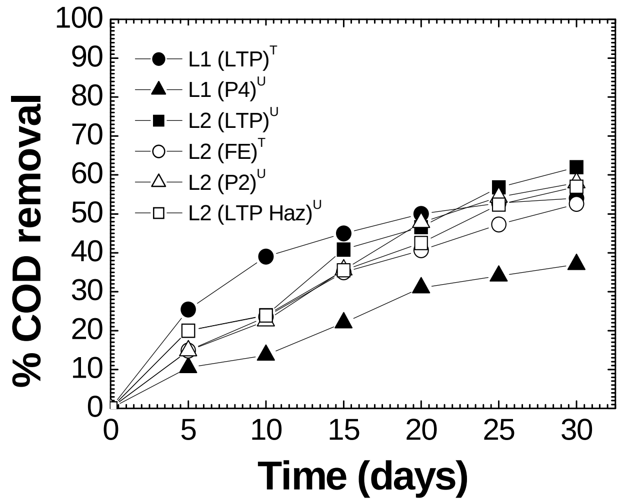


Fig 2: The percentage COD removal over time during aerobic biodegradation for all of the untreated and treated leachate samples (T = treated and U = untreated)

The above results show an increasing amount of removal of degradable compounds with time during aerobic biological treatment of different landfill leachate samples. The final concentration of COD in all the untreated and treated leachate samples after 30 days aeration as shown in Fig 1 indicate the presence of significant amount of recalcitrant organic compounds. This suggests that leachates could receive further treatment before they are discharged to the receiving water.

## 4. CONCLUSION

The present study reported the composition of four untreated and two treated leachate samples collected from two MSW landfills L1 and L2 in the UK. The experimental results showed that all of the untreated and treated leachate samples were high in pH and low in organic contents. The results also revealed that L1 leachate was stronger than L2 leachate in terms of solids, organic and inorganic matter content.

The study also considered the applicability of an aerobic biological treatment process for recalcitrant COD removal from the untreated and treated leachate samples. This laboratory scale aerobic treatment system achieved a greater reduction in all of the leachate CODs. The recalcitrant organic matter remaining for the untreated and treated leachate samples that can be further removed suggests that leachates could receive further treatment before they are discharged to the receiving water and may reduce the chance of any potential environmental impacts.

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# BIOCONVERSION OF GIANT REED AND SORGHUM HYDROLYSATES INTO LIPIDS FOR THE PRODUCTION OF BIODIESEL

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## ABSTRACT

Hydrolysates of Giant Reed and Sorghum were studied as nutrients for the *Lipomyces starkeyi*. The conditions to maximize the yield of lipids and the efficiency of the biomass conversion were found in terms of $H_2SO_4$ concentration and of medium composition. The key factor of the growth of microorganism in the hydrolysate was the C/N ratio. Dilution of the hydrolysate (50% and 25%) enhanced the growth of microbes reducing the inhibitory activities of antimicrobial compounds. *Lipomyces starkeyi* was able to grow in the wide range of temperature. Detoxification of hydrolysate with overlime and activated charcoal was carried out to reduce the concentration of growth inhibitors, improving the growth of the yeasts in the undiluted hydrolysate. This study demonstrated the potentiality of *L. starkeyi* as a source of lipids to be used as a feedstock for the synthesis of II generation biodiesel.

**Keywords:** lignocellulosic biomass, *Lipomyces starkeyi,* Detoxification, fermentation, lipids, biodiesel

## 1.INTRODUCTION

Lignocelluloses, which mainly produced by conventional agriculture and forestry practices is one of the cheapest and most abundant resources in the world. The utilization of cellulose resource has induced researcher‘s great attention and recognition all over the world in order to solve the food and energy crisis [1]. Presently, plant oils are traditionally used as triglycerides feedstock to produce biodiesel. Unfortunately, the cost of these oils is relatively high. As a result, the price of the biodiesel, that is mainly due (70-85%) to the vegetable oils used as feedstock, still exceeds that of the mineral diesel. Therefore, cost effective microbial oil has been suggested for biodiesel production in the near future [2, 3]. The conversion of lignocellulosic materials has been proposed by chemical and biological methods. In contrast, the biological conversion is considered environmentally friendly and less energy intensive [4].

A widely distributed perennial grass *Arundo donax* (Giant reed) is being considered among the group of more promising industrial crops [5]. Giant reed has also been identified as a prime biomass source for fuel and an alternative crop for paper/pulp or wood substitutes. The high yield potential and low input demands of Giant reed make it an attractive biomass crop [6] . It has specific feature such as annual harvesting period, high biomass productivity (up to

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37 $t^{-1}$ $year^{-1}$ $ha^{-1}$) [7], ability to be intensively cultivated [8] and easy adaptability to different climatic and soil conditions[9] which make *A. donax* one of the more promising industrial crops.
Another prospective source of lignocellulosic biomass is Sorghum and currently ranks fourth in acreage among cereal crops produced in the world. Although Sorghum (*Sorghum bicolor (L.) Moench*) has-been primarily used for grain and forage, the vegetative biomass has recently received more attention as a carbohydrate source for anaerobic fermentation to methane [10] or ethanol [11]. Structural component composition of the Sorghum stem is an important consideration when vegetative biomass is the primary product. It was found to contain 43.6–58.2% soluble sucrose, glucose and fructose in the stalk [12-15]. Moreover, it can grow under more harsh climatic and soil conditions.
In the present study the experimental activity has been aimed to the optimization of the conversion of lignocellulosic biomass into fermentable sugar, as well as the achievement of satisfactory yields in terms of triglycerides [16]. The overall objective of this research is to enhance the economic attractiveness of agro-industrial wastes for production of biodiesel through the production of lipids by oleaginous yeasts.

## 2. MATERIALS AND METHODS

### 2.1. Microorganisms and culture media

*Lipomyces starkeyi,* was kept on potato dextrose agar (Sigma) at T = 5 ± 1 °C. The microorganisms was cultivated in a N-limiting medium, containing (g l-1): KH2PO4 (Serva), 1.0; MgSO4 · 7H2O (BDH), 0.5; (NH4)2SO4 (Carlo Erba), 2.0; yeast extract (Fluka) 0.5, glucose 70.0. The microorganisms were grown under aerobic conditions at 30°C on a rotary shaker 160 rpm (Minitron, Infors HT, Switzerland).

### 2.2. Pre-treatment (acid hydrolysis) of lignocellulosic biomass

Lignocellulosic biomass such as Giant Reed (*Arundo donax* ) and Sorghum (*Sorghum bicolor)* were collected from S. Angelo dei Lombardi (Campania, Italy) agro-land. Leaves were separated from stems and were cut with a hex saw at 2 cm. Then washed and dried over night at 80°C and grind with a chopper. The powdered biomasses were stored in desiccators. In a typical test, $H_2SO_4$ at 10%, 5%, 2.5% (w/v) was used to oven-dried biomass at a solid to liquid ratio of 1:10 with 3g of samples in 30 ml of acid solution in a 100ml glass bottle. Then they were autoclaved at 121°C for 20 min (Fakas et al., 2008). After vacuum filtration the filtrate was neutralized to pH 6.5 with saturated KOH solution. Hydrolysates were steriled in autoclave before inoculation.

### 2.3. Fermentation with hydrolysates

The fermentation tests were carried out in conical flask of 500 ml. The liquid medium was inoculated by 2 ml of microorganism suspension, obtained dissolving 10 loops of solid culture in 8 ml of physiological solution. The flasks were incubated in a rotary shaker at an agitation rate of 160 ± 5 rpm and an incubation temperature T = 30 ± 1 °C. The pH value of the medium was 6.5- 6.68 before sterilization. One hundred fifty ml of the medium was transferred in a 500-ml shaking flask. At the end of fermentation pH value of the medium was 7.5-9.0, that varies with the composition of medium.

### 2.4. Lipid extraction and measurement

Total lipids extracted according to Bligh and Dyer [17] with little modification. In a typical test, 5 ml of methanol and 2.5 ml of chloroform were added to 200 mg of dry biomass and vortexed 5 seconds. Subsequently, the cells were disrupted for 12 min in an Ultrasonic

Homogenizer (Omni Ruptor 250, USA) at 50% power and 90% pulser. The cells were then filtered off with Whatman no.1 filter paper and the solvent-lipid mixture was placed in a 50 ml tube fitting with centrifuge racks. The layers were separated by centrifugation for 10 min at 2000 rpm in a thermostatic centrifuge (Rotanta 460R, Hettich, USA) at 20°C. The lower layer was then transferred to a pear-shape flask with Pasteur pipette. Again, 10 ml of 10% (v/v) methanol in chloroform were added to the residue, a new centrifugation was carried out, and the lower phase was added to that from the first extraction. The solvent in the pear-shape flask was evaporated to dryness (BÜCHI Rotavapor R-200, Switzerland) and extracted weight was finally recorded after drying at 105°C for 1 h.

### 2.5. Measurement of reducing sugar

In each test, 0.1, 0.2, 0.3 ml of sample were up taken from each batch. All were marked up to 2 ml adding distilled water. Then added 1ml of alkaline copper-tartrate reagent and put in boiling bath for 10 min , cold and added 1 ml of arsenomolybolic acid reagent and fill up to 10 ml. Reagents were prepared according to Nelson-Somogyi method [18]. Optical density was measured at 620nm.

### 2.6. Analysis of Microbial Biomass

The total count of microorganisms was carried out by sequential dilution and insemination in plate count agar medium (Difco Laboratories, Detroit, MI, USA). The colonies were counted after 48 h of culture on agar medium. After each fermentation ordeal, the biomass was recovered by centrifugation (4000 rpm for 10 min) and lyophilized (LYOBETA- 50, Spain), to enable the determination of the dry biomass and the lipid content. The TOC measurements were carried out with a TOC-VCSH/CSN (Shimadzu, Japan), upon suitable dilution of a culture medium sample. The TOC values were obtained subtracting the IC (inorganic carbon) value from the TC (total carbon) value.

### 2.6. Effect of Temperature

To observe the effect of temperature on the growth of *L. starkeyi* in the hydrolysate (50%) of giant reed stem, fermenters were put at 15˚C, 20˚C, 30˚C and in fluctuated temperature -24 hrs at 15˚C and next 24 hours at 30˚C. Inoculation was performed as described in section 2.3.

### 2.7. Detoxification of hydrolysate

The detoxification treatment included over-liming, activated charcoal treatment and both together. Firstly, hydrolysate was neutralized with NaOH to pH 6.5. The activated charcoals were added to the hydrolysates at weight ratios of 0.05 [19]. The hydrolysates containing activated charcoal were incubated at 30°C, 160 rpm for overnight then vacuum filtration to remove the adsorbent resulted in the detoxified hydrolysate. Finally, pH was adjusted to 6.5 with $Ca(OH)_2$ or 5 M $H_2SO_4$. For over-liming, the pH of hydrolysate was increased to 10.0 by addition of $Ca(OH)_2$. After 1 h, the hydrolysate was filtrated under vacuum and acidified to pH 5.5 with 5M $H_2SO_4$ and filtrated again after 1 h for precipitate removal [20]. Finally, the over-limed hydrolysate was recovered by vacuum filtration. One fragment of over-limed hydrolysate was treated by activated charcoal as described above. Inoculation was performed as described in section 2.3.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Pretreatment (Hydrolysis) of LCM

In most instances, pretreatment is a prerequisite condition to use agro-industrial residues in bioconversion to fuels and chemicals. The main purpose of pretreatment is to separate the components of lignocellulosic biomass, as well as to reduce lignocellulosic biomass crystallinity, render cellulose accessibility, and remove lignin [21]. Since lignocellulosic materials are very complicated, their pretreatment is not simple either. The best method and conditions of pretreatment depend greatly on the type of lignocelluloses. Different types of pretreatment methods were applied depending on the properties of substrate

Acid hydrolysis is the mostly usable pretreatment method for the lignocellulosic materials and Sulfuric acid is the most applied acid, while other acids such as HCl, phosphoric and nitric acid were also reported. In the present study, we carried out hydrolysis with dilute H2SO4, since it is at present more convenient, applicable, and suggested for our selective biomass. In a preliminary experiment, we arbitrarily selected one lignocellulosic biomass to observe the effect of the $H_2SO_4$ concentration on the hydrolysis process. It was observed that, for our autoclave setting, i.e., 121˚C for 20 min, a lower concentration of acid was required (Figure 1) to maximize the amount of fermentable sugars obtained from the biomass degradation. The formation of reducing sugar from cellulosic biomass reached a maximum at 5% of $H_2SO_4$ in the hydrolysis process. This behavior can be explained by considering that higher concentrations of acid may lead to further sugar degradation that‘s why most of the hydrolysis was conducted at lower concentration of acid [22, 23].

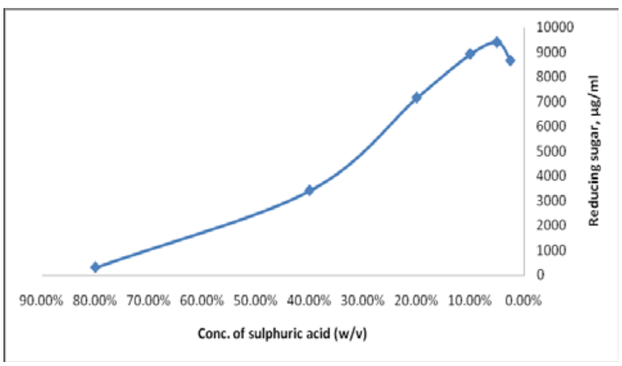



Figure 1: Effect of concentration of $H_2SO_4$ on hydrolysis process at condition-121°C, 20 min

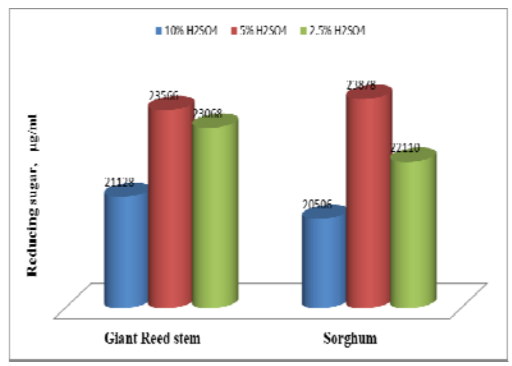



Figure 2: Optimization of acid hydrolysis.

Subsequently, selected biomass Giant reed stem (GRS) and Sorghum (SGM) were hydrolyzed with $H_2SO_4$ of 10%, 5% and 2.5% respectively. This experiment also showed almost similar result (Figure 2) as before. Therefore, we selected 5% $H_2SO_4$ for giant reed stem and Sorghum in subsequent experiments.

### 3.2. Composition of Sorghum plant

Sweet Sorghum has been recognized as one of the most promising ethanol crops in China [24-26]. Although dry matter and sugar accumulation of sweet Sorghum have been documented, little is known about differences in total soluble sugar, cellulose, hemicellulose, and grain yield as a whole for energy purposes. It was found to contain 43.6–58.2% soluble sucrose, glucose and fructose in the stalk [12-15] and 22.6–47.8% insoluble cellulose and hemicellulose [13, 15].

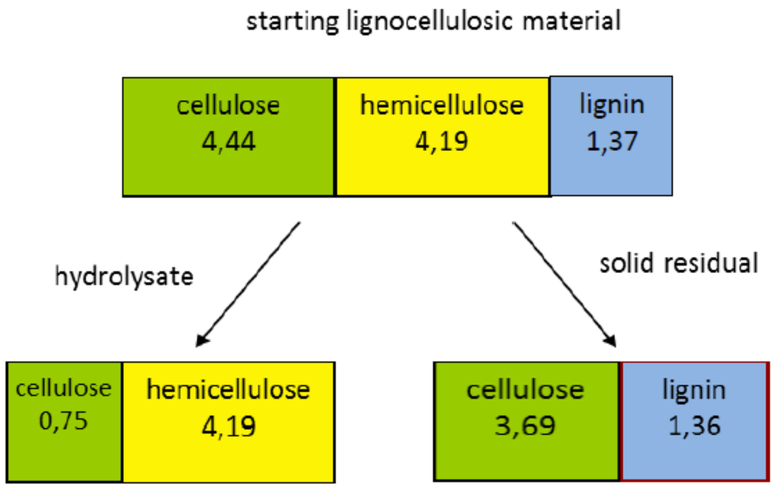
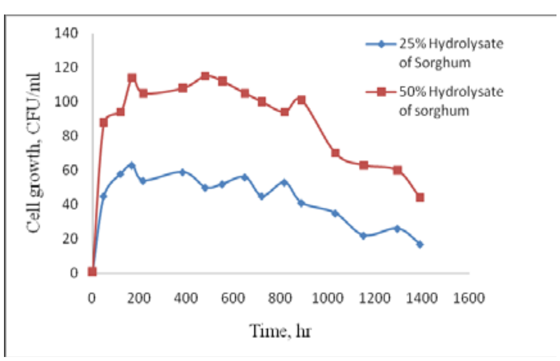


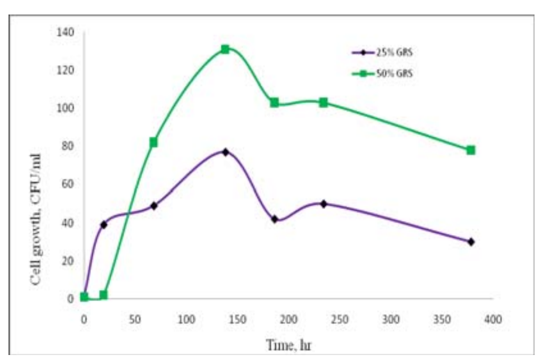

Figure 3: Composition of stem of Sorghum and their distribution to hydrolysate and residual fraction (values on basis 10)

In the present study, the composition of Sorghum was found as 44.4% cellulose, 41.9% hemicellulose and 13.7% lignin regarded in the first approximation as a mixture of cellulose, hemicellulose, and lignin. In the acid hydrolysis process cent percent hemicellulose was decomposed to hydrolysate (Figure 3) and little fraction of cellulose (7.5%) disintegrated to liquid medium. But total fraction of lignin remained in the solid residue and also most of the part of cellulose.

### 3.3. Optimization of cultural medium

Microorganism was cultured in the broth containing 100%, 50% and 25% of hydrolysate of Sorghum stem and Giant reed stem. There was no microorganism grown in 100% hydrolysate medium. It might occur due to higher concentration of inhibitors. Growth rate was higher in 50% broth than 25% and reached at maximum within 7 days (150-200 hrs) (Figure 4). Higher concentrated broth consumed lower amount of fresh water. This concept leads to produce microbial oil through solid-state fermentation [27, 28].




(a) (b)

Figure 4: Optimization of cultural medium (a) Sorghum (b) Giant Reed stem in terms of dilution

### 3.4. Growth kinetics

Kinetics growth profiles of GRS and SGM were almost similar in sequence. However, colony forming unit (CFU) was a little bit higher for GRS and survival period was also longer (Figure 5). On the other hand, dry biomass yield was lower than that of SGM, even lipid content. The possible reason of the different kinetics behavior is the effect of inhibitors [29].

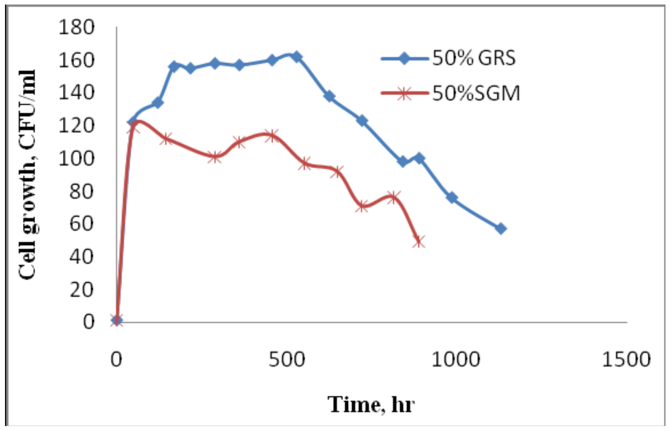
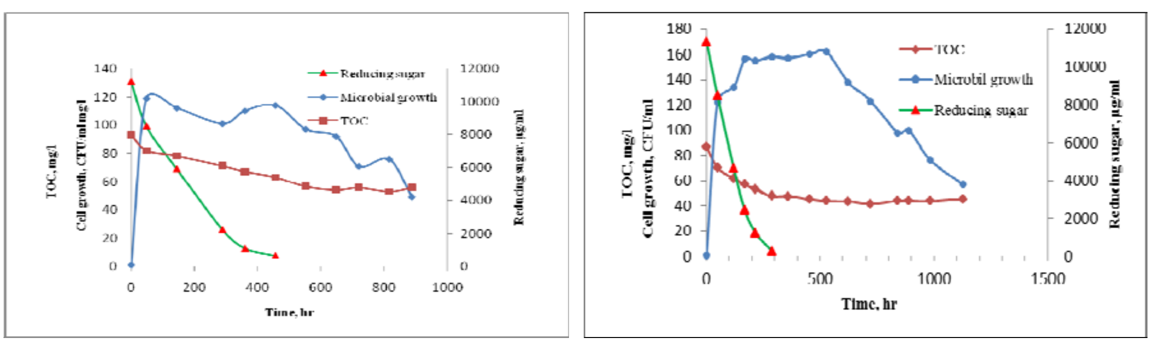


Figure 5: Growth kinetics of microorganism in cellulosic hydrolysate

### 3.5. Nutrient consumption by *L. starkeyi*

Consumption of fermentable sugar by *L. starkeyi* in hydrolysate medium of SGM and GRS is illustrated in the Figure 6a and 6b respectively. In both cases, cell growth was correlated with the sugar utilization from the beginning of the fermentation. Sugar concentration was gradually declining with respect to the microbial cell growth up to 200-300hrs. When cell growth was stopped, no significant change of reducing sugar was observed. Similar growth profile was described for *Trichosporon fermentans* cultured in cane molasses [16] and *Mortierella isabellina* cultured in sweet Sorghum [27]. So, sugar was the main C nutrient and growth factor of *L. starkeyi*.




(a) (b)

Figure 6: Change of Carbon sources with microbial growth of *L. starkeyi* in (a) SGM (b) GRS

In the same time, total organic carbon (TOC) values were also falling with growth of microbes but it never be finished. It seemed to almost constant when growth of cell was stopped. This phenomena of TOC indicated that hydrolysate medium contain other C sources which were not metabolized by *L. starkeyi*.

### 3.6. Biomass and Lipid yields

Optimistic result of lipid accumulation by *L. starkeyi* was observed using GRS and SGM hydrolysate, considering them as alternative C and N sources. Superior lipid accumulation was occurred in the bioconversion of SGM hydrolysate due to the comparatively higher C/N ratio (53.28) than that of GRS hydrolysate (Table 1).

Table 1: Comparison between Giant reed stem and Sorghum in terms of biomass and lipid production

| Carbon sources | Initial C/N | Dry Biomass yield (g/l) | Lipid content (%) | Lipid yield (g/l) |
|---|---|---|---|---|
| Giant reed stem | 30.95 | 2.76 | 7.08 | 0.196 |
| Sorghum | 53.28 | 2.89 | 15.53 | 0.449 |

Whereas Angerbauer et al., mentioned that lipid productivity of *L. starkeyi* at C/N ratio 150 and 60 were similar (6.4g/l and 5.9 g/l). Though cell growth was faster in GRS (Figure 5), lipid yield (0.449 g/l) was significantly higher in SGM than that of GRS hydrolysate medium. It may cause of favorable composition (e.g. C/N ratio, lower inhibitors) of hydrolysate.

### 3.7. Effect of Temperature

Microbial growth was studied at different temperature like 15˚C, 20˚C, 30˚C and fluctuated (T-F). According to Figure 7, growth rate of *L. starkeyi* was slower at lower temperature (T-15, T-20) than that of higher and fluctuated temperature (T-30, T-F). It is interesting that growth profile of *L.starkeyi* was almost similar at T-30 and T-F, which indicated that it would be cultured in open environment or in uncontrolled temperature.

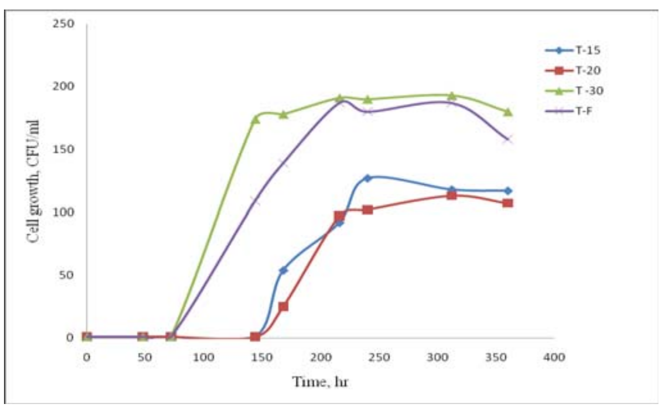



Figure 7: Growth profile of *L. starkeyi* at temp. 15˚C, 20˚C, 30˚C and fluctuated (15-30˚C)

The influence of temperature on biomass and lipid yield was not significantly high (Table 2). Only it varies in fluctuated temperature. May be this condition interrupted the metabolic function of *L. starkeyi*.

Table 2: Effect of temperature on Biomass and Lipid yield

| Temperature | Biomass yield g/lt | Lipid content % | Lipid yield g/lt |
|---|---|---|---|
| T-30 | 4.3 | 8 | 0.344 |
| T-F | 3.8 | 7.2 | 0.275 |
| T-20 | 4.5 | 7.6 | 0.345 |
| T-15 | 4.9 | 7.7 | 0.385 |

**3.8. Efficiency of detoxification methods**

To improve the fermentability of the lignocellulosic hydrolysates, various detoxification methods have been studied such as extraction with organic solvents [30], overliming [31-33], evaporation [32], steam stripping [34], sulfite treatment [32, 33], ion-exchange [36], enzyme treatment [37, 38], zeolite treatment [39] and activated carbon treatment [34,40].

In this study, we implemented overlime and activated charcoal to remove inhibitors like furfural and phenolic compounds. In the previous experiments, microorganisms were not able to grow in 100% hydrolysate of GRS and SGM. As a result, hydrolysates were diluted to 50% and it was fermentable but this process consumed huge amount of fresh water. Therefore, for achieving high fermentability, detoxification of hydrolysates is necessary before the fermentations to remove the inhibitory compounds.

The hydrolysates was detoxified in three ways i) overlimed ii) treated with activated charcoal and iii) both together. Figure 8 illustrated the influence of these three methods on the growth of *L. starkeyi.* Untreated hydrolysate was totally unfermentable and *L. starkeyi* was unable to survive due to high inhibitory activity. Activated charcoal showed better influential role to remove toxic compounds than others.

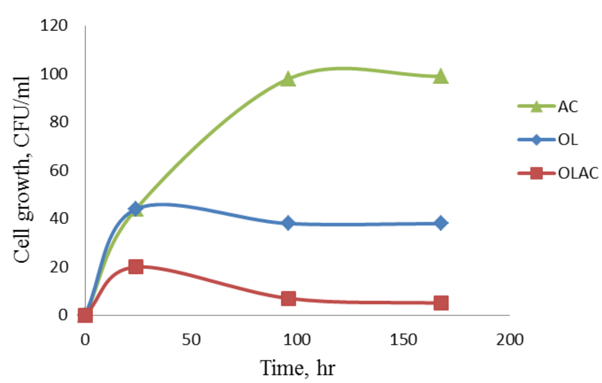



Figure 8: Growth of *L. starkeyi* in the detoxified mediums

In a previous report on the detoxification of the hydrolysates by using activated carbon with high absorptivity, not only removed inhibitors that can affect fermentations but also some amounts of the fermentable sugars. On the other hand, Miyafuji et al. [19] found almost the same concentrations of various sugars in the hydrolysates treated with the wood charcoals and in the untreated hydrolysate. These results indicated that the wood charcoals were capable in selectively removing the inhibitors such as furan and phenolic compounds without removing the fermentable sugars. Whereas in the present study, activated charcoals and overliming removed inhibitors as well as significant amounts of reducing sugars (Table 3). But growth profile of *L. starkeyi* (Figure 8) and biomass yield proved that activated charcoals efficiently removed inhibitors than others.

Table 3: The influence of different detoxification methods on RS, TOC and biomass yield

| Sample | Reducing Sugar µg/ml | TOC mg/lt | Biomass yield g/l |
|---|---|---|---|
| WT (without treatment) | 32415 | 39600 | 00 |
| AC (activated charcoal) | 25041 | 29840 | 4.073 |
| OL (overlime) | 25433 | 35164 | 1.808 |
| OLAC(activated charcoal & overlime) | 18204 | 20580 | 1.958 |

When hydrolysate was treated with both OL and AC (OLAC), reducing sugar was removed by 44%. As a result microbial growth was unfavorable.

## 4. CONCLUSION

Giant reed steam and Sorghum appear to be a viable feedstock for biodiesel. Cellulose and hemicellulose content of GRS and SGM were adequate to hydrolyse into fermentable sugar Detoxification treatment has beneficial effect to reduce inhibitor. *L. starkeyi* was able to grow in wide range of temperature, i.e., sophisticated environment not required to culture them. The fermentation of hydrolysates of lignocellulosic materials is of great strategically importance, due to the abundance of the agricultural and forestal residues, offering a renewable sources for biodiesel.

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# OPPORTUNITIES AND UTILIZATION OF RAINWATER HARVESTING IN RESIDENCES OF DHAKA CITY

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## ABSTRACT

The study explores the opportunities and possibilities of utilizing rainwater harvesting as a secondary resource. As 87% of the supply water comes from groundwater, a search for alternative water sources is critical. This study identifies and analyzes different systems of rainwater harvesting; analyzes different types and components of rainwater harvesting systems, studies the importance of rainwater harvesting in the urban areas of Dhaka and analyzes the utilization of rainwater as a secondary resource in flushing Water Closets (WC). The study investigates the rainwater collected on a six-storied residential building with 25 persons residing in the building. This research shows that rainwater harvesting as a secondary source of water can provide a supply of 717 $m^3$/ year against a demand of 245 $m^3$/ year. Surplus water for flushing the harvested rainwater is 472 $m^3$/ year. Surplus water for flushing the harvested rainwater is 472 $m^3$/ year. This water supply is 293% expressed as a percentage against its demand.

**Keywords:** Rainwater harvesting systems; secondary resource; water supply and demand

## 1. INTRODUCTION

### 1.1. Problem Formulation

A recent study shows that there is acute crisis in the quantity and quality of water in Dhaka, the capital of Bangladesh. The problem is so severe in some areas that people do not get the minimum required quantity of water for drinking. Scarcity of safe water is the main reason for the outbreak of diarrhea and other intestinal diseases in the city, which have assumed epidemic proportions [1].

The Dhaka Water Supply and Sewerage Authority (WASA) has a daily production capacity of some 1940 million litres against the stated demand of 2200 million litres and the per capita need of water in Dhaka has been estimated to be 160 litres a day [1]. Actual pumping of water is below the capacity due to frequent load shedding of electricity. In addition, the water distribution lines are very old, inadequate and faulty. Huge wastage of water is an important reason of the crisis. Construction works, car washing, watering gardens, toilet flushing and even production in mills and factories are done with safe water meant for drinking.

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Safe drinking water is very scarce due to arsenic contamination [2] and salinity problem [3] in Bangladesh. Climate change is expected to make drinking water even scarcer [3]. In the past few decades, a significant no of shallow tube well have been installed in Bangladesh to provide 'safe' potable water to people. Dependence on ground water based system has increased the risk of arsenic contamination in an alarming way. Therefore, alternative water supply options are becoming significantly important due to water scarcity and contamination risks.

Rainwater harvesting (RWH), an alternative water supply option, is a common practice in countries like Bangladesh where the annual precipitation is high [4]. Around 35.5% of the households in coastal areas use RWH method as a source of drinking water due to high salinity problems [5]. Globally, rainwater-harvesting system is used for domestic, agriculture, runoff control, air condition etc. since a long time back [6].

Rainwater, in this study, is considered as water collected from roof surfaces during rain events. Rainwater Harvesting (RWH) is the collection, conveyance and storage of rainwater. Thus, Rainwater Harvesting Systems (RWHS) for purposes of this study are defined as systems that collect, store and use precipitation collected from rooftops. This water is then suggested to be stored in tanks for later use as indoor non-potable application, such as flushing Water Closets (WC).

### 1.2. Aim

The aim of this study is to explore the opportunities and possibilities of utilizing rainwater harvesting as a secondary resource.

### 1.3. Objectives

1) To analyze different types and components of rainwater harvesting systems
2) To study the importance of rainwater harvesting in the urban areas of Dhaka
3) To analyze the utilization of rainwater as a secondary resource in flushing Water Closets (WC)

### 1.4. Delimitations

1) The research will be delimited to the urban area of Dhaka, Bangladesh.
2) The study will be confined to use of rainwater as a secondary source for flushing water closets in residential buildings of Dhaka.

## 2. METHODOLOGY

The study comprised of a literature review to gather the data for the objectives set out in this research. The review investigates different types and components of rainwater harvesting systems commonly applied in different countries, importance of rainwater harvesting in urban area of Dhaka and potential benefits of rainwater harvesting. The data were analyzed and evaluated using quantitative and qualitative methods. Calculations were made to study the supply of rainwater on a roof with a catchment area of a six-storied residence building and the demand of water for flushing water closets (WC) of 25 residents in the building.

## 2.1. Literature Review

### 2.1.1. Historical Background of RWH

A detail history of rainwater harvesting system is given by [7]. The oldest known examples date backs several thousand years and is associated with the early civilizations of the Middle East and Asia. In India, evidence has been found of simple stone-rubble structures for harvesting water that date back to the third millennium BC [8]. Rainwater was used for agriculture and domestic purpose about 2000 BC in Israel [9]. There is evidence in the Mediterranean region of a sophisticated rainwater collection and storage system at the Palace of Knossos, which is believed to have been in use as early as 1700 BC [10]. Many Roman villas and cities are known to have used rainwater as the primary source of drinking water and for domestic purposes [11].

### 2.1.2. Types and Components of RWH System

Different RWH systems are currently in use globally and a wide variety of both potable and non-potable applications are evident. Non-potable demands includes washing, cooling, fire suppression, household cleaning, industrial process, irrigation, laundry washing, toilet flushing, pool filling, vehicle washing and potable demands includes drinking, cooking, bathing and dishwashing [12].

Rainwater harvesting is an appropriate water supply and storm water solution for residential, commercial, industrial, and agricultural applications [12]. Water usage patterns are different in different types of buildings. However, study [13] shows that, Water Closet (WC) use the highest part of average water used in household, commercial and industrial buildings.

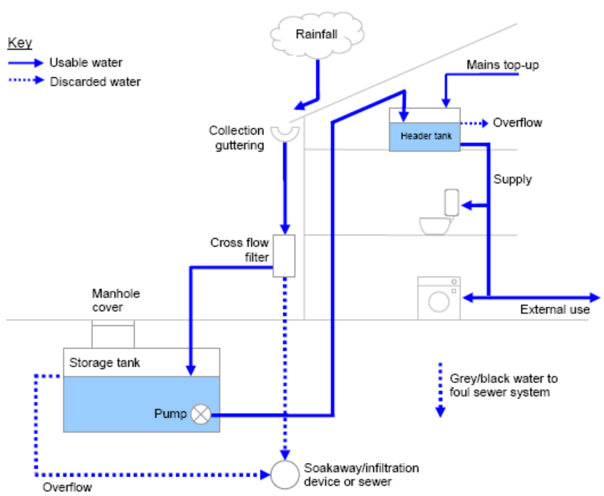


Fig 1: RWH: Indirect pump system.

Source: [18]

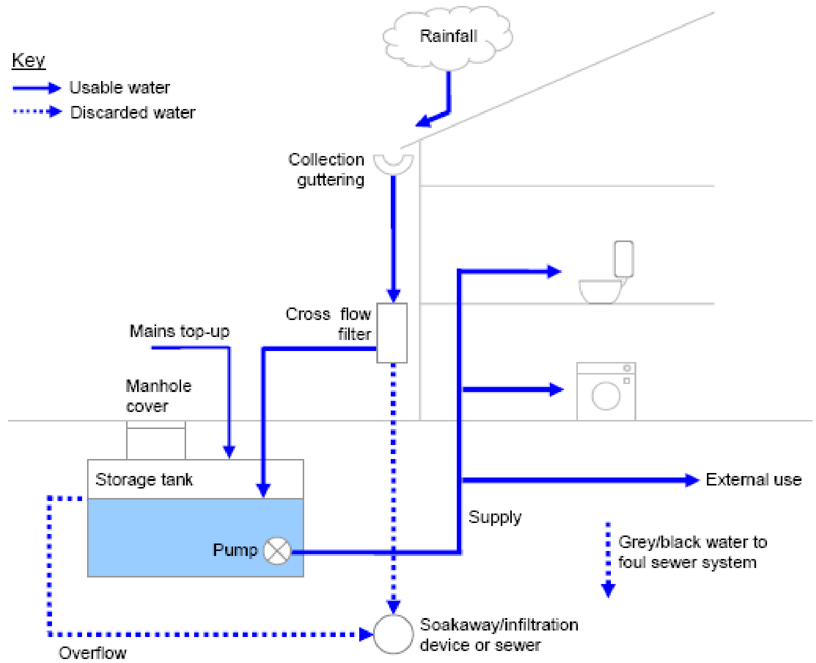


Figure 2: RWH: Direct pump system

Source: [18]

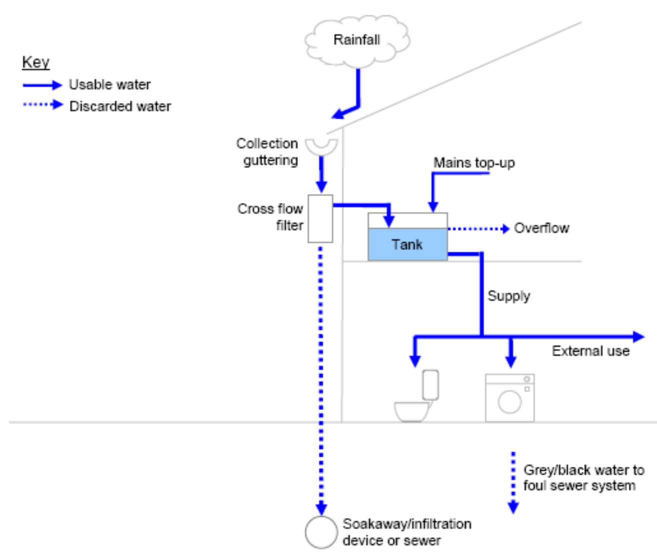


Figure 3: RWH: Gravity fed system

Source: [18]

Three basic types of system for supplying non-potable water to buildings for internal and external uses are identified by Leggett et al [13]: directly pumped, indirectly pumped and gravity fed. A comparative analysis of the three RWH systems is given below:

Table 1: Comparative RWH system

| Features | Indirect pump system | Direct pump system | Gravity Fed |
|---|---|---|---|
| **Flow system** | Rainwater is initially held in a storage tank and then pumped to a header tank within the building, which is usually located within the roof void. | In a directly pumped system rainwater is initially held in a storage tank and then pumped directly to the point of use when required. | The main storage tank is located within the roof void of the building |
| **Advantages** | If the pump fails then water will still be supplied to the associated fixtures and fittings via the mains top-up function. In the event of a power failure it is still possible to flush the toilet. | The main advantages of directly pumped systems are that water is provided at mains pressure. | They do not require a pump or electrical supply as is the case with the direct and indirect versions. There is no pump; there is no risk of pump-associated supply failure. |
| **Disadvantages** | Low water pressures can leads to slow filling of WC cisterns and the system may not provide enough pressure to work with some appliances. There may not always be sufficient space in the roof void to site the tank | If the pump fails then no water can be supplied. WCs would have to be flushed manually. Mains top-up controls can also be more complicated than with indirect and gravity fed systems | The main disadvantages are that the water pressure is likely to be less than that of the mains supply. High structural load impose to the building. |
| **Cost** | High installation cost due to additional header tank. | Low installation cost due to single storage system | Low installation cost. |
| **Efficiency** | Low cost pumps and simple controls are possible and systems tend to be energy efficient. | Moderately efficient. | Efficiency would be low if relative levels of the various components (roof, filter and tank) are not arranged properly. |
| **User-friendly** | Very user friendly | Moderate user friendly | Very user friendly |

Source: [18]

The storage tank or cistern, in general, is the most important component in the design of a rainwater harvesting system [14]. Water storage capacity is required in order to balance out the difference between supply and demand [7]. In the developed world, the most commonly used storage device is the underground tank [15]. Installing tanks underground has a number of advantages: it helps to prevent algal growth by shielding the tank from daylight [16], protects the tank from extreme weather conditions at the surface such as freezing spells [13] and helps to regulate the water temperature in the tank, keeping it cool and limiting bacterial growth [17]. There are different materials available for the storage tank. Most common materials are concrete, plastic, wood, bricks, steel, glass reinforced plastic (GRP), high-density polyethylene fiberglass, polyethylene, ferro-cement ([13]; [18]; [14]; [19]). A qualitative comparison of the common storage tank materials are given below:

Table 2: Comparative analysis of different RWH material context of Dhaka

| | **Longevity** | **Local Availability** | **Construction & maintenance** | **Transportability** | **Cost** |
|---|---|---|---|---|---|
| **Concrete** | High | Available | Required | No | High |
| **Ferrocement** | High | Available | Required | No | High |
| **Plastic** | High | Moderate | No | Yes | Medium |
| **wood** | Medium | Available | Required | Yes | High |
| **Polyethylene** | Very High | Moderate | No | Yes | High |
| **Fiberglass** | Very high | No | No | Yes | Very High |
| **Steel** | High | Moderate | Required | Yes | Very High |

Source: GRHG, 2009; Pushard, 2010

It is preferable to construct the tank using brick and RCC. The cost will be between 10,000-12,000/Taka (143 $-171$). Although its initial cost is high compared to other RWHS, the cost of collecting water is low when compared to other systems. All the filter media and chemical used here is available and of low cost [20].

All RWH systems consist of the same basic components: a collection surface a conveyance system, pre-tank treatment, water storage and distribution. Harvested rainwater used for indoor use will also often include additional treatment [12]. Modern RWH system includes UV or electrical control systems [18]. Basic components of RWH systems are as follows:

- Roof catchment
- Gutters and downpipes
- First flush device
- Filter chamber
- Dosing chamber (chlorination/ de-chlorination)
- Storage tank(underground /overhead)
- UV unit.

- Electronic controls/management systems.
- Water pump/supply system

The roof of a building or house is the obvious first choice for catchment. Catchment includes rooftops, compounds, rocky surface or hill slopes or artificially prepared impervious/semi-pervious land surface. For the selected building, rooftop is considered as the catchment area as there is no other effective catchment area. For additional capacity, an open-sided barn (called a rain barn or pole barn) which provides additional roof catchment can be built. Runoff coefficient (c) of the catchment area varies dependent of the materials type such as tiles (0.8-0.9), metals (0.7-0.9), concrete (0.6-0.8) or open slope ground (0.1-0.3) [21]. Gutters and down pipes of different materials like PVC pipes, G.I pipes, ferro-cement pipes, wooden pipes can be used for gutters.

In a first flush device a separate vertical pipe is fixed to the rainwater down pipe using a "T" junction or similar. When this chamber becomes full, the floating ball seals the chamber and the continuing water flows down the collection pipe into the storage tank. Water diverters improve water quality, reduce tank maintenance and protect pumps by preventing the first flush of water, which may contain contaminants from the roof, from entering the tank.

To get rid of solid particles (leaves etc.), wire mesh filter at down pipes are used. Dosing chamber is used when the water is used for drinking purposes. UV filtration systems are also used in developed countries

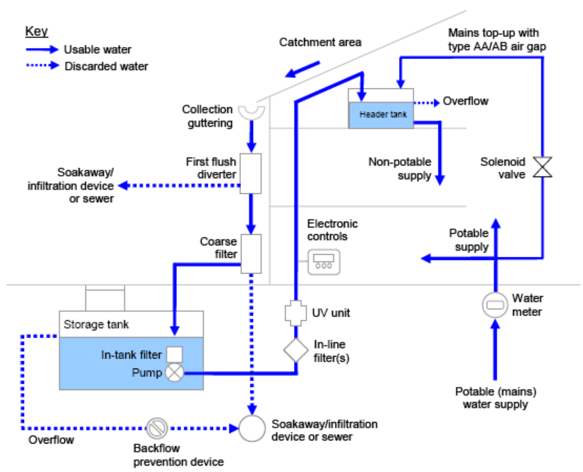


Figure 4: A modern RWH system components

Source: [18]

Both overhead and underground storage tank can be constructed using different materials. Different types of overhead tanks are available in the market of different standard sizes. For both the type, most commonly used materials are: cement concrete, R.C.C, precast R.C.C, ferro-cement, G.I storage tank etc.

### 2.2. Benefits of RWH System

Numerous socio-economical and environmental benefits are gained from rainwater harvesting [12]. Rainwater can pick up detrimental pollutants like bacteria from animal excrements or decaying animals, chemicals, metals, nitrogen and phosphorus from fertilizers, oil, pesticides, sediment and trash [22]. Rainwater harvesting was identified as one of 'Best Management Practice' (BMP) that would have a 'positive impact' on the volume, peak rate, and quality of storm-water runoff from a site [23].

The economic feasibility of harvesting rainwater differs based on many factors, i.e. precipitation frequency, water consumption needs, prices of local water and wastewater treatment, cost of installation and maintenance. According to Krishna [24], the most important benefit of rainwater harvesting is that the water is free; the only cost is for collection and use. Having lower hardness than groundwater, rainwater helps prevent scale on appliances and extends their use [25]

It was learned that rainwater harvesting tanks, more than modern water equipment, are necessary for life support systems in new settlements for the refugees [26]. Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are also readily available. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems.

Moreover, stored rainwater gives its owner more independence from the effects of irregularities of rain events. RWH is by nature decentralized and relatively less vulnerable to natural disasters than public water supplies. Widespread adoption of rainwater harvesting can increase the efficiency of expensive water supply infrastructure.

Rainwater run-off during rainfall from roofs and other sealed surfaces during heavy rain lead to flooding. If rainwater harvesting is used in buildings it will not only greatly reduce demands on the conventional water sources, but also significantly reduce run-off, thus reducing flooding problems [27].

## 3. RESULT AND DISCUSSION

### 3.1. Water Supply Management

According to Haq [27] the demand for water in 2006 was around 1760 MLD at 160 l/per capita. Against this demand DWASA has a production potential of 1600 MLD, but actual production ranges from 1400 to 1500 MLD. The water supply system is groundwater based and 82% of the supply is abstracted from underground aquifers through 390 production wells. The remaining 18% is derived from three surface water treatment plants. The service area population, water demand, actual water supply and deficit are shown in Table 3.

Table 3: Population, water demand, supply and deficit

| Year | Populations (million) | Water demand (MLD) | Water supply (MLD) | Deficit (%) |
|---|---|---|---|---|
| **1996** | 7.55 | 1300 | 810 | 38 |
| **1997** | 8.00 | 1350 | 870 | 36 |
| **1998** | 8.50 | 1400 | 930 | 34 |
| **1999** | 9.00 | 1440 | 1070 | 26 |
| **2000** | 9.50 | 1550 | 1130 | 25 |
| **2001** | 10.00 | 1600 | 1220 | 24 |
| **2002** | 10.50 | 1680 | 1300 | 23 |
| **2003** | 11.00 | 1760 | 1400 | 20 |

Source: [28] ; [29]

The table shows the gap between demand and supply. It can be seen from the Table that DWASA started its operation in 1963 with a modest deficit of 13%. This gap between demand and supply continued to increase for the next 33 years and peaked at 49% in 1990. From 1996, the deficit started to decline and by 2003 the deficit between the demand and supply was at its lowest during the entire history of DWASA except for the inception year of 1963.

Haq [27] confirms that the deficit between demand and supply widened again from 2004, but at a much faster rate due to the inability of the DWASA to secure the necessary funding for the construction of two more surface-water treatment plants. Haq [27] says that the problems of quality of both the surface and groundwater have also added a new dimension to the water supply scenario. According to him, this report shows that the groundwater table is falling at an alarming rate of over 2 m per year and the groundwater is being mined in significant amounts.

Studies indicate that the groundwater resources within the greater Dhaka area are insufficient to meet even the current needs for water supply in Dhaka [30]. Groundwater of the city is going down by three metres every year but Dhaka Water Supply Authority (WASA) is still dependent on it. Meanwhile, as the population of the city has increased, the water demand has doubled. As 87% of the supply water comes from groundwater, WASA is looking for alternative water sources [31]. Rainwater harvesting can thus be an attempt to shift the dependence from groundwater to all forms of surface water. In a pioneering effort, Dhaka WASA has started to collect rainwater from the rooftop of its administrative building. In 2002, Dhaka WASA collected and utilized 11.5 million litres of rainwater. This water has been supplied for non-potable uses thereby reducing the building’s water demand considerably from other sources such as surface and groundwater [27]. Haq [27] stresses that there are plans to set up a rainwater collection system in government buildings, semi-government buildings and buildings of autonomous bodies.

Dhaka has an annual average rainfall of 2000 mm [27]. About 80% of the annual rainfall occurs in the rainy season. If more buildings could be brought into such a programme it will not only greatly reduce demands on the conventional water sources, but also significantly reduce run-off, thus reducing flooding problems. In case of a severe storm, part of the run-off can be used for induced groundwater recharge as has been done in DWASA's Rooftop Rainwater Harvesting Project. Rainwater has the added advantage that it is free from arsenic. It is thus important to harvest rainwater in the urban areas of Dhaka. Experts have reported that alternative sources like rainwater harvesting by city dwellers can meet 15% of the annual water demand in Dhaka and stressed that a provision of rainwater harvesting system should be included in the building code [29]. It is, therefore, highly recommended that use of rainwater be integrated as a secondary resource in the integrated water management plan.

Table 4. Rainfall data for 2003

| **Month** | **Average precipitation (mm)** |
|---|---|
| **Jan** | 0 |
| **Feb** | 25 |
| **March** | 96 |
| **April** | 123 |
| **May** | 140 |
| **June** | 473 |
| **July** | 191 |
| **Aug** | 202 |
| **Sept** | 264 |
| **Oct** | 134 |
| **Nov** | 0 |
| **Dec** | 45 |

Source: [32]

As a secondary water source rainwater can be used for gardening, urban firming, washing and cleaning, flushing of toilets, recreational activities, ground water recharge and many more urban activities. This study analyzed different RWH systems for supplying flushing water to Water Closets in toilets. Flushing Water Closets require minimum water head for operation. Indirect pump system is ideal for flushing for operating flushing; however, this system requires high investment cost. Direct pumping system is only possible if sufficient rainwater is available during the pumping time. Gravity fed system can be applied in flushing Water Closets. However, maintaining elevation gap between catchment roof, storage tank and flushing device is critical for operating flushes efficiently.

### 3.2. Demand and Supply of Rainwater for Flushing WC (WATER CLOSET)

#### 3.2.1. Demand of Rainwater

The per capita water consumption for each flush of water is assumed to 5.68 litres/ flush and the frequency of use is 4 times/ day. The total per capita consumption of water for flush is thus 22.7 litres (5.68 x 4) or 0.0227 $m^3$ .The building on which the rain water is harvested is assumed to be six-storied , with the ground floor free for parking. Each household has 6 persons and thus the total number of people in the six-storied building is 30. The monthly rainwater demand is the product of consumption per capita per day (0.0227 $m^3$), total number of persons in the six-storied building (25) and numbers of days in a month (30). This figure (20.43 $m^3$) multiplied by 12 gives the yearly demand of rainwater, i.e. 245 $m^3$

**Demand calculation:**

Consumption per capita per day = 0.0227 $m^3$
Number of people per household = 6
Total number of people in 6-storied building with ground floor free=5x 6=30
Monthly rainwater demand = 0.0227x 30x 30 = 20.43 $m^3$
Yearly demand = 20.43x 12= 245 $m^3$

#### 3.2.1. Rainwater Harvesting Potential

Supply of rainwater depends on the factors namely, run off co-efficient; amount of rainfall and the catchment area [32]. Runoff depends upon the area, type and surface of the catchment over which it falls. Calculations relating to the performance of rainwater catchment systems involve the use of runoff coefficient to account for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all contribute to reducing the amount of runoff. Based on these factors the water harvesting potential of a site could be estimated using the formula given below [33].

Water harvesting potential = Rainfall (m) x Area of catchment ($m^2$) x Runoff coefficient

The catchment area is 448$m^2$. This is the typical size is of a large residential building in Dhaka. The run off coefficient for a concrete roof is assumed to be 0.8 [21]. The average yearly rainfall in Dhaka is of 2000 mm [27]. The average yearly water supply from rain is thus the product of the catchment area, the runoff coefficient and the average yearly rainfall, 717 $m^3$.

**Supply calculation:**

Average catchment area for rainwater harvesting= 448$m^2$ (approximately)
Run-off coefficient = 0.8 (for concrete)
Average yearly rainfall = 2 m
Average yearly water supply from rainfall = 448 $m^2$ x 0.8 x 2 m = 717 $m^3$

Table 4: Demand and supply of rainwater for flushing WC

| Demand | | Supply | | Surplus water ($m^3$/ year) | Percentage of rainwater supply expressed against its demand |
|---|---|---|---|---|---|
| Service | Annual ($m^3$/ year) | Source | Annual ($m^3$/ year) | 472 | 293% |
| Sanitation | 245 | Rainwater harvesting | 717 | | |

Rainwater harvesting as a secondary source of water can provide a supply of 717 $m^3$/ year against a total demand of 245 $m^3$/ year. Surplus water from rainwater harvesting is 472 $m^3$/ year. This water supply is 293% expressed as a percentage against its demand. This indicates that supply of water is almost three times the demand. It has to be emphasized that the supply of 717 $m^3$/ year rain water harvested is only for the purpose of flushing the WCs of toilets in a typical large sized six storied residential building having a total of 30 residents. The results indicate that if rain water harvesting is to be used for flushing purposes in Dhaka city, it can significantly reduce the load on Dhaka Water Supply Authority (DWASA). Moreover surplus water can be used for other purposes such as gardening, car washing, washing clothes, etc. If the buildings in Dhaka adopted rainwater-harvesting system for flushing the WCs, it would not only reduce demands on the conventional water sources, but also significantly reduce run-off, thus reducing flooding problems. However, as heavy rainfall occurs in the rainy season from April to October [6], water has to be stored during rainy seasons for the rest of the year. Preservation of harvested rain water is thus one of the prime challenges in rainwater harvesting. Proper care has to be taken to store the rain water collected during the rainy season to be used for flushing WCs throughout the year.

## 4. CONCLUSOIN:

It has been seen in this study that there are different types and components of rainwater harvesting systems. The importance of rainwater harvesting in the urban areas of Dhaka has been observed. Rainwater harvesting by city dwellers is said to meet 15% of the annual water demand in Dhaka. Rainwater harvested in typical large sized residential buildings can provide 293% of its demand for flushing Water Closets in toilets, thereby significantly reducing the load on Dhaka Water Supply Authority (DWASA). As most of the rainwater harvested for flushing purposes is during the rainy season, preservation and maintenance of the rainwater is an important issue that needs proper attention. It can be stressed that a provision, preservation and maintenance of rainwater harvesting system should be included in the building code of Dhaka city.

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# SOMPUR MAHAVIHARA AT PAHARPUR, BANGLADESH: VIRTUAL HERITAGE AND USER INTERPRETATION

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## ABSTRACT

The escalating development of Virtual Reality (VR) technologies, interfaces, interaction techniques and devices has significantly improved the efficiency and usability advanced virtual technologies and supports their transaction from the research laboratory to the public realm. The 8th century Buddhist Monastery of Sompur Mahavihara at Paharpur drew attention of the architectural historians of the South Asia from the very discovery of the ruins for its unique architectural features and strategic spatio-temporal location. In the first phase of the study, a preliminary reconstructed 3D model of Sompur Mahavihara- as 'professional interpretation'. The second phase attempts to investigate about 'public interpretation'. The study proposes a novel approach of heritage interpretation for public opposing the traditional interpretation method. With an interactive system, supported both from online or offline; would be installed in public spaces (like museum) serving as like other artifacts, at the same time collect and store numerous data, such as photographs, emails, images, text and voice comments provided by general public. This participatory approach of interpretation and rebuilding will provide an understanding of public view about this monument and at the same time will allow of a differentiation of the deviation of the professional and public reconstruction.

**Keywords:** Sompur Mahavihara, Virtual Heritage, Heritage interpretation, Interactive Interface

## 1. INTRODUCTION

### 1.1. Problem Formulation

#### 1.1.1. General Problem

Sompur Mahavihara (Fig.1-a) is definitely the mostly studied historical monument in Bengal. There exist different arguments regarding the three-dimensional articulation of the missing superstructure. There are also some attempts of theoretical reconstruction of the central

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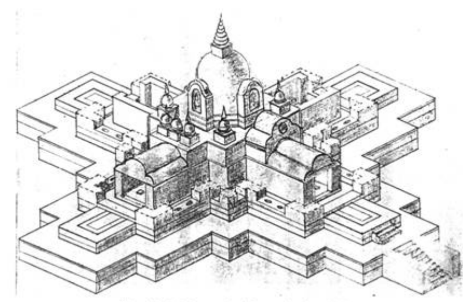
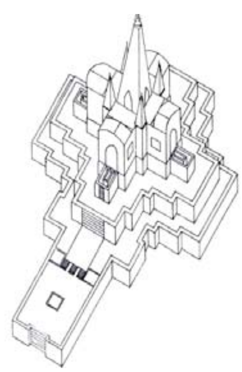
structure by different scholars such as [1], Mayer (1969), Naqi (1999), Shihabuddin (2004), Rashid (2007). However, the nature and the extent of the earlier studies are not sufficient to generate necessary potential for a discourse. The reason may be manifold, but the most important one is the non-availability of substantial amount resource including a comprehensive architectural documentation at the disposal of the researchers. The first hand evidences like the archaeological remains are mostly at foundation level and inadequate. The epigraphic records remain almost mum regarding this monument. Consequently, most of the works done so far are mainly limited on the findings of the archaeological excavation and studying the artifacts from the archaeological perspective. Hence, the history Buddhist architecture in Bengal is yet to recover from the amnesia of centuries. Our study attempts to investigate the both way of heritage interpretation from professional and public.



(a) Present situation of Sompuer Mahavihara central temple

(b) Mayer’s perception of the central temple (Artibus Asiae, 1969)



(c) Naqi’s perception of central temple (Naqi, 1999)

(d) Shihabuddin’s perception of central temple (2004)

Fig.1: Conjectural reconstructions of Sompur Mahavihara Bangladesh by different researchers

Source: [1];

### 1.1.2. Specific Problem

This study is designed to address following two problems:

*Firstly:* A historical building is a memory of past and it should be preserved for its particular location in the history. Actually, a monument poses wide ranges of values, both tangible and intangible, towards itself. The physical conservation in its true form not only ensures the formal characteristics of the monument, but also at the same time put a considerable impact on the others, especially on the intangible aspects. This phenomenon is of utmost importance in the cases like Sompur Mahavihara, where archaeological information is scarce. Hence, it is more practical and rational to go for an interactive virtual model, which eventually addresses all the related issues and disciplines.

*Secondly:* The problem deals mainly with conceptions of architectural knowledge of the public about this building. In general case with professional reconstruction certain gap has been retained between the architectural masterpieces and public. There is very little role to play either in conservation or evaluating monument. Lost monuments, like in our case has very little or no impact on the general architectural knowledge of the common people. However, public may not have significant historical and commemorative value but posses certain degree of cultural value as well. Hence, it is important to let the people participate in the process of this re-construction. The intention is not to retrieve the lost architecture of this monument but to develop an interactive process where we challenge the conventional way of information flow in heritage interpretation (Fig. 02) and this way to involve public in heritage conservation.

### 1.3. Aim

This study aims at interpreting and rebuilding understanding of public view about Sompur Mahavihara.

### 1.4. Objectives

The objectives of the study are twofold: to build a preliminary reconstructed 3D model of Sompur Mahavihara as professional interpretation and to investigate about ‘public interpretation’.

## 2. METHODOLOGY

Bush [2] who believed in social software as an instrument to extend the power of the mind later developed the ideas of hyper linking and augmentation are paved the way of social software. The development of computer supported collaborative software continued throughout 1970s, 80s and 90s illustrated in developments such as Groupware and Computer Supported Collaborative or Cooperative Work (CSCW) [3]. In present days, the term social software become common and described in other terms such as, social computing, computer mediated communication, social networking software and collaborative software etc. In this study we propose a framework that opposes Fitch’s model, where information flows in reverse order; from general public to professional. We proposed a system will be developed around a 3D model with hyperlinked content. It will explore the implementation of interpretive framework to enhance visitor understanding; through a virtual environment which will be flexible enough to allow users to deliberate a range of possibilities of data collection and input. It will focus on engagement and interaction by allowing users to personalize workspace; adding their own interpretations of the history, form and space-usages. This will also allow manipulating views and digital captures of the 3D model by user's will.

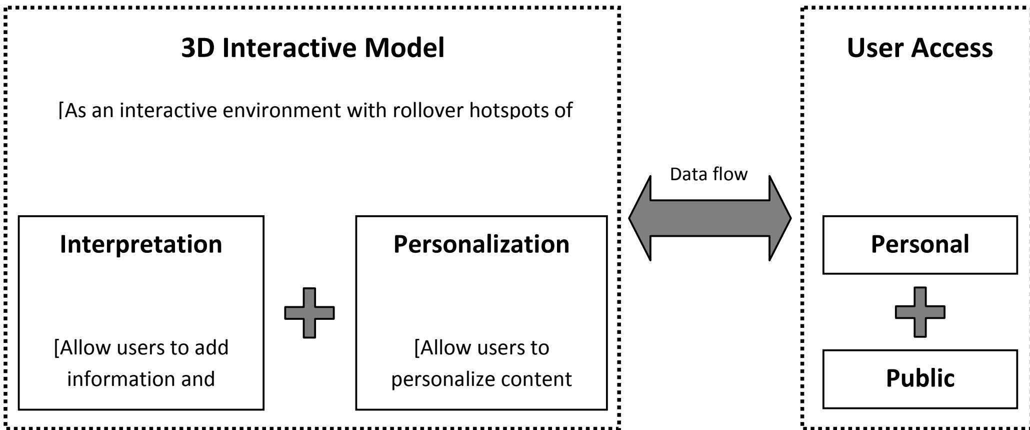



Fig. 2: Structure of the possible interactive 3D environment

Source: [17] 2005

## 3. LITERATURE REVIEW

### 3.1. Virtual Heritage

The term 'heritage' broadly refers to the study of human activity not only through the recovery of remains, as is the case with archaeology, but also through tradition, art and cultural evidences, and narratives. On the other hand 'virtual heritage' (VH) is a term use to describe works that deals with virtual-reality (VR) and cultural-heritage [4](Roussou 2002). In general, virtual heritage and cultural heritage have independent meanings: cultural heritage refers to "properties and sites with archaeological, aesthetic and historical value" and 'virtual heritage' refers to instances of these properties and sites within a technological domain. To virtualize heritage means to actualize the heritage content digitally and to simulate it using computer graphics technology. According to Roussou [4], the functions of 'virtual heritage' are to facilitate the synthesis, conservation, reproduction, representation, digital reprocessing, and display of cultural evidence with the use of advances in VR imaging technology. Some scholars also described 'virtual heritage' as a vehicle for preservation, access and economic development at the service of archaeological remains valued for their artistic qualities [5] (Beng-Kiang & Rahaman 2009).

The representation of landscapes, objects, or sites of the past and the overall process of visualization of archaeological data with the use of VR technology form a sub-domain known as Virtual Archaeology [6](Barceló 2000). Some extended form of VR technology mixed with real-world known as 'Mixed Reality' and 'Augmented Reality' have also been applied in experiencing archaeology and heritage. These applications are frequently identified with the reconstruction of ancient sites in the form of reproducing accurate 3D models[7] (Valtolina *et al*. 2005 ; [8]Yang, Peng & Sun 2006).

### 3.1.1. Fields of Virtual Heritage

Digital tools and techniques now emerging from academic, government and industry labs offer new hope to the often painstakingly complex tasks of archaeology, surveying, historic research, conversation and education [9](Addison 2000). The increasing development of VR technologies, interfaces, interaction techniques and devices has greatly improve the efficacy and usability of VR, providing more natural and obvious modes of interaction and motivational elements. This has helped institutions, such as museums, media research and cultural centers to welcome advanced virtual technologies and support their transaction from the research laboratory to the public realm.

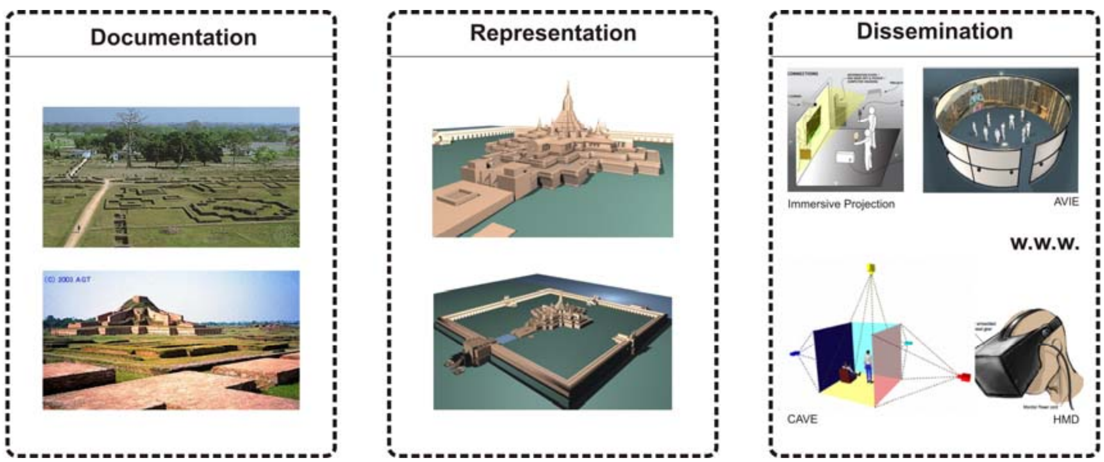



Fig. 3: Basic domains of virtual heritage

According to Addison [9](2000) there are three major domains in virtual heritage:

- 3D Documentation: everything from site survey to epigraphy
- 3D Representation: from historic reconstruction to visualization
- 3D Dissemination: from immersive-networked worlds to ‘in-situ’ augmented reality.

Figure 03 explains the present method of developing and disseminating virtual heritage. The first stage is about finding information, analysis and documenting the authentic data from both cultural and architectural past. The next stage is for representation, which is conditioned by media, only supports (at this time) the tangible heritage, and mostly focused on accuracy of visualization. The final stage is devoted to distributing these information and knowledge to public by means of interactive digital media, which can vary from in-situ, internet or independent installation based distribution.

### 3.2. Interpretation of Heritage

*"The chief aim of interpretation is not instruction but provocation"* – [10]Freeman Tilden (1977) The word interpretation is often used to mean the storylines that are adopted to help visitors to engage with and understand the place of objects that they are looking at. In fact in a broader sense interpretation is a mutual combination of 'presentation', 'supplementary education' and visitor satisfaction' [11](Goodchild 2007). Interpretation is not a board of exhibit or not information presented through multimedia, but it is a communication process, designed to reveal meaning and relationship of natural and cultural heritage to public. It reveals to visitors in powerful and memorable ways - to enrich visitor's understanding and appreciation to make them have steward senses. According to Howard [12] (Howard 2003, p246) interpretation is deciding - what to say about heritage and how; and to whom. However, it seemed very simple concept, but heritage interpretation by nature is political, sensitive and emotive.

The interpretation of heritage for public can be as first person or guided using a range of tools such as - printed and oral information and range of media from image to film, from interactive multi-media to virtual reality. [10]Freeman Tilden (1977), who is considered as 'father of heritage interpretation' defined interpretation and developed six principles for visitors to enable themselves to relate with a heritage site/resources. According to Tilden, interpretation is "an educational activity which aims to reveal meanings and relationship through the use of original objects by firsthand experience and by illustrative media, rather than simply to communicate factual information".

### 3.2.2. Interpretation: Professional and Popular

Fitch [13](1982) has defined two levels of interpretation, 'Professional' and 'Popular'. The first level of interpretation is carried out by professionals such as archaeologists, historians and architects. From available evidences (excavations, ruins, artifacts, documents etc) professionals examine and verify for authenticity and document them to feed second level of interpretation for public. The public is only imparted information in the second level of interpretation that is the 'popular' level. However, information gathered at the professional level is used as the basis for interpretation in the popular stage, thus generally public are not able to communicate with the original evidences. Fitch [13](1982, p339) also believes that the most effective way to teach history to the general public is by interpreting historical incidents in terms of the actual scenes in which they occurred. According to him, such interpretation enriches visitor's understanding of the monument and effective to imprint historical information on visitor's memory. Fitch [13]explained this kind of public interpretation could be through:

1. Guided tours led by trained docents (e.g. Winterthur or Williamsburg)
2. Equipping the visitor with individual headphone sets and taped lectures covering a predetermined route through the monument (e.g. Metropolitan Museum, NY)
3. *Son-et-lumiere* performances for a mass audience (e.g. at Versailles)
4. Documentary films on the monument (e.g Sunnyside or Philipse Manor, NY)

5. Live demonstrations of relevant activities (e.g. blacksmithing and weaving at Cooperstown)
6. Guidebooks which visitors could consult as they move in and around the site.

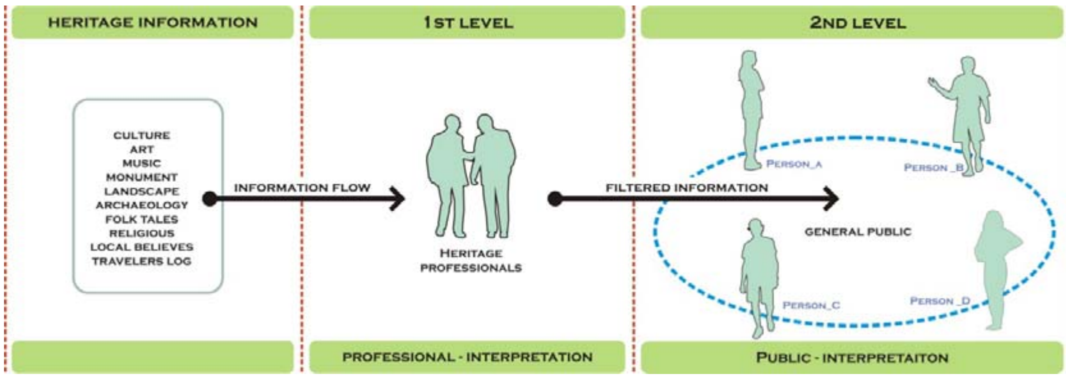



Fig. 4: Fitch's model of heritage interpretation

Presenting archaeology or heritage to the public is not a new idea. In an early time the vision of public involvement was brought up by M.W. Thompson [14](1981). He explained 'primary interpretation' – in which someone has to confront the ruin and give an intelligible account of it and 'secondary interpretation' (presentation) the popular transmission of this account, or the more interesting parts of it, to other people. Actually, Fitch's definition of 'professional' and 'popular' interpretation is similar to Thomson's definition. Similar definition can also be found from Tim Copeland [15] (2004, p135). While defining heritage interpretation he explained 'expert construction' and 'public construction'; which is actually contains the same meaning of Thompson and Fitch's idea. So all these theoretical discourses are mainly explain a linear flow of information where general public act as the receiver (Fig. 04) and do not have any role in heritage re-construction as the interpretation is descriptive and pre-defined by heritage professionals.

## 4. RESULT

### 4.1. First Phase: Professional Interpretation

#### 4.1.1. Limitations

Earlier attempts of understanding architecture of this monastery were unsuccessful because of the limited resources. It is almost impossible to depend solely on materials that are available at first hand to demonstrate a continuous narrative of this monument. Mostly the present constraints are:

(a) The lack of sufficient physical resources, which hinder to demonstrate a tentative description of architecture and most parts of the architecture, is missing.

(b) Earlier works on reconstructing the monument does not necessarily indicate a disjunction, rather it demonstrates the array of possibilities and at the same time arise confusion of looking at the problem.

(c) Architecture of this building is a part of the material culture of this region overlaid by religious contestation of multiple themes, ideas and authorship. Therefore, this architecture poses a complex layered of meanings and articulation.

#### 4.1.2. Professional Interpretation

In order to accumulate these above constrains it was important here to understand the process through which architecture is conceived and materialized rather than seeking for a definite solution. We have started our study from a much broader perspective to develop a broader picture of Buddhist religious building and tried to identify the location our case within this. Later we gradually zoom down by discerning each of the layer one after another. We tried to develop a system where the threads all the available resources will be put together in a scientific manner to construct the bigger scenario. We kept the other end of the thread for inflow of the future resources so that the model or the proposal can be modified when newer resources would be available [16](for more detail please see Rashid, Md Mizanur & Rahaman 2008). Based on this a three dimensional virtual model has been developed at the end. In this work an attempt was made to understand the lost architectural features of the monument by using these cross-disciplinary resources in a systematic manner [1](Rashid, Md. Mizanur 2007). It looked into the history in a more dynamic way and uses virtual reconstruction as a flexible tool to reconstruct the lost form of the building. Based on this we developed a preliminary virtual model for the central structure of Sompur Mahavihara (Fig. 05).

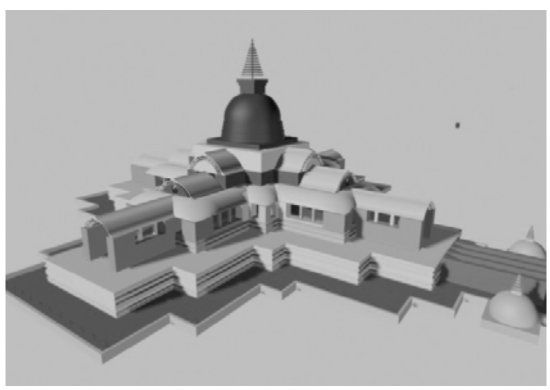


Fig. 5: Preliminary Reconstruction of the lost central structure of Sompur Mahavihara, Paharpur.

### 4.2. The Second Phase: Public Interpretation

#### 4.2.1. Objective

Several attempts have been made so far to recover the memories of this medieval Buddhist Monastery after the amnesia of a millennium. However, the limited amount of archaeological resource, literary evidences and epigraphic records at the disposal of the architectural historians appears as the main ticket. The second phase attempts to make an interactive interface of the monastery based on the study of earlier reconstruction. During the process of the earlier reconstruction, attention was drawn to the distance between a heritage building and the public.  Especially in the case where the heritage building is presently ruined (this case) and a limited amount of archaeological resources are available to fill up the lacuna. It is a great challenge for the architectural historians to bring back the real form of architecture based on such fragmented resources, which are mostly inconspicuous in nature. In the attempt of the previous reconstruction made by the authors an attempt, it felt almost impossible to retrieve the lost form as it was. Rather it was more convenient to collate and examine all the available resources that may have had some impact on the architectural form of this building. The idea was to develop a process that is open for future feedback and correction. Now the question that emerged is whether this recovery of architectural form is sufficient enough to understand the building as well as enliven the memories of the heritage back to the people and collectively re-interpret the heritage by public participation? The second phase of the study is designed to understand issues regarding the lost heritage of Sompur Mahavihara as a case. It is aimed to fulfill these following objectives:

1. To identity the public's conception of 'form' and 'history' of Sompur Mahavihara
2. To understand how public interpret history and culture in a collective manner through interaction in an interactive environment?
3. How can a reconstruction of virtual model be developed through the feedbacks from scholars and aspiring public at the same time and how can further development of the earlier framework of knowledge regarding this monument be made?

## 5. CONCLUSOIN

Virtual heritage is an intersection of virtual reality and cultural heritage. The main functions of virtual heritage (VH) are to facilitate the synthesis, conservation, reproduction, representation, digital processing and display of cultural evidence with the use of virtual reality and digital imaging technology. Present technologies hold a great potentiality for photo-realistic and historic reconstructions of heritage monuments and culturally significant places. The potential of virtual heritage opens wide ranges of possibilities, which can be, accommodate to re-new and re-invent our present method of historical interpretation. However, most of them are highly motivated on demonstrated the technical artistry and power of technology to attain a degree of 'reality' and accurate reproduction of real and historical environments.

Architecture not only deals with the built-form and spatial quality, but contains different layers of socio-cultural aspects. A building may possess a rich cultural environment and it cannot be understood by just watching 'photorealistic' representation instead embodied interpretation. In the first step of this study, a static virtual model of the lost mind has been reconstructed. The second step is ongoing in preset research. In this section, it is hoped that the proposed interface will allow a development of a new model of the same artifacts through public participation. It is believed that  this might play a very important in the field of conserving heritage building and grow public awareness. Once completed, this study would demonstrate the differences *(if any)* between the public and professional re-construction of the same monument. This methodology may also be used as to collect public views and opinions of further re-construction or repair of any other historical monument.

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# EVALUATION OF ACCESSIBILITY AND MOBILITY IN TRANSPORTATION PLANNING AND ITS RELEVANCE TO DHAKA CITY

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## ABSTRACT

Generally accessibility refers to the ability to reach opportunity while mobility refers to the efficient movement of people and goods. Accessibility and mobility also has another meaning which will be used in this study. Accessibility is the travel time it takes to reach a certain place while mobility is the travel time it takes to go somewhere from a certain place. Thus, both accessibility and mobility is a measure of time. One of the goals in transportation planning is to reduce travel time because travel time is associated with the economy and also the environment. This signifies the importance of having knowledge about accessibility and mobility because it gives transportation planners information about travel time. To study travel times in a city, a better approach is to study the accessibility and mobility index instead of just accessibility and mobility by dividing a city into zones. In this research study, accessibility and mobility index for the 90 administrative wards in Dhaka city was determined. Results of this study indicate that the highest accessibility was found in ward number 56, important area of this zone are Bangladesh University of Engineering and Technology (BUET), Dhaka Medical College (DMC), Carzon Hall, Police Headquarter, Bangladesh Secretariat etc. The lowest accessible zone is ward no 53, important area of this zone are Ramna, Eskaton Garden, Siddeswari, Mouchak Market etc. On the other hand, the highest mobile zone is ward no. 55 and the lowest mobile zone is again ward no. 53.

**Keywords:** accessibility, accessibility index, mobility, mobility index, transportation planning, travel time, zone wise analysis

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## 1. INTRODUCTION

The concept of ‘Accessibility’ has become increasingly important to transport planning in recent years. It takes into account people’s opportunities to reach commonly used services. So it is necessary to measure how easy it is to access health, education, banking, shopping, and employment. Successful consideration of accessibility, therefore, could reduce car use and contribute to a more sustainable transport system. The study mainly concentrates on the definitions, factors and evaluating measuring techniques as well as the improvement measures for these indicators. Next the accessibility and mobility of Dhaka city was measured. It was a travel time based measurement. So far no significant study was undertaken with respect to the measurement of accessibility or mobility on Dhaka city.

## 2 EVALUATION OF ACCESSIBILITY

In most of the developed and developing countries a significant proportion of the available public investment is allocated to transport sector and current development plans suggest that the trend will continue. Given a high demand for transport, investment decisions have to be accommodate with in resource constraint, for this purpose judicious decision making is extremely important to allocate resource, among competing sectors as well as within transport sector. There is no doubt about the importance of Accessibility analysis as well as mobility analysis which aids transport planners to making decisions in allocating resource.

### 2.1 Definition of Accessibility

The words ‘Accessibility’ and ‘Access’ have many meaning and implications. In a very simple term, ‘Accessibility’ (or just ‘Access’) is the ability to reach desired goods, services, activities and destination (together called opportunities). Accessibility can be defined in terms of potential (opportunities that could be reached) or in terms of activity (opportunities that actually are reached). A stepladder provides access to the top shelf in kitchen. A store provides access to the goods. A library, telephone and the internet provides access to various types of information. A highway or transit improvement can increase the services and jobs accessible from a neighborhood. Even people who don’t currently use a particular form of access may value having it available for possible future use, called option value. For example, motorists may value having public transport services available, in case for some reason they are unable to drive in the future.

On the other hand, in pedestrian planning it often refers to ‘accessible design’, meaning facilities designated to accommodate people with disabilities and other special needs. For example, a pathway designed to accommodate people in wheelchairs may be called ‘accessible’. A ‘limited access’ highway has minimal connections to adjacent properties, while a local road provides direct access. Sometimes access management refers to the programs to limit the number of driveways and intersections on highway to improve traffic flow & safety.

In effect, access is the ultimate goal of most transportation, except the small portion of travel in which movement is an end in itself, (e.g.  Crushing, Jogging). Land use has great influences on accessibility.

Various disciplines analyze accessibility, but their perspective is often limited:

• Transport planners generally focus on mobility, particularly vehicle traffic.

• Land use planners generally focus on geographic accessibility (distances between activities).

• Communications experts focus on telecommunication quality.

• Social service planners focus on accessibility options for specific groups to specific services (Such as disabled people’s ability to reach medical clinics and recreation centers).

**2.2 Factors That Affect Accessibility**

The table below lists factors that affect accessibility and the degree to which they are considered in current transport planning. Some of these factors tend to be overlooked or undervalued, particularly non-motorized travel demand, alternative mode service quality, user information, integration, affordability, prioritization and the value of inaccessibility.

Table 1: Factors that affect accessibility and their consideration currently in planning.

| Name | Description | Current Consideration |
|---|---|---|
| Transport Demand | The amount of mobility and access that people and businesses would choose under various conditions (times, prices, levels of service, etc). | Motorized travel demand is well studied, but non-motorized demand is not. Travel demand is often considered exogenous rather than affected by planning decisions. |
| Mobility | The distance and speed of travel, including personal mobility (measured as person-miles) and vehicle mobility (measured as vehicle-miles). | Conventional transport planning primarily evaluates mobility, particularly vehicle mobility. |
| Transportation Options | The quantity and quality of access options, including walking, cycling, ridesharing, transit, taxi, delivery services, and telecommunications. Qualitative factors include their availability, speed, frequency, convenience, comfort, safety and prestige. | Motor Vehicle options and quality are usually considered, using indicators such as roadway level-of-service, but other modes lack such indicators and some important service quantity factors are often overlooked. |

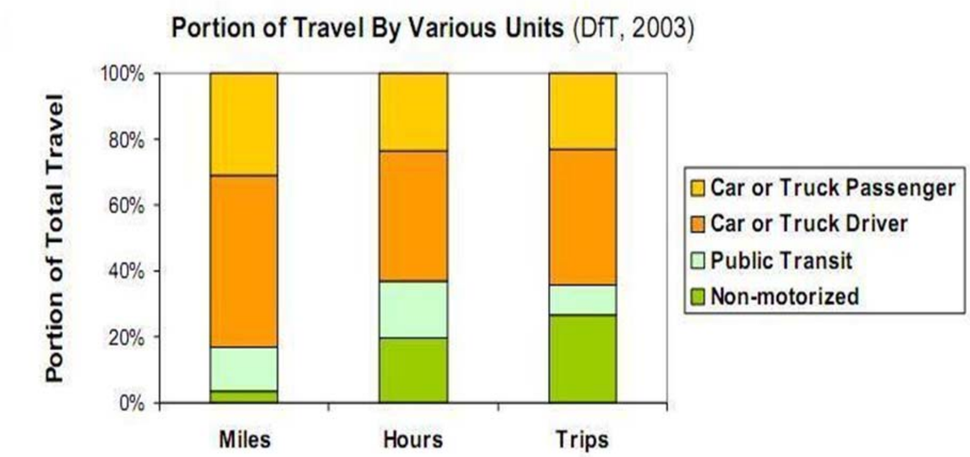
| | | |
|---|---|---|
| User Information | The quality (convenience and reliability) of information available to users on their mobility and accessibility options. | Frequently considered when dealing with a particular mode or location, but often not comprehensive. |
| Integration | The degree of integration among transport system links and modes, including terminals and parking facilities. | Automobile transport is generally well integrated, but connections between other modes are often poorly evaluated. |
| Affordability | The cost to users of transport and location options relative to incomes. | Automobile operating costs and transit fares are usually considered. |
| Mobility Substitutes | The quantity of telecommunications and delivery services that substitute for physical travel. | Not usually considered in transport planning. |
| Land Use Factors | Degree that factors such as land use density and mix affect accessibility. | Considered in land use planning, but less in transport planning. |
| Transport Network Connectivity | The density of connections between roads and paths, and therefore the directness by which people can travel between destinations. | Conventional planning seldom considers the effects of roadway connectivity on accessibility. |
| Roadway Design and Management | How road design and management practices affect vehicle traffic, mobility and accessibility. | Some factors are generally considered, but others are not. |
| Prioritization | Various strategies that increase transport system efficiency. | Often overlooked or undervalued in conventional planning. |
| Inaccessibility | The value of inaccessibility and external costs of increased mobility. | Not generally considered in transport planning. |

## 2.3 Current Evaluation Practices

Evaluation refers to methods of measuring the impacts of an activity or decision, such as the costs and benefits of various transportation improvement options. The methods used for evaluation affect planning decisions (Levinson and El-Geneidy, 2007;Litman, 2003). Current evaluation practices tend to measure mobility rather than overall accessibility. Traffic models are commonly used to evaluate automobile and transit service quality. They measure travel speeds, operating costs and fares. Such models only account for travel between zones, not travel within zones; many fail to account for generated traffic impacts (which overstates the congestion reduction benefits of roadway capacity expansion); few incorporate transit service quality factors other than travel speed; and they often do a poor job of predicting the impacts of mobility management strategies such as pricing reforms, HOV priority measures or improved user information.

Current transportation evaluation methods often fail to incorporate many these factors. They generally focus on impacts that are easy to measure at the expense of more difficult to measure impacts. For example, current transport models generally assign the same travel time cost value to all travel, regardless of comfort and convenience. This favors transport system improvements that increase vehicle travel speeds over improvements that increase travel comfort and convenience (such as nicer walking conditions, more pleasant transit waiting areas and reduced transit vehicle crowding).

When measured based on distance, as is common in conventional transport planning, non-motorized modes represent a tiny of total travel, suggesting that it is unimportant, but when measured based on time, as people generally experience travel, non-motorized modes represent a much larger portion of travel, and so are recognized as relatively important, as illustrated in Figure below. Measuring transportation based on time or trips therefore increases the value places on improving walking and cycling conditions and creating shortcuts to non-motorized travel. This is one example of shifting from mobility- based to accessibility-based transportation evaluation.




*Nonmotorized modes only represent 3-5% of travel distance, implying low importance, but 20-25% of travel time and trips, indicating greater importance.*

Fig 1: Portion of Travel by Various Units

### 2.4 Strategies for Improving Accessibility

This section describes various ways to improve accessibility.

Current transport planning and evaluation practices tend to focus on certain types of accessibility improvements, particularly those that increase motor vehicle travel speeds and parking convenience, which limits the scope of potential solutions to transport problem.

Table 2: Potential Accessibility Improvement strategies

| Name | Improvement Strategies |
|---|---|
| Access and Mobility Demand | Use research to better understand people's accessibility and mobility needs, preferences and abilities, and use social marketing strategies to develop better options that respond to these demand, and to encourage consumers to choose more efficient and equitable options. |
| Basic Access and Mobility | Prioritize transportation improvements and activities to favor access to goods, services and activities considered most important to society. |
| Mobility | Improve traffic speed and capacity, such as improving and expanding roadways. |
| Transportation Options | Improve the convenience, comfort, safety, reliability, affordability and speed of transport options, including walking, cycling, automobile, rideshare, taxi, car share and public transit. |
| User Information | Improve the quantity and quality of User information regarding travel and location options, including signs, maps, brochures, websites and telephone services. Special attention can be given to providing convenient information on alternative modes and efficient locations. |
| Integration | Improve connections between different modes and destinations, such as more integrated information, fares, walk ability, baggage transfers, automobile and bicycle parking. |
| Affordability | Improve the quantity and quality of affordable modes (walking, cycling, ridesharing, public transit, and taxi), and improve housing affordability in accessible locations. |
| Mobility Substitutes | Improve the quantity and quality of telecommunications and delivery services that substitute for physical travel. |
| Land Use Factors | Improve land use accessibility by increasing density and mix, in order to create activity centers and urban villages that contain the appropriate combination of housing, jobs and services within convenient walking and cycling distance. |
| Transport Network | Improve road and path connectivity to allow more direct travel between destinations, including special shortcuts for non-motorized travel where |

| | |
|---|---|
| Connectivity | appropriate. |
| Roadway Design and Management | Improve roadways to increase traffic flows (for example, by reducing the number of driveways), to favor higher occupant vehicles, and to improve walking and cycling conditions. |
| Prioritization | Use mobility and parking management strategies to favor higher value trips and more resource-efficient vehicles, and to encourage more accessible land use development. |
| Improve Payment System | Better road and parking pricing methods reduce transaction costs and increase the feasibility of implementing pricing reforms to increase overall transportation system efficiency. |
| Inaccessibility | Where appropriate, limit mobility and accessibility. |

## 3. METHODOLOGY

The concepts abstracted from literature were then applied to determine the accessibility and mobility of different zones of Dhaka City. For this purpose Dhaka City was divided into 90 administrative wards as trip origin-destination zones.

### 3.1 Data Format

In large scale accessibility studies, the unavailability of illustrative and homogeneous data is always a limiting factor. For this reason, a simpler study was adopted here, which can be considered as the simplified weighted formula and explained in the subsequent section. The data have been extracted from Habib, K.N.M.(2002), Evaluation of Planning Options to Alleviate Traffic Congestion and Resulting Air Pollution in Dhaka City, M.Sc. Thesis, Department of Civil Engineering, BUET, Dhaka.(Travel Time zone to zone in minutes, considering average time of all the motorized travel modes).

### 3.2 Analysis

Let us consider 6 zones, which are mutually interconnected.

Let, we get a Travel Time$T_{ij}$;  Where, i= origin of trip, j=destination of trip

For 6 zones, 36(=6*6) travel time are obtained which can be arranged in matrix form,

$$\begin{bmatrix} T_{11} & T_{12} & T_{13} & T_{14} & T_{15} & T_{16} \\ T_{21} & T_{22} & T_{23} & T_{24} & T_{25} & T_{26} \\ T_{31} & T_{32} & T_{33} & T_{34} & T_{35} & T_{36} \\ T_{41} & T_{42} & T_{43} & T_{44} & T_{45} & T_{46} \\ T_{51} & T_{52} & T_{53} & T_{54} & T_{55} & T_{56} \\ T_{61} & T_{62} & T_{63} & T_{64} & T_{65} & T_{66} \end{bmatrix}$$

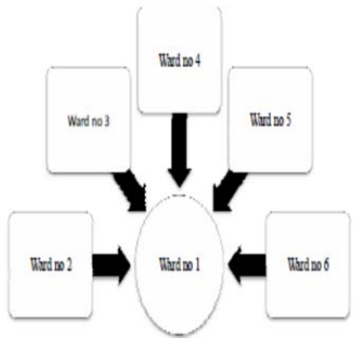



Fig: 2 Analysis of Accessibility

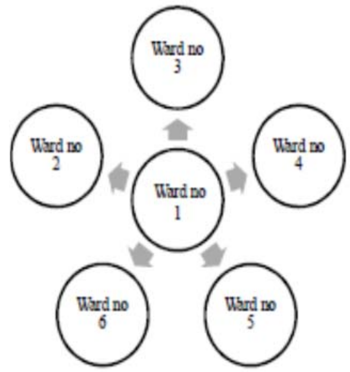



Fig: 3 Analysis of Mobility

If $A_j$ represents regional accessibility of zone-j then, $A_j = \frac{\sum_{i=1}^{n} T_{ij}}{\sum_{i,j=1}^{n} T_{ij}}$

If $M_i$ represents regional mobility of zone-i then, $M_j = \frac{\sum_{j=1}^{n} T_{ij}}{\sum_{i,j=1}^{n} T_{ij}}$

### 3.3 Result

A Spreadsheet Program based on the analysis below has undertaken to find out the Accessibility Index, A[j] and Mobility Index, M [i] of each zone.

Table 3: Accessibility Index, A [j] and Mobility Index, M [i] of 90 administrative zones.

| Ward No. | Accessibility Index, A [j] | Mobility Index, M [i] | Ward No. | Accessibility Index, A [j] | Mobility Index, M [i] | Ward No. | Accessibility Index, A [j] | Mobility Index, M [i] |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.016351 | 0.017195 | 31 | 0.00922 | 0.009115 | 61 | 0.009742 | 0.009862 |
| 2 | 0.014118 | 0.015337 | 32 | 0.009415 | 0.00895 | 62 | 0.008288 | 0.008821 |
| 3 | 0.01469 | 0.01506 | 33 | 0.008424 | 0.008357 | 63 | 0.008253 | 0.008631 |
| 4 | 0.015102 | 0.014843 | 34 | 0.00877 | 0.008706 | 64 | 0.008871 | 0.009312 |
| 5 | 0.014842 | 0.015892 | 35 | 0.008551 | 0.008721 | 65 | 0.009416 | 0.009465 |
| 6 | 0.015493 | 0.016326 | 36 | 0.008683 | 0.00852 | 66 | 0.009443 | 0.009564 |
| 7 | 0.014723 | 0.015559 | 37 | 0.010301 | 0.010764 | 67 | 0.009415 | 0.009558 |
| 8 | 0.016829 | 0.016292 | 38 | 0.010802 | 0.011063 | 68 | 0.00963 | 0.009729 |
| 9 | 0.015642 | 0.013808 | 39 | 0.00893 | 0.009118 | 69 | 0.009212 | 0.009099 |
| 10 | 0.016333 | 0.014656 | 40 | 0.009734 | 0.01023 | 70 | 0.00844 | 0.00837 |
| 11 | 0.015735 | 0.01494 | 41 | 0.011954 | 0.013168 | 71 | 0.009007 | 0.008994 |
| 12 | 0.015726 | 0.015116 | 42 | 0.012255 | 0.011632 | 72 | 0.009751 | 0.010071 |
| 13 | 0.012711 | 0.014186 | 43 | 0.013114 | 0.012143 | 73 | 0.009277 | 0.00969 |
| 14 | 0.01629 | 0.015696 | 44 | 0.010648 | 0.010404 | 74 | 0.008959 | 0.008861 |
| 15 | 0.014885 | 0.014024 | 45 | 0.00902 | 0.009322 | 75 | 0.008722 | 0.008671 |
| 16 | 0.014214 | 0.013491 | 46 | 0.011325 | 0.011063 | 76 | 0.010609 | 0.010046 |
| 17 | 0.015159 | 0.016879 | 47 | 0.011269 | 0.011151 | 77 | 0.009238 | 0.009276 |
| 18 | 0.014969 | 0.016789 | 48 | 0.010123 | 0.010996 | 78 | 0.009735 | 0.010144 |
| 19 | 0.013462 | 0.013939 | 49 | 0.009836 | 0.009809 | 79 | 0.010278 | 0.010443 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20 | 0.011458 | 0.011249 | 50 | 0.00827 | 0.008526 | 80 | 0.010985 | 0.010344 |
| 21 | 0.013098 | 0.014258 | 51 | 0.008423 | 0.009035 | 81 | 0.010214 | 0.009735 |
| 22 | 0.01061 | 0.011248 | 52 | 0.008337 | 0.008542 | 82 | 0.010903 | 0.010429 |
| 23 | 0.009723 | 0.009478 | 53 | 0.020524 | 0.017671 | 83 | 0.010845 | 0.010848 |
| 24 | 0.011323 | 0.010562 | 54 | 0.008609 | 0.008514 | 84 | 0.011262 | 0.010335 |
| 25 | 0.00918 | 0.009078 | 55 | 0.008445 | 0.008248 | 85 | 0.011056 | 0.010998 |
| 26 | 0.010016 | 0.009862 | 56 | 0.007844 | 0.008505 | 86 | 0.009731 | 0.009226 |
| 27 | 0.010795 | 0.010365 | 57 | 0.008299 | 0.008752 | 87 | 0.010678 | 0.010526 |
| 28 | 0.008494 | 0.008487 | 58 | 0.009499 | 0.009644 | 88 | 0.011841 | 0.011911 |
| 29 | 0.009358 | 0.009144 | 59 | 0.01003 | 0.010226 | 89 | 0.012041 | 0.011758 |
| 30 | 0.010814 | 0.009963 | 60 | 0.009732 | 0.01005 | 90 | 0.011626 | 0.010617 |

### 3.4 Findings of the Study

Based on the analysis on Dhaka City Corporation (DCC), the highest accessible zone is ward no 56, important area of this zone are Bangladesh University of Engineering and Technology (BUET), Dhaka Medical College (DMC), Carzon Hall, Police Headquarter, Bangladesh Secretariat etc. Perhaps the reason for greater accessibility is that here road width is wide enough, road condition is good and there is less disturbance on and along the road compared to other DCC ward. The lowest accessible zone is ward no 53, important areas of this zone are Ramna, Eskaton Garden, Siddeswari, Mouchak Market etc. Perhaps the reason for lower accessibility is that here road width is narrow, road condition is bad & there is huge disturbance on and along the road compared to other DCC ward. On the other hand, the highest mobile zone is ward no. 55 and the lowest mobile zone is again ward no. 53.

## 4. CONCLUSION AND RECOMMENDATION

This research paper discusses the concept of accessibility and how it can be incorporated in transport planning. Mobility-based planning favors solutions that increase motor vehicle travel, despite the diminishing benefits and increasing costs of expanding roads and parking facilities, and increasing vehicle traffic and personal mobility. Transportation should be evaluated based on accessibility in addition to mobility. A better understanding of accessibility can help identify truly optimal solutions to transport problems.

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# REDUCING TRAFFIC CONGESTION BY ENFORCING THE SCHOOLS IN DHAKA CITY TO HAVE A SCHOOL BUS SYSTEM

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## ABSTRACT

Dhaka is one of the most congested cities in the world. This congestion is also having a negative impact on the economy. Several approaches have been suggested by national and international transportation and urban planners to reduce the traffic congestion in Dhaka such as constructing expressways, implementing a mass rapid transit system etc. In this paper, one more approach will be suggested to reduce traffic congestion in Dhaka City, which is to reduce the number of trips during peak hours. Other than home to work trips, the other major trip that takes place in Dhaka during peak hour is home to school trip. As most schools in Dhaka do not have any school bus system and as the road environment is not safe enough for a child to go to his or her school alone, guardians have to accompany their child to and from school. The findings of this study shows that if all the schools of Dhaka City implements a school bus service which will provide a point to point service then traffic congestion during the peak hour in Dhaka will reduce significantly.

**Key Words**: reduce traffic congestion, reduce total trip, school bus system, effective and sustainable approach, transportation planning, reduce economic cost, less environmental impact.

## 1. INTRODUCTION

With a population of more than 10 million people, Dhaka is becoming one of the most populated and crowded cities in the world. This is also making Dhaka one of the most congested cities in the world. A study conducted by Roads and Highways Department in Bangladesh concluded that financial loss due to traffic congestion in Dhaka is about $3 billion yearly[1]. Unplanned land use planning and transportation planning in addition with unplanned population growth in the city can be blamed for the traffic congestion in Dhaka City.

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A traditional way of solving traffic congestion is to add more lanes to the existing road network or by building completely new roads and highways. However, as construction cost has increased due to increase of construction material cost and increase in labor cost it is not an economically feasible option for many cities to use this traditional approach. Moreover, in already built up and congested cities such as Dhaka, there is also no place to add more lanes to the existing road network or build new roads. This lack of place in the city is also making it hard to build an underground or an overhead mass rapid transit rail network. Many cities are solving traffic congestion by implementing a biking and walking friendly environment by adding bike lanes and having a continuous sidewalk. A more modern and clever approach to reduce traffic congestion is by reducing the number of trips during peak hours. Other than home to work trips, the other major trip that takes place in Dhaka during peak hour is home to school trip. As most schools in Dhaka do not have any school bus system and as the road environment is not safe enough for a child to go to his or her school alone, guardians have to accompany their child to and from school. Thus, a lack of a school bus system is unnecessarily increasing the number of school related trips during the peak hour. One way to reduce the number of school related trips is by having a school bus system which will be run by the government and will transport students of all schools. However, to enhance the effectiveness of this service it may need to run only through the major roads, it may not necessarily stop in front of the schools or homes. Thus, it may not be very effective because guardians may not feel safe letting their kids walk on their own from the major road to their respective school. An effective and sustainable approach of reducing school related trips during peak hour is by enforcing schools in Dhaka to have a school bus system which will provide a point to point service. The purpose of this study is to demonstrate that if all the schools of Dhaka City implement a school bus service which will provide a point to point service then traffic congestion during the peak hour in Dhaka will reduce significantly because total number of trips during the peak hour will reduce significantly.

## 2. METHODOLOGY

The methodology that will be used to demonstrate that enforcing all the schools in Dhaka to implement a school bus service that will provide a point to point service will reduce traffic congestion significantly during the peak hours in Dhaka because total number of trips during the peak hour will reduce significantly is described below.

The first task will be to determine the number of students going to school in Dhaka City. This type of data may be available on the, the Ministry of Education website for the Government of Bangladesh. Secondly, the transportation modes that are used by students to go to school will be determined. Then the shares of these different transportation modes will be determined. It is assumed that this type of data may be available from either the Ministry of Education website for the Government of Bangladesh or the Ministry of Communication website for the Government of Bangladesh. After that the total number of students that go to school without using the school bus, walking, biking or public bus will be added up. In other words, the number of students that go to school by rickshaw, auto rickshaw and privately owned vehicles will be added up.

The next step will be to determine the total school related trips that occur in the morning peak hour. It is important to note that not all students who ride the rickshaw, auto rickshaw or privately owned vehicles go to school with their guardian. Some of these students go to school together with their siblings or cousins or friends while some of them do travel by themselves. Considering these factors it will be assumed that for every three students going to school, there will be a total of two trips. It will also be assumed that one out of every three school going students will go to school with their guardian. In addition, this guardian will return back to home. Thus, the total number of trips that will happen when three students will go to school is equal to: two (two student trips) + one (guardian coming back home) = three. This basically means that for each student that takes either a rickshaw, auto rickshaw or privately owned vehicles will produce a total of one school related trip.

After that the total number of school trips that will occur if all the students going to school using rickshaw, auto rickshaw or privately owned vehicles went to school by school bus will be calculated. In reality, it may be that if school bus is implemented due to whatever reasons, some of these students may decide to walk or bike or take the public transit but for this research, it will be assumed that all of the students that currently ride the rickshaw, auto rickshaw or privately owned vehicles will ride the school bus. Since many of the roads in Dhaka especially the residential streets (goli) are very narrow, it will be assumed that only microbuses or vans which will have a seating capacity of 12 passengers will be used as the school buses. Another reason for using microbuses or van is that it is easier for this type of vehicle to maneuver in traffic than a regular bus. This means that by having a school bus system, there will be only one school related trip for every 12 students who used to go to school before by riding rickshaw, auto rickshaw or privately owned vehicles.

The final step will be to calculate the reduction in the total number of school related trips if the students going to school using rickshaw, auto rickshaw or privately owned vehicles went to school by riding the school bus. This will be done by subtracting the total number of school related trips that occur if students used to go to school using the rickshaw, auto rickshaw or privately owned vehicles from the total number of school trips that will occur if the students going to school using rickshaw, auto rickshaw or privately owned vehicles went to school by school bus.

## 3. DATA COLLECTION

To obtain the data necessary for this study, the Ministry of Education and the Ministry of Communication website was visited. Unfortunately the data that was required for this study was not found on the two websites that is mentioned. The authors of this paper tried to refer to previous studies that may contain data required for this study but were not able to find any data that is relevant for this study. As the necessary data required to conduct this study was not available, the authors decided to assume different scenarios that will help demonstrate how implementing a school bus system will reduce the total number of school related trips in the morning peak hour and as a result of this reduce traffic congestion. The different scenarios was assumed by assuming different values for the number of students who currently go to school by riding rickshaw, auto rickshaw or by privately owned vehicles. It was assumed that the total number of school related trips produced in the morning peak hour (consists of all transportation modes) is 400,000.

## 4. DATA ANALYSIS

The table below demonstrates how school related trips are reduced if students currently going to school by rickshaw, auto rickshaw or privately owned vehicles ride the school bus to school. It is assumed that by all the transportation modes (rickshaw, auto rickshaw, privately owned vehicles, public bus, walking and biking), a total of 400,000 school related trips are produced during the morning peak hour.

Table 1: Trip Reduction Calculation if School Bus is used

| Column A Total Number of School Related Trips | Column B Total Number of Students Going to School By Riding Rickshaw, Auto Rickshaw or Privately Owned Vehicles | Column C Total Number of Trips Produced by Students Going to School By Riding Rickshaw, Auto Rickshaw or Privately Owned Vehicles | Column D Total Number of Trips Produced by if the Students Going to School By Riding Rickshaw, Auto Rickshaw or Privately Owned Vehicles Ride the School Bus (1 School Bus = 12 Students) | Column E Trip Reduction (Column C - Column D) | Column F Percentage of Trip Reduction |
|---|---|---|---|---|---|
| 400000 | 300000 | 300000 | 25000 | 275000 | 69% |
| 400000 | 275000 | 275000 | 22917 | 252083 | 63% |
| 400000 | 250000 | 250000 | 20833 | 229167 | 57% |
| 400000 | 225000 | 225000 | 18750 | 206250 | 52% |
| 400000 | 200000 | 200000 | 16667 | 183333 | 46% |
| 400000 | 175000 | 175000 | 14583 | 160417 | 40% |
| 400000 | 150000 | 150000 | 12500 | 137500 | 34% |
| 400000 | 125000 | 125000 | 10417 | 114583 | 29% |
| 400000 | 100000 | 100000 | 8333 | 91667 | 23% |

The above table demonstrates that, if a total of total of 400,000 school related trips are produced in the morning and if 300,000 of those trips are produced by rickshaw, auto rickshaw and privately owned vehicles, then a 69 percent reduction or a reduction of 275,000 trips can be achieved for school related trips of the school trips currently occurring by rickshaw, auto rickshaw and privately owned vehicles can be converted into school bus trips. This will definitely a huge reduction in trip reduction and it will certainly help to reduce traffic congestion in Dhaka City during the morning peak hour. This table also demonstrates that even if only 100,000 out of the 400,000 school related trips that are produced in the morning are produced by rickshaw, auto rickshaw and privately owned vehicles and if these trips are then converted into school bus trips then a reduction of 23 percent or a reduction of 91667 trips can be achieved. This is also a very good reduction and this will also help to reduce traffic congestion in Dhaka City.

Thus, the analysis of this research demonstrates that to decrease traffic congestion in Dhaka City, one of the methods that can be approached is enforcing the schools in Dhaka City to enforce a school bus system.

## 5. CONCLUSION

The analysis of this research study demonstrates that if students who are currently going to school by riding rickshaw, auto rickshaw or privately owned vehicles take the school bus then the total school related trips during the morning peak will reduce significantly. This will also reduce the total number of trips in the morning peak hour. As a result, the traffic congestion will also reduce significantly during the morning peak hour. This is a great approach as traffic congestion is being reduced without adding any new lanes to the existing road network or building any new highway, which is making it economically sustainable for the government and the city authority. However, to make student the school bus system effective, the government has to enforce the schools to have a school bus system. This can be done by having a law that states that existing and new schools have to have a school bus system. As it is not possible for a school to overnight have a school bus system, the government can give the schools one year to set up the school bus service. In addition, many schools may not have the financial ability to buy the necessary school buses, to start the school bus service. For this reason, the government can provide the schools an interest free loan to buy the school buses. To make this school bus service successful, the schools should ensure that children are safe on the school bus and that children are accompanied by an adult if drop off or pick up point cannot be provided from the front of their residence. The school bus service is also sustainable environmentally because it will reduce the number of vehicle trips which will reduce air pollution. Before, the children from upper class were riding privately owned vehicles while children from other classes were riding rickshaw or auto rickshaw, which was creating a social gap. However, if everyone rides the school bus then this gap will not exist anymore, thus the school bus system is also socially sustainable.

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# FEASIBILITY STUDY OF WIND ENERGY IN BANGLADESH: A WAY TOWARDS SUSTAINABLE DEVELOPMENT

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## ABSTRACT

Bangladesh, a developing country requires huge amount of energy for its development and economic growth. But current demand for energy significantly increasing which was about to exceed the availability and forecast determines that this projection will be increased more in near future. In the case of the emerging energy problem in Bangladesh, sustainable energy specially wind energy can play a significant role in this case. This paper presents the overview of the Renewable Energy Resources in Bangladesh and the percentage of wind energy feasibility. It also emphasis on average speed vs time duration, speed vs location as well. It is also provided the information obstracle to impliment of wind energy in Bangladesh and as well as government policies and future plan to overcome this situation. After considering all the problem, The wind speed in some regions is satisfactory for operating pumps and also for generation of electricity.

**Key Words**: Bangladesh, Coastal region, Wind energy, Velocity duration, Feasibility study, Energy Policy

## 1. INTRODUCTION

Limited source of energy but unlimited want of power need to drive us searching for alternative sources. Of the several available option of renewable energy, wind systems have captured interest for a long time. The modern development of wind turbines was started from 1973 and the main achievement of this development lies in the improvement of aerodynamic efficiency and reliability, leading to lower costs per kWh generated. A WMO (World Meteorological Organization) report [1] reveals that $1.75X10^{14}$ kWh of wind energy is available over the entire globe that can be utilized for betterment of human race. Recently worldwide capacity of wind energy reached 159.213 MW and Asia accounted for the largest share of new installations (40. 4 %).If this current trend will be continued then wind capacity doubles every three years. [2]. But this statics doesn't full the current energy crisis situation in Bangladesh.

The rural populations are deprived of the benefits of electricity, this modern input of civilization. Moreover, routine closedown, reduction of generation capacity due to prolonged

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use beyond economic life and the other contributing factors result of such shortfall of generating capacity, compared to the demand. Thus, Load-shedding became inevitable throughout the country during peak hours. So new energy source is then searching.

## 2. OVERVIEW OF ENERGY CONSUMPTION IN BANGLADESH

The availability of the most useful form of energy, electricity, is extremely small. According to, Electricity Generation and Consumption in Bangladesh, 2005-2006, installation capacity 5,275 MW and also average demand and average generation are 4300-4500 MW and 3200-3300 MW. So, per capita generation and per capita consumption are 167 KWh and 136 KWh. From the total energy in Bangladesh major comes from oil and coal 56% where solar, wind and geothermal take places 5% of the total energy. For renewable energy sector, upcoming in solar photovoltaic installed capacity will be 800 KWp and wind turbine will be 20 KW.

## 3. WIND REGION ON BANGLADESH

Bangladesh has approximately 724 km. long coastal belt, more than 200 km long hilly coast-line and more than 50 islands in the Bay of Bengal. The strong South/South-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surfaces, enters into Asia over the coastal areas of Bangladesh. This trade-wind blows over our country from March to October. The wind is enhanced when it enters the V-shaped coastal regions of our country. Since this trade wind strikes the coastal belt of Bangladesh, after travelling a long distance over ocean water surfaces, it becomes energetic.

## 4. DATA ANALYSIS OF WIND ENERGY IN VARIOUS PARTS IN BANGLADESH

There are 18 location from the data are collected. The locations are Barisal, Bogra, Chittagong, Comilla, Cox’s Bazar, Dhaka, Dinajpur , Hatiya, Jessore, Khulna, Khepupara, Kutubdia, Mongla, Patenga, Rangamati , Sandip, Sathkira, Sylhet, Teknaf and Thakurgaon.

The first wind speed studies conducted by BAEC, the Study sponsored by GTZ and the more comprehensive ODA funded WEST Study by Bangladesh Centre for Advanced Studies (BCAS) has established the potential of setting up wind turbines in the coastal districts and off-shore islands, with good wind speeds with high probabilities in the range of 4 - 7 meters and above. The aim of this project is to assess the potential of utilizing wind energy as mechanical and electrical power. They collect and analyze wind speed data at seven areas of Bangladesh. The locations are widely dispersed along the vast coastline in the district of Cox’s Bazar, Chittagong, Noakhali, Bhola and Patuakhali.

Hossain et al [3] found that monsoon is the main source of the wind in the Barisal division, in the south central part of Bangladesh.

A study on the wind power potential of five selected meteorological stations of Rajshahi division, in the northwest of Bangladesh is done by Hossain et al. From the available observed raw wind data long term averages on monthly and annual basis have been obtained, from which probability distribution of wind speed, velocity duration curves and distribution of power in the wind are plotted. Wind roses have also been plotted for the stations. The results indicate that out of the five stations Ishwardi has higher wind potential than the others [4].

From five LGED stations (Kutubdia, Sitakunda, Khagrachari, CUET and Kuakata) it was found that the average annual wind speed values at different heights for the five wind stations vary from 1.73 m/s to 4.17 m/s. The highest average annual wind speed (4.17 m/s) was observed in Kuakata and the lowest value (1.32 m/s) was observed at Khagrachari. Maximum wind power density was in Kuakata (88kW/$m^2$) at height 30m and minimum in Khagrachari (13kW/$m^2$) at a height of 10m. The highest potential was found for Kuakata and Kutubdia, whereas Khagrachari and CUET have low potential for wind electricity generation. [5]

Sanjay presents at his paper [6] wind and wind power characteristics in the southern coastal islands of Bangladesh which are surrounded by the Bay of Bengal. Mean flow pattern was studied in four coastal island: Hatia, Sandwip, Bhola and Kutubdia. It is found that Hatia is an Island of high wind power potential. The analysis also reveals that all the four demonstration sites should have a wind speed more than 3.0 m/s for about 30% time of the total year.

Wind resource assessment over Bangladesh has been done independently by RISOE National Loboratory, Denmark using KAMM (Karlsruhe Atmospheric Meso- scale) model. The model uses upper atmosphere wind speed data and satellite information. Based on a comparison between KAMM (done by RISOE) and WAsP results (done by RERC) the wind resource map for Bangladesh has been developed and added to SWERA archives. Wind energy density predicted by RISOE show locations with power density above 200W/$m^2$ over 2000$km^2$ which is highly encouraging. This has to be established from experimental measurements to go for large scale applications of wind energy.

## 5. GOVERNMENT POLICIES REGARDING WIND ENERGY

An independent institution, Sustainable Energy Development Agency (SEDA), shall be established under the Companies Act, 1994, as a focal point for sustainable energy development and promotion, 'sustainable energy' comprising renewable energy and energy efficiency. SEDA will consider providing subsidies to utilities for installation of solar, wind, biomass or any other renewable/clean energy projects. In 1998, The Government of Bangladesh (GOB) lifted import duty and Value Added Tax (VAT) from solar photovoltaic and wind turbines. Evasion of VAT or misuse of this opportunity is the common phenomena in Bangladesh

## 6. WIND PROJECT ASSOCIATION IN BANGLADESH

At present, Power is entrusted by the Ministry of Energy and Mineral Resources (MEMR) to foster development of RETs in Bangladesh. The following associations are working simultaneously are- Local Government Engineering Department (LGED); Renewable Energy Research Center- University of Dhaka; Center for Energy Studies, Bangladesh University of Engineering and Technology (BUET); Bangladesh Power Developement Board(BPDB);

Bangladesh Center For Advanced Studies(BCAS); Bangladesh Rural Advancement Committe(BRAC); Grameem Shakti(GS); Renewable Energy Program (REP). At present, several wind resource assessment program (WERM, SWERA, WRAP of BPDB) is ongoing in the country.

## 7. RESEARCH AND DEVELOPMENT ACTIVITIES

The different institutes, universities and research organizations (both public and private) are carrying out research and development (R&D) activities in various fields of renewable energy technologies. R&D activities of Bangladesh are characterized by many constraints, including the lack of expert knowledge and fund obtained. All after that, some researcher are working to reach the certain goal of improving electricity problem.

## 8. PRESENT SITUATION OF WIND ENERGY IN BANGLADESH

### 8.1 Wind Energy Programme under Grameen Shakti

Grameen Shakti is experimenting with the possibility of developing systems to utilize wind energy in the coastal areas of Bangladesh. GS installed 4 hybrid power stations (combination of wind turbine and diesel generator) in four cyclone shelters of Grameen Bank. Power generated from the wind turbines is connected to four cyclone shelters for lighting.

### 8.2 Wind Energy Programme under Bangladesh Center for Advanced Studies (BCAS)

BRAC under REP installed 11 small Wind Turbine at a capacity of 0.3 KW in various coastal area of Bangladesh. BCAS installed a wind pump in an agricultural field at Patenga .The Tower height was 40 ft and the rotor consisted of 12 blades. Daily water output has been varying and the average water output between November and January was about 8000 liters/day

### 8.3 Wind Energy Programme under Bangladesh Power Development Board (BPDB)

BPDB installed pilot basis 1MW at Muhuri Dam, at Feni District of Bangladesh and target to reach up to 10MW power at the same place. Moreover 1 MW New Wind Project implemented at Kutubdia . Total installation by BPDB = 2 MW

### 8.4 Wind Energy Technology under Local Government Engineering Department (LGED)

**LGED** has set up a number of 27 ft high wind pumps having a power of 0.5 h.p. (385W)at a wind speed of 4m/s in Tangail, Kuslitia, Cox's Bazar and other places. But due to the low wind speed no quantitative results are available. **LGED** again installed 10Kwp in Wind-Solar hybrid system at St. Martins Island and another 400Wp at Kuakata LGED guest house.

### 8.5 Wind Energy Technology under Center for energy, BUET

A research Group of **BUET** is now conducting a wind speed study at close to Dhaka at a height of about 60ft withwind speed of 2-3 m/sec.

## 9. FUTURE PLAN

At March 2010, government announced for the installation of generating 100MW-200MW of electricity wind-based independent power plant in the Bay of Bengal.This will be the first large wind-based power plant in Bangladesh. A pilot wind turbine plant may be set up and be linked with the existing 250 KW diesel power station at Kutubdia, to study the overall performance of a hybrid wind-diesel system in an isolated local grid. GS is experimenting with the possibility of developing systems to utilize wind energy in the coastal areas of Bangladesh.

## 10. COST ANALYSIS AND SUSTAINABLE DEVELOPMENT

As a survey on kuakata the following data is obtain per KWh cost of each type of Power generation and it is clearly shown that Hybrid is cost effective.

| Power Generated | Location | Wind speed | Generation Mode | Cost/kWh (Taka) |
|---|---|---|---|---|
| 100 kW | Kuakata | 5.5 m/s | Diesel only | 29.7 |
| | | | Wind-Diesel | 16.3 |
| | | | PV-Wind-Diesel | 16.8 |
| | | | PV-Wind | 19.8 |
| | | | Wind | 24.4 |

Potential for electricity generation from Solar and Wind energy technologies and the scope of $CO_2$ mitigation by 2020 is projected as follows

| RET | Indicative Potential | In place of conventional generation using | $CO_2$ reduction potential ($MtCO_2$/year) |
|---|---|---|---|
| Hydro electricity | 300MW | grid | 1.4 |
| Solar Home Systems | 50W, 2 million | Kerosene & Grid | 1.5 |
| Solar lights for the poor | 10W, 2 million | Kerosene | 0.6 |
| Wind Diesel hybrid | 100kW, 300 | Diesel genset | 0.1 |
| PV Diesel hybrid | 100kW,300 | Diesel genset | 0.1 |
| Wind electricity generation | 200MW | Diesel genset | 2.1 |
| Grid connected PV | 200MW | Grid | 0.8 |
| Total | | | 6.6 |

Right Now in Bangladesh GHG emission from electricity grid is 9 million tons. Where as GHG emission factors for only wind energy is 0 ton $CO_2$/MWh. So if GHG emission is reduced by implementing wind or wind related hybrid system Bangladesh may earn \$5 (approximately 70 taka) or so for each ton of reduction through carbon trading. For 10% reduction of $CO_2$ Bangladesh would earn around 50 million dollars or so.

## 10. MAIN OBSTACLES

### 10.1 Policy Barriers

- No dedicated financial incentive policies to encourage wind energy.

- Lack of legal, regulatory and policy framework for market oriented programs emphasize promotion and encouragement of commercialization and private sector involvement.
- Importantly emphasis on primary technology and R&D but on scarred basis.
- Lack of standardized power purchase agreement for wind energy.
- Various ministries, agencies and institutions should make good coordination in between them by utilizing limited human and financial resources efficiently.
- Limited spatial distribution of suppliers limits access into this sector.
- Lack of coordination between policy maker and private sector.

### 10.2 Technical Barriers

- The main disadvantage regarding wind power is down to the winds unreliability factor. The most common reason for failure of earlier wind energy project was that they were installed without appropriate wind energy resource survey.
- The noise pollution generated by the wind turbine is sometimes similar to a small jet engine thus local people living within a few meters have to face a great trouble.
- There was a risk that the turbine might be affected in cyclones.
- Lack of standards and quality control for wind energy equipment.
- Bulk procurement of wind energy technologies is limited.
- Local manufacturing and/or assembly of wind energy technology components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country.
- Limited technical capacity to design, install, operate, manage and maintain wind energy.

### 10.3 Commercial Barriers

- High initial capital costs.
- Limited knowledge on the wind energy market potential for both public and private.
- Market distortions by the subsidizes or grant-based hardware installation programs.
- Government budgets for subsidizing RETs projects especially for wind energy is limited as the demand for financing the various national priority areas (health, education, disaster management etc.) is great.
- Small and dispersed size of the wind energy market in Bangladesh does not facilitate benefits such as economies of scale.
- Higher perceived risks of the renewable energy technology.
- □Financial institutions biased and unfamiliarity with financing wind energy projects, lack of appropriate financing mechanisms for wind energy and no dedicate financing on wind energy.

### 10.4 Information Barriers

- Lack of information about wind energy resources, technical/economic information about wind energy, equipment suppliers, and potential financiers.

- Lack of awareness of renewable energy in public, industry, utility, financial institutions and policymakers.
- Availability and access to existing wind energy resource information is limited.
- Lack of capacity for data collection and analyzing.
- Scattered information regarding wind energy.

### 10.5 Human Resource Barriers

- Lack of expertise in technical, business management and marketing.
- Lack of expertise in resource assessment, system design, installation, operation and maintenance of wind energy.

## 11. RECOMMENDATION

### 11.1 Implementing in Hybrid system

In many areas, the winds strength is too low to support a wind turbine or wind farm, and this is where the use of solar power or geothermal power could be great alternatives or hybrid can be a good alternative. Because of low insolation and high wind speed in Monsoon, a solar-wind-hybrid backed up by a diesel generator is a necessity for the sake of uninterrupted supply.

### 11.2 Scattered information should be organized

A central information point does not exist, instead information is scattered among various sectors. Making a center where public, private organization can require data. Also, the potential of wind energy has not been fully explored in Bangladesh, mainly due to lack of reliable wind speed data.

### 11.3 Some suggested measures to promote large scale wind farms

There is the need to create more financial support avenues to promote large scale wind farms. A ‘wind fund’ in line with the one in UK can be created in India to support wind projects. Such a fund will provide equity finance for small-scale wind energy projects and will offer investment

### 11.4 Geographic information systems for wind sitting

Latest methods like Geographical Information Systems (GIS) have to be utilized for large area screening of prospective sites for wind power development. Wind speeds at the height of a wind turbine depend strongly on terrain elevation, exposure, slope, and orientation to prevailing winds, which can be calculated from a GIS-based Digital Elevation Model (DEM). In addition, with the appropriate database, a GIS can account for other factors that affect wind site suitability, such as the distance to transmission lines, proximity to protected areas, and type of vegetation cover.

### 11.5 Off-shore wind farms

Off-shore wind farms produce on an average produce 30% more energy compared to On-shore. Moreover with Megawatt size wind turbines available, it is sensible to install them offshore on large scale. In India a beginning can be made to identify windy sites off-shore to erect large wind turbines

### 11.6 Steps against natural disaster

As Bangladesh coastal side is in great danger by cyclone so ‘Additional care will be needed to protect the turbine during cyclones.

### 11.7 Segmentation of the entire Bangladesh

Under the availability of wind energy bassis Bangladesh can be divided into two regions- one Macro (National)region and other one is Micro(site) bassis**.**Economic wind speeds are available only at very specific coastal and offshore island sites. In other parts of Bangladesh, i.e. Chittagong Hills Tracts, Panchagar etc., however, there may also be ‘pockets’ of wind speeds, depending on formation of ‘thermals’, ‘tunnel-effects’. Further work in this direction is being continued. However, the general observation on the critical factor of good wind speed availability is that, the ‘roughage factor’ in the frontal zone of a wind turbine or wind farm site must be minimum to avoid frictional deceleration of wind speeds. On this consideration, one should go as close to the sea as possible.

### 11.8 Focusing on wind energy management system

As there is no certain management system is followed in Bangladesh so the government of Bangladesh will work on it.

## 12. CONCLUSION

Wind Energy has also made some inroads but its potential is mainly limited to coastal areas, and offshore islands with strong wind regimes. These coastal settings afford good opportunities for wind-powered pumping and electricity generation. Although wind energy has not been fully explored, it has the potential to be a source of decentralized energy for Bangladesh. However, based on current turbine technology, for wind energy to be economically viable it has to deliver to a wind turbine an average annual wind speed of at least 5.36 m/s and above. The critical months (lower wind velocities), as has been analyzed through these studies are the winter months (November - February). Good wind speeds (4m to 7m/s) are available during the summer and especially the monsoons, when the solar energy insolation remains low. With improved design for wind turbines, financial package, political will to support large-scale wind projects through public sector undertakings, and a remunerative price for wind generated electricity, it is hoped that wind energy will play a supplementary role to meet the growing power demands in the country.

The typical spatial scale for changes of the diurnal cycle apparently depends on many factors such as the area covered by sea breeze, the geometry of the coastal region, or the mutual orientation of the land and sea and the direction of air flow. From the above analysis it might be concluded that the daily cycle of wind speed should be taken into account when a wind farm is planned in the vicinity of a specific site

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# VCHICULAR EMISSION DUE TO INCREASED TRAFFIC OF DHAKA CITY

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## ABSTRACT

Rapid urbanization and population growth in last decades have changed the physical environment of Dhaka. Population of Dhaka metropolitan area is estimated to be 12 million and the city has grown at a rate of 4.5 sq km per year in the recent past. Dhaka has a heterogeneous vehicle fleet, which is growing at an average rate of 17% per year. Thirty nine percent of total vehicles on road in Bangladesh have been registered in Dhaka within last 12 years. Most of the vehicles plying on roads are old and improperly maintained, thus considered as the main source of pollutants. Diesel run vehicles, particularly the buses, minibuses, human haulers and trucks are the main culprits those contribute to deteriorating air quality of Dhaka city. This study summaries several monitoring and surveys on ambient concentrations of HC, NOx, $SO_2$, CO, SPM have been carried out by the author, Bangladesh Atomic Energy Commission and Department of Environment in Bangladesh. In this study we estimated the CO, $NO_x$, $SO_x$, SPM, and HC emission for the year 2003 to 2008 due to vehicle fleet and projected the vehicular emission for the year 2015. The CO, $NO_x$, $SO_x$, SPM, and HC emission in 2015 may increase 36%, 40%, 41%, 40%, and 35% respectively than the amount emitted in 2008. In future this increased level of emission may lead to serious heath hazard problems for the peoples exposed in highly dense traffic especially traffic police, school and college going students, office going peoples etc. The percentage of deaths due to respiratory infections, asthma, pneumonia etc may increase in 2015.

**Key Words:** SPM, HC, CO, Emission Factors, ARI, asthma, pneumonia

## 1. INTRODUCTION

Air is a life sustaining precious natural resource. Human activities can be interfered by the pollution of this vital resource. The level of air pollution in many of the developing countries is so bad that it is being recognized as one of the priority issues. This is an important public health problem in most of the cities in developing countries. Pollution in the cities like Bangkok, Cairo, Delhi, Mexico and Dhaka far exceeds the acceptable limits set by the World Health Organization (WHO). Epidemiological studies show that air pollution in developing countries accounts for tens of thousands of excess deaths and billions of dollars of lost productivity every year (Faiz wt al., 1996). In South Asian region, urban air pollution is

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estimated to cause over 250,000 deaths and billions of cases of respiratory illness every year (WB, 2004). The children are more vulnerable to such situation.

Dhaka, which is both the nation's administrative capital and business hub, has a total estimated population of more than nine million and it is projected to swell to 16 million by the year 2015, making it the seventh largest populous city in the world. This overcrowded city is already considered as one of the worlds' most polluted urban centers. Presently, on any working day, filthy gray haze emits mists from auto exhausts and chemicals hang lower and lower than ever over the city. The smog causes the eyes to water, coats lungs with layers of microscopic, noxious soot. Emissions from all types of automobiles like car, jeep, bus, truck, minibus, microbus, two- stroke engine driven vehicles (auto-rickshaw, tempo, mini-truck) and motor cycles have been unabatedly polluting the city's air. Aircraft, railway engines, industrial plants, power plants, brick fields, open burning incineration, solid waste disposal sites and dust particles are also contributing to the air pollution. Dust pollution due to road diggings, constructions arid other development activities further compound the city's air pollution situation. This poor air quality threatens human health, structures, and vegetation; lowered visibility; and, enhanced greenhouse gas emissions. It has been estimated by the World Bank (WB) that the country could avoid 15,000 deaths and save $200 million to $800 million annually by reducing in cities of Dhaka, Chittagong, Rajshahi and Khulna (UNEP, UNICEF & WHO, 2002). The yearly costs of health maintenance due to air pollution in Dhaka City have been estimated in excess of US$ 100 million and causes more than 8,000 excess deaths in the city. The loss caused by air pollution and the associated degradation in quality of life impose a significant burden on people in all sectors but especially the poor. Thus it attracted growing attention from the industry, government, civil society and the public at large.

## 2. MATERIAL AND METHOD

### 2.1 Study Area Dhaka City

Dhaka city is congested with a large number of motor vehicles, including both public and private transportation. Constant headache and eye irritations to the pedestrians are the indicator of the severity of the air pollution in Dhaka city. World Bank claims that air pollution causes about 15,000 deaths per year (5000 in Dhaka) in major cities of Bangladesh and incurs $200 to $800 million economic loss due to deaths and sicknesses of habitants. Peoples who are exposed to city streets, intersections and traffic jams due to their nature of professions are more prone to air pollution. Exposures to polluted air affect their health in both short and long terms. in Bangladesh, there are significant emissions from uncontrolled motor vehicles and other anthropogenic activities related to the extremely high population density that has given rise to severe air and other forms of pollution. However, there are lacks in regular air pollution monitoring network to measure and assess ambient air pollution level and environmental conditions have not yet been examined in detail. Several academic and research projects attempted to measure a limited number of air pollutants near roadways in the central business district. At present, air pollution has become a major environmental issue for Dhaka. Therefore, comprehensive studies of concentration of different pollutant and elemental composition and concentrations in street dust are needed to determine the present situation of the atmospheric environment in Dhaka city.

### 2.2 Analytical procedures

Due to time and resource constrains, assessment on vehicular emission of Dhaka has been made based on secondary data collected from Department of Environment (DOE), Air Quality Management Project (AQMP), Continuous Air Monitoring Station (CAMS), Bangladesh Road Transport Authority (BRTA), Bangladesh Atomic Energy Commission (BAEC), different government organizations/institutions and published research works. Efforts will be made to quantify total daily emissions of major pollutants and contributions of exhaust emissions from different vehicles plying in Dhaka city.

## 3. DATA ANALYSIS

### 3.1 Vehicle number in Dhaka

The transportation system of Dhaka is predominantly road based and non-motorized transportation has a substantial share. It has a heterogeneous vehicle fleet, categorized by cars (passenger, taxis and light duty vehicle); trucks and buses; motorcycles; and auto-rickshaws (tricycles). Table 1 shows the growth trends of various categories of vehicles in Dhaka during 1994 to 2007 with their average annual increase in fleet size. The table shows that the vehicle fleet of Dhaka city has been growing at an average rate of 17% per year. To evaluate growth trends of vehicular fleet, data were collected from Bangladesh Road Transport Authority (BRTA).

Table 1: Registered Vehicle Fleet in Dhaka

| Type of Vehicles | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2007 | Annual Growth % |
|---|---|---|---|---|---|---|---|---|---|
| Motor Car | 36998 | 52307 | 63819 | 70601 | 81703 | 92600 | 109383 | 120975 | 17.46 |
| Jeep/St. Wagon /Microbus | 17937 | 20880 | 23810 | 26091 | 30581 | 34505 | 41766 | 46050 | 12.06 |
| Taxi | 787 | 847 | 963 | 1526 | 4389 | 9892 | 11161 | 11161 | 101.40 |
| Bus | 269 | 487 | 729 | 1155 | 2240 | 3393 | 5279 | 6620 | 181.61 |
| Minibus | 2009 | 3100 | 3797 | 4254 | 7009 | 8428 | 11671 | 13208 | 42.88 |
| Truck | 9775 | 11192 | 13707 | 16197 | 18214 | 21779 | 24737 | 26145 | 12.88 |
| Auto-rickshaw/ Auto-tempo | 8359 | 20275 | 23866 | 26429 | 29120 | 39460 | 39772 | 39891 | 29.02 |
| Human hauler | - | - | - | - | - | 809 | 854 | 871 | 5.88 |
| Covered Van | - | - | - | - | - | 527 | 802 | 939 | 19.54 |
| Motorcycle | 61478 | 69932 | 80270 | 94368 | 112060 | 127171 | 157167 | 170901 | 13.69 |
| Others | 2063 | 3769 | 4275 | 6420 | 9257 | 13814 | 13935 | 13994 | 44.49 |
| Total | 139675 | 182189 | 214636 | 2464441 | 293973 | 351778 | 415927 | 450755 | 17.10 |

*Data Source: BRTA (2008).*

## 4. ESTIMATION OF POLLUTANT EMISSIONS IN DIFFERENT YEARS

### 4.1 Selection of Emission Factor

The emission factor is defined as the estimated average emission rate for a given pollutant for a given class of vehicles. It is estimated by emissions produced per km traveled by vehicle. Estimates of vehicle emissions are obtained by multiplying an estimated distance traveled by a given class of vehicles by an appropriate emission factor. Legislation on motor vehicle emissions was first addressed by visible smoke, than carbon monoxide, and later on hydrocarbons and oxides of nitrogen. Reduction of lead in gasoline and sulpher in diesel fuel received attention from all corner. It is very difficult to quantify the contribution of vehicles to the city's air pollution accurately. Data for in service vehicles are surprisingly poor in Bangladesh. The most important sources of uncertainty are the sensitivity of vehicle emissions to the driving cycle, the wide variety of driving patterns, and the effect of driving error, given the highly skewed distribution of emission levels of vehicles. In Bangladesh, although vehicle emission standards during registration of vehicles have been set, emission standards for in service vehicles are not available. Jaigirdar (1998) made an attempt to determine the emission factors for various types of vehicles. Although the procedure was simpler, it is difficult to relate this emission in real situation with variable traffic and weather condition. More so, in his study only the exhaust emission was measured, but there are other emissions also, like, evaporation and crankcase emissions. From literature review average value of the available emission factors are taken in to consideration. From analysis of all data, practicable emission factor in Table 2 for each category of vehicles have been considered for evaluation in this study.

Table 2: Emission Factors for Vehicular Fleet in Dhaka (gm/km)

| **Category of Vehicles** | **CO** | **$NO_x$** | **$SO_x$** | **HC** | ***SPM*** |
|---|---|---|---|---|---|
| Motor Car | | | | | |
| a. Gasoline driven | 25.00 | 1.50 | 0.40 | 4.00 | 0.10 |
| b. CNG driven | 5.00 | 1.50 | - | 2.00 | 0.03 |
| Jeep/St Wagon/Microbus | | | | | |
| a. Gasoline driven | 28.00 | 1.60 | 0.50 | 4.00 | 1.00 |
| b. CNG driven | 5.00 | 1.50 | - | 2.00 | 0.60 |
| Taxi (CNG Driven) | 5.00 | 1.50 | - | 2.00 | 0.03 |
| Bus | 20.00 | 17.00 | 2.00 | 4.00 | 1.60 |
| Minibus | 20.00 | 17.00 | 2.00 | 4.00 | 1.60 |
| Truck | 30.00 | 17.00 | 3.00 | 4.00 | 1.60 |
| Auto-rickshaws | 5.00 | 1.50 | - | 2.00 | 0.03 |
| Human Hauler | 25.00 | 1.50 | 0.40 | 4.00 | 1.60 |
| Pickup Van | 25.00 | 10.00 | 2.00 | 4.00 | 1.60 |
| Motorcycle | 5.00 | 0.30 | 0.20 | 4.00 | 0.75 |

### 4.2 Estimation of Vehicle Fleet Plying On Road and Average Mileage/Day

In Bangladesh, owners do not often change the model of their vehicles out of fashion or old age. Vehicle owners make all out efforts to get maximum service out of their old vehicles by carrying out minor/major repair works till such time vehicles get fully damaged. Therefore, wastage rate of vehicles in Bangladesh will be lower in comparison with other developed countries. In Dhaka city, there are good numbers of military vehicles plying on road, which are not registered in BRTA. Based on these aspects, wastage rate of 10% is considered for evaluation of vehicular emissions in Dhaka city. Vehicles in the category of bus, minibus, auto-rickshaw and taxi, ply maximum on road. Average km run by each category of vehicles in a day has been estimated from DOE (2005), statements of vehicle owners and assumptions. Table 3 shows on road vehicular fleet in Dhaka city with their average usage (in km/day).

Table 3: Vehicular Fleet and Average Mileage/Day

| Category of Vehicles | No of Registered Vehicles | No of Vehicles on Road (Estimated) | Avg Mileage/Day (Km/Day) |
|---|---|---|---|
| Motor Car | | | |
| a. Gasoline driven | 120975 | 54438 | 40 |
| b. CNG driven | | 54438 | |
| Jeep/Microbus | | | |
| a. Gasoline driven | 46050 | 20722 | 60 |
| b. CNG driven | | 20722 | |
| Taxi (CNG Driven) | 11161 | 10044 | 130 |
| Bus | 6620 | 5956 | 130 |
| Minibus | 13208 | 11886 | 130 |
| Truck | 26145 | 23530 | 60 |
| Auto-rickshaws | 39891 | 35900 | 130 |
| Human Hauler | 871 | 780 | 100 |
| Pickup Van | 939 | 845 | 100 |
| Motorcycle | 170901 | 153810 | 30 |

*Data Source: DOE (2005).*

### 4.3 Estimation of Pollutant Emissions from Vehicles in different years

The vehicular fleet of Dhaka has peculiar blending of motorized and non-motorized vehicles. Most of the vehicles are aged old and primary contributor to city's ambient air pollution. Using the above information daily emission of each pollutant can be determined by multiplying three variables as shown below:

*Daily Emission (Ton/day) = [(No of vehicles)*(Daily use of vehicle, in km/day)* (Emission factor, in gm/km)] / $(1000)^2$ ...................(1)*

The variation of pollutant emission in the years 2003 to 2007 is shown in Fig 1, 2, 3, 4 and 5. Table 4 shows the emission of different pollutant in 2008. From the projected pollutant emission for 2015 and estimated emission in 2008 ( Table 5) it can be concluded that increased CO emission 36%, $NO_x$ emission 40%, Sox emission 41%, SPM emission 40% and HC emission 35% . Science the daily emission is increasing the concentration of these pollutant will also increase.

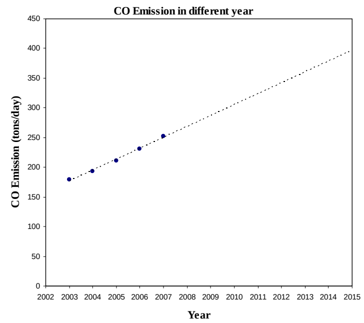


Fig 1: CO Emission in different year

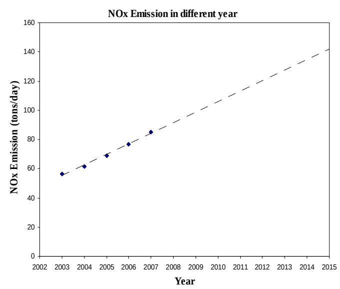


Fig 2: $NO_x$ Emission in different year

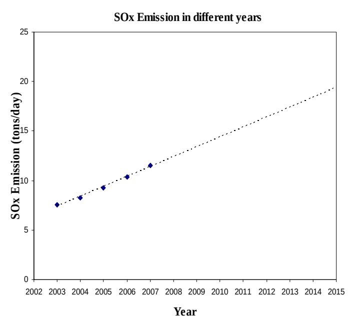


Fig 3: $SO_x$ Emission in different year

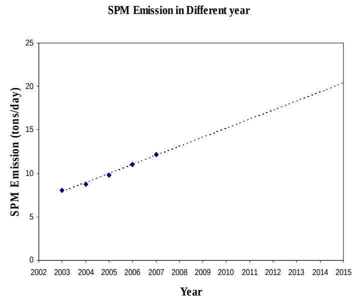


Fig 4: SPM Emission in different year

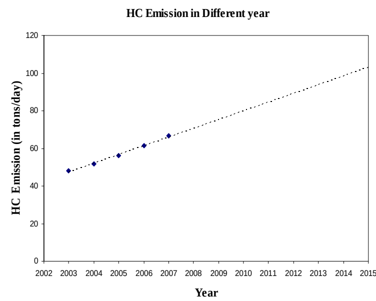


Fig 5: HC Emission in different year

Table 4: Estimated Vehicular Emission in 2008 of Dhaka City

| **Types of Vehicles** | **CO (Ton/Day)** | **$NO_x$ (Ton/Day)** | **$SO_x$ (Ton/Day)** | **HC (Ton/Day)** | **SPM (Ton/Day)** | **Total (Ton/Day)** |
|---|---|---|---|---|---|---|
| Motor Car | 65.33 | 6.54 | 0.87 | 13.07 | 0.29 | 86.1 |
| Jeep/Microbus | 41.03 | 3.85 | 0.62 | 7.46 | 1.99 | 54.95 |
| Taxi | 6.53 | 1.96 | - | 2.61 | 0.04 | 11.14 |
| Bus | 15.49 | 13.16 | 1.55 | 3.10 | 1.24 | 34.54 |
| Minibus | 30.90 | 26.27 | 3.09 | 6.18 | 2.47 | 68.91 |
| Truck | 42.35 | 24.00 | 4.24 | 5.65 | 2.26 | 78.50 |
| Auto rickshaws | 23.34 | 7.00 | - | 9.33 | 0.14 | 39.81 |
| Human Hauler | 1.95 | 0.12 | 0.03 | 0.31 | 0.12 | 2.53 |
| Pickup Van | 2.11 | 0.85 | 0.17 | 0.34 | 0.14 | 3.61 |
| Motorcycle | 23.07 | 1.38 | 0.92 | 18.46 | 3.46 | 47.29 |
| *Total* | ***252.10*** | ***85.13*** | ***11.49*** | ***66.51*** | ***12.15*** | ***427.38*** |

Table 5: Projected Vehicular Emission of Dhaka City

| **Pollutant Type** | **Estimated Emission in 2008** | **Projected Emission in 2015 (tons/day) of Dhaka City** | **Percentage of Increase** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| CO | 252.1 | 396.225 | 36% |
| $NO_x$ | 85.13 | 142.2785 | 40% |
| $SO_x$ | 11.49 | 19.4465 | 41% |
| SPM | 12.15 | 20.363 | 40% |
| HC | 66.51 | 103.0405 | 35% |

## 5. HEALTH EFFECTS DUE THE INCREASED POLLUTANT CONCENTRATION

In a in Athens (Touloumi et al., 1996), $SO_2$ is positively correlated with health showing a 3% to 8% increase in total number of daily deaths for every additional 100 μg/$m^3$ of $SO_2$ . Based on hospital admission records, Schwartz and Morris (1995) report a relative risk of 1.018 in heart diseases for every 18ppb (parts per billion) increase in $SO_2$. An increase in mortality of 3.1% is also concluded for each interquartile range increase in $NO_2$, in a study in Korea (Hong et al., 2002), while the cardiovascular deaths related to air pollution rise by 1% for every 10μg/$m^3$ increase in $NO_2$ levels, for seven cities of Spain (Saez et al., 2002). In another study, Cho et al. (2000) conclude that, for respiratory admissions, the relative risk in relation to $NO_2$ is 1.47 (95% C.I.: 1.03-2.10). Similarly, Schwartz (2004) argues that NO effects on respiratory problems are quite apparent, especially on children, while Braat et al. (2002) link NO to the aggravation of respiratory diseases and allergies, although the significance level of the pollutant could not allow for generalizations. Generalized Linear Models (GLM) assuming Gaussian (normal) distribution for Dhaka city may give the exact scenario as found for the above mentioned cities. To develop GLM model continuous monitoring of the pollutant at the traffic stream is required for Dhaka City which was not avail able for this study. So we analyzed the avail able hospital data. Table 6 shows the percentage wise top 10 causes of death, where air pollution related diseases (ARI, Asthma, Pulmonary heart diseases etc) play dominant role in overall mortality rate of Bangladesh. The shocking truth is that the poor, elderly people and children suffer more from these diseases. Complications of these diseases become more acute during the dry season. According to the Dhaka Shishu Hospital (DSH), at least 15-20 patients/day come with pneumonia from November to January (dry season) while the number is less than half during other seasons. Nearly 48.62% of the total patients were found to have respiratory problems or symptoms within July-December 2003, whereas the record of the same hospital shows patients with ARI in winter was 56% in 2000. Bangladesh accounts for about 120,000 deaths, including children, every year of which Dhaka city alone may account for the larger part (Dana, 2002). Table 7 and 8 and Figure 6 shows the percentage of patients with pneumonia and ARI of different years in DSH. Trend of ARI patients in Dhaka is upward, which is a point of concern. So the percentage of ARI patient may also severely increase due this elevated concentration by vehicular emission.

Table 6: Top 10 Causes of Death (Percentage Wise) in Bangladesh

| Causes of Death | SVRS Report 2003 (%) | | | SVRS Report 2004 (%) | | |
|---|---|---|---|---|---|---|
| | Both Sex | Male | Female | Both Sex | Male | Female |
| Old Age Complications | 15.51 | 14.68 | 16.62 | 17.35 | 15.39 | 19.99 |
| Asthma | 13.74 | 13.37 | 14.23 | 15.52 | 17.53 | 12.80 |
| Fever | 10.83 | 10.45 | 11.34 | 9.47 | 8.64 | 10.60 |
| Heart Diseases | 10.64 | 12.47 | 8.19 | 10.70 | 12.64 | 8.08 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Accident and Injuries | 5.96 | 6.90 | 4.69 | 6.21 | 6.56 | 5.74 |
| Tumor, Cancer | 4.85 | 4.68 | 5.07 | 4.60 | 4.69 | 4.48 |
| Diarrhea | 3.86 | 3.91 | 3.80 | 3.76 | 2.97 | 4.83 |
| Jaundice, Liver | 3.82 | 3.87 | 3.74 | 2.50 | 2.60 | 2.36 |
| Tuberculosis | 2.17 | 2.70 | 1.48 | 1.39 | 1.89 | 0.71 |
| Tetanus | 1.90 | 1.96 | 1.82 | 1.05 | 1.30 | 0.71 |

*Source: BBS (2006).*

Table 7: Patients in DSH with Pneumonia

| Year | Admitted | % of Total Patients | Death |
|---|---|---|---|
| July-December, 2003 | 1863 | 31.14 | 74 |
| January-March, 2004 | 500 | 32.43 | 51 |

*Source: DSH (2008).*

Table 8: Percentage of Patients in DSH with ARI and Wheezing

| Year | Winter (Nov-Feb) | | Summer (Mar-Jun) | | Monsoon (Jul-Oct) | |
|---|---|---|---|---|---|---|
| | ARI | Wheezing | ARI | Wheezing | ARI | Wheezing |
| 1996 | 39 | 21 | 35 | 10 | 25 | 8 |
| 1997 | 48 | 25 | 42 | 10 | 32 | 9 |
| 1998 | 52 | 33 | 45 | 15 | 35 | 11 |
| 1999 | 56 | 42 | 54 | 24 | 41 | 15 |
| 2000 | 56 | 45 | 55 | 27 | 45 | 19 |

*Source: DSH (2003)*

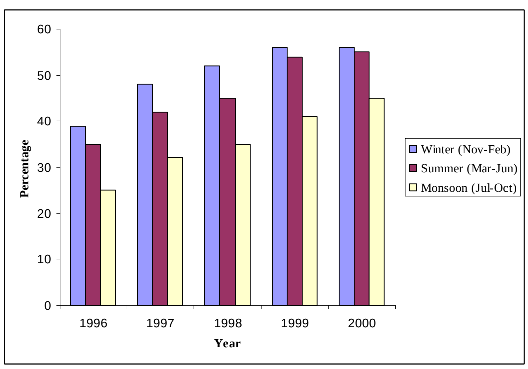


Figure 7: Seasonal Variations of ARI in DSH (1996-2000)

## 6. CONCLUSION

Emissions from all types of motorized vehicles have been unabatedly polluting city's air. A total of estimated 427 ton of various kinds of pollutants emit from the vehicle fleet in the Dhaka city every day in 2008 while in 2015 the amount is 681 ton. Pollutants emissions of CO-396 ton/day, NOx-142 ton/day, HC-104 ton/day, SPM-20 ton/day and SOx-19 ton/day pollutant loads are emitted from vehicular fleet in 2015. Among the pollutants, CO emission increases about 36%, SOx (41%), SPM (40%), $NO_X$ (40%), and HC (35%). This increased emission will cause serious health hazard for the urban peoples especially those who are highly exposed to traffic.

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# WATER QUALITY AT THE POINT OF CONSUMPTION IN DHAKA CITY AND HEALTH RISK ASSESSMENT

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## ABSTRACT

The quality of drinking water is a complex issue and involves various disciplines. The risk of outbreak of water borne diseases is high from contaminated drinking water. The aim of the paper was to determine the water quality at the point of consumption in Dhaka city of Bangladesh to assess risks to human health. The investigation was done on the basis of laboratory tests on 60 water samples, obtained from residential areas, slum areas, bottle mineral water and vending water. The test parameters were electrical conductance, hardness, $P^H$, turbidity, essential and trace elements and fecal coliform (FC) bacteria. It was found that the drinking water of all categories except bottle mineral water was contaminated by fecal coliforms. Hardness value and magnesium concentration of all the samples were low. $P^H$, turbidity, color results were satisfactory as concentration were in the acceptable range. Electrical conductivity of the slum area showed higher value than the guideline value given by WHO and Bangladesh standard. Calcium and magnesium concentrations in many of the bottle waters were too low. Health risk by arsenic and fecal coliforms were analyzed by **APSU QHRA [1]** model which showed health risks in Dhaka were higher for fecal coliforms and not for arsenic. Statistical significance tests showed that the higher risk was associated with low income people living in slum area. The results of this paper will help in enhancing awareness of health hazards of contaminated drinking water among the consumers as well as in drawing attention of health regulatory authorities.

**Key Words**: water quality, bottle water, vending water, physico-chemical, bacteriological analysis, fecal coliform, health risk.

## 1. INTRODUCTION

Drinking water should be aesthetically acceptable. It should be free from apparent turbidity, color, odor, and from any objectionable taste. According to WHO [2] more than 80 percent of human diseases are water borne. In the developing countries 60 percent of population has no access to pure drinking water [3].Although drinking water quality standards may vary from country to country; the objectives remain the prevention of any harmful health impact on the consumers. Due to the scarcity of fresh water, tap water may be erroneously regarded by many rural people to be panacea and concerns regarding its safety as less pressing or even irrelevant.

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The present study was planned to monitor the quality of water consumed by the population of Dhaka city for drinking purposes and the impact of the quality of water on health. The population constituted all classes of people including the low income class in the slum area .The aim of the paper was to explore and compare all types of drinking water sources and to make a health risk assessment of all the water samples collected from different areas of Dhaka city.

## 2. METHODOLOGY

All the sampling and preservation procedures for water samples were performed according to the standard methods for the examination of water according to the guidelines of drinking water quality given by WHO and Bangladesh standard (BS).

### 2.1 Sample Collection and Analysis

The study was done on different consumer category. Out of these 60 samples, 33.33% were from residential, 33.33% were from slum and 33.33% from commercial supply. Two different residential areas were studied. One located in Mohammadpur was termed as residential area1 and other in Dhanmondi was termed as residential area 2. Slum area in Mohammadpur was termed as slum area 1 and another slum area in Lalbagh was termed as slum area 2. Vending water companies were Apang, Sabeel, Nilgiri, Niagra, Enueres, Pure Water Company, Reliable pure drinking water, Ahad Company, Shamim water supply and Drops drinking water. Tested mineral water companies were 'Shanti', 'Acme', 'Spa', 'Jibon' , 'Pran', 'Mum', 'Fresh' , 'Libra', 'Fyne' and 'Duncan' .Water samples were taken to Environmental laboratory of BUET for their physical, chemical and bacteriological analysis. For determination of the concentration of the chemical constituents' spectrophotometric method was used. Bacteriological analysis was done using the membrane filter method.

### 2.2 Statistical Analysis

The mean value of all the parameters of all the categories was determined. To observe the overall quality, samples were compared by Student's t- test. Here, $p<.05$ was considered as the minimum value for statistical significance.

## 3. RESULTS

The results of different parameters analyzed in the study are given below.

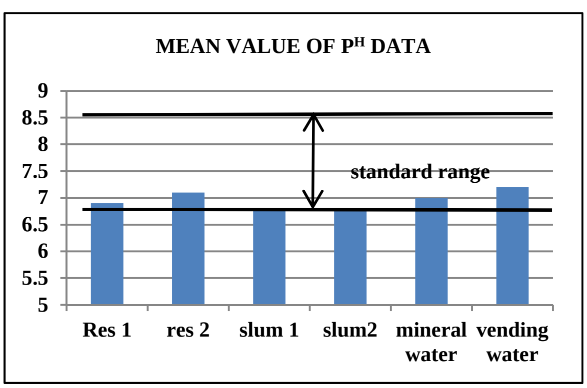



Fig 1: Mean value of $P^H$ data

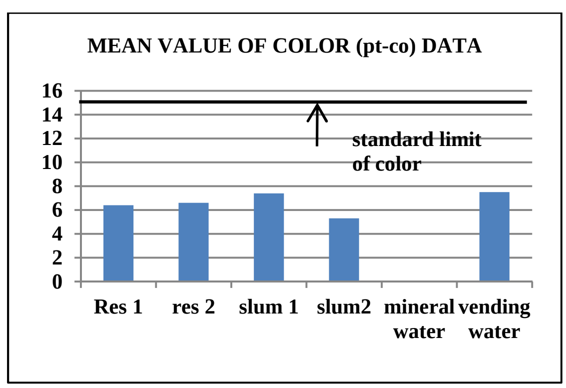
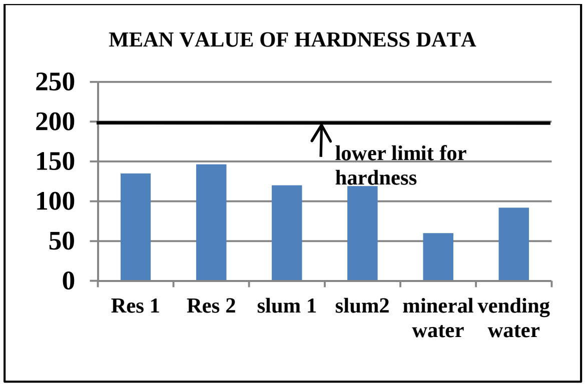



Fig 2: Mean value of color data



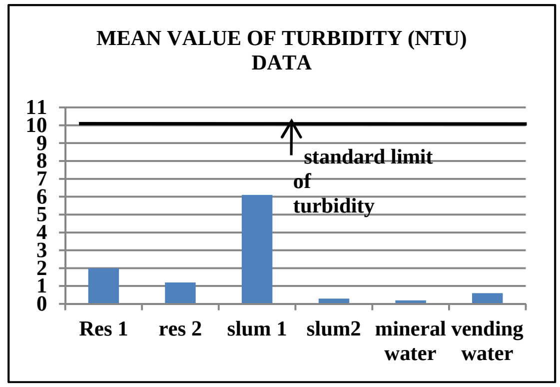
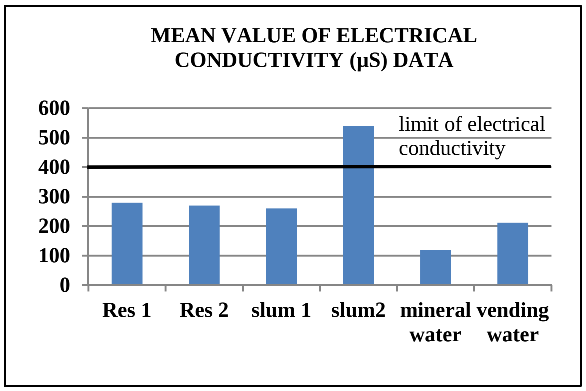




Fig 3: Mean value of Hardness data

Fig 4: Mean value of Turbidity data



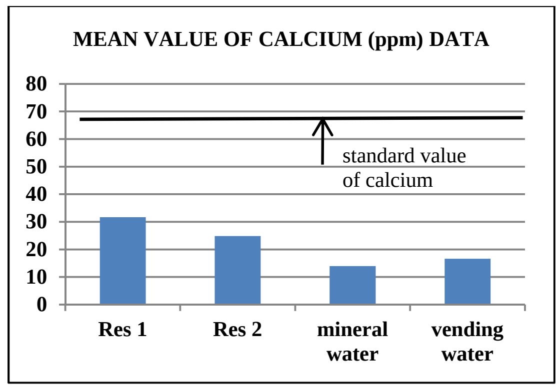
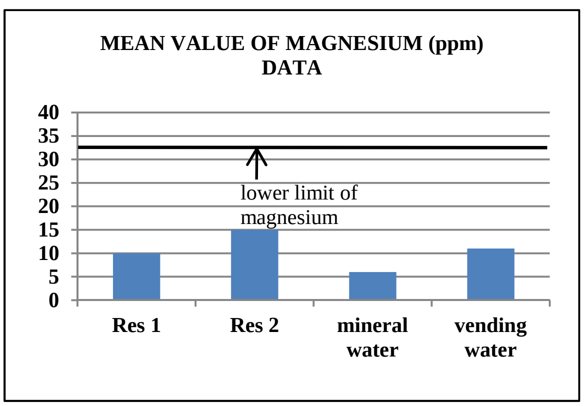




Fig 5: Mean value of Electrical conductivity data

Fig 6: Mean value of Calcium data



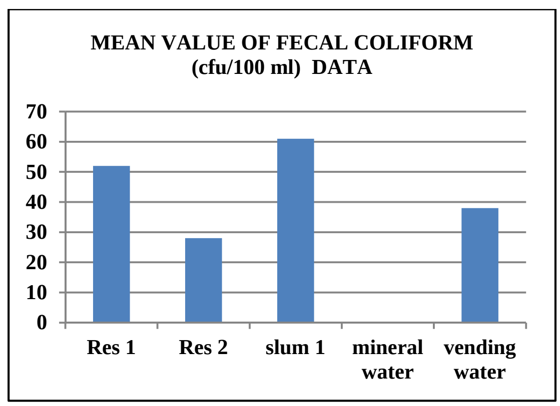




Fig 7: Mean value of Magnesium data

Fig 8: Mean value of Fecal coliform data

From fig 1 to fig 7, it was evident that the physicochemical parameteres were within guideline values.Arsenic concentration of all the samples collected were from 0.43 ppb to 2.41 ppb, which is much below the of WHO guideline value. So, all the samples were free from arsenic hazard. Results of microbial examination of the samples showed that 60% of the total samples were found contaminated by coliform bacteria. Residential area 1 and 2 are 100% positive for fecal coliform where as the samples of slum areas were found TNTC (too numerous to count). Bottle mineral water were free from microbial contamination but the vended water samples were found contaminated which had bacterial growth as high as 200 per 100 ml.

## 4. COMPARISON OF DIFFERENT AREAS

### 4.1 Comparison of Physicochemical Parameters

It was very interesting to compare data of different areas. Comparison was made between slum and residential area and also between mineral water and vending water for different parameters and using statistics. The result is presented in Table 1.

Table 1: Comparison of Physicochemical parameters of different categories.

| **Name of parameter** | **Mean ± confidence interval (95%)** | | **Result of significance test** | **Mean ± confidence interval (95%)** | | **Result of significance test** |
|---|---|---|---|---|---|---|
| | **Slum area** | **Residential area** | | **Bottle mineral water** | **Vending water** | |
| $p^H$ | 6.53- 6.99 | 6.72 - 7.1 | There is significant difference ($p<.05$). | 6.68 - 7.4 | 6.73-7.46 | There was significant difference ($p<0.05$) |
| Electrical conductivity (µS /cm) | 232.86 - 291.94 | 176.62- 381.38 | There is significant difference ($p<.05$). | 0- 342.03 | 13.16- 410.64 | There was significant difference ($p<0.05$) |
| Hardness (ppm) | 52.9 -200 | 92.68- 140.12 | There is significant difference ($p<.05$). | 0 - 201.26 | 5.16 -173.64 | There was significant difference ($p<0.05$) |
| Turbidity (NTU) | 0 - 18.7 | 0 - 4.33 | There was highly significant difference ($p<.05$) | 0.15 - 0.31 | 0 -1.99 | There was highly significant difference ($p<.05$) |
| $Ca^{++}$ (ppm) | -- | -- | -- | 0 -45.38 | 0 -34.09 | There was highly significant difference ($p<0.05$). |
| $Mg^{++}$ (ppm) | -- | -- | -- | 0-12.56 | 0 - 34.39 | There is no significant difference ($p>0.05$). |

### 4.2 Comparison of Bacteriological Parameters

For comparison of bacteriological quality of drinking water all the category were compared in one figure below.

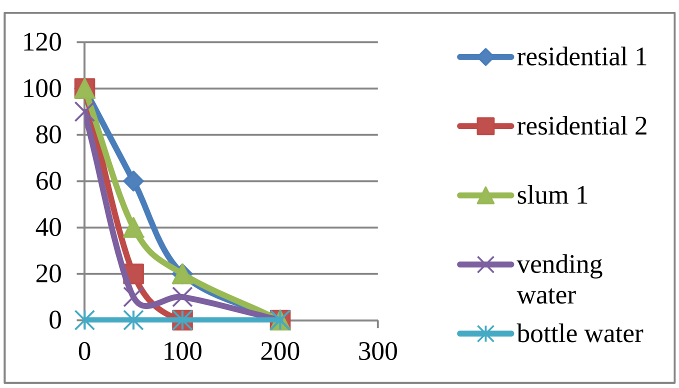



Figure 9: Percent of the samples greater than the indicated value versus FC count.

Although the mean values of individual area (Fig 8) showed higher concentration of FC in slum area (the comparison of the percent of samples greater than the indicated value versus FC count showed that the most vulnerable areas were residential area-1 and slum area-1(Fig 9).

## 5. HEALTH EFFECTS ASSESSMENT

In this study, Microbial and Arsenic disease burden was assessed using APSU QHRA model. This model provides a prediction of disease burdens associated with water supplies based on reference pathogens and arsenic. Disease burden has been expressed in disability adjusted life year (DALY) as recommended by WHO (2004b) .From Figure 10, it can be seen that Viral and bacterial disease burden were predicted to be a greater proportion of the total DALYs. Arsenical burden has almost no contribution to the total DALYs and is well below the guideline values both for 10 µg/l and 50 µg/l arsenic GV. The water samples are subjected to more microbial related health risk than arsenic.

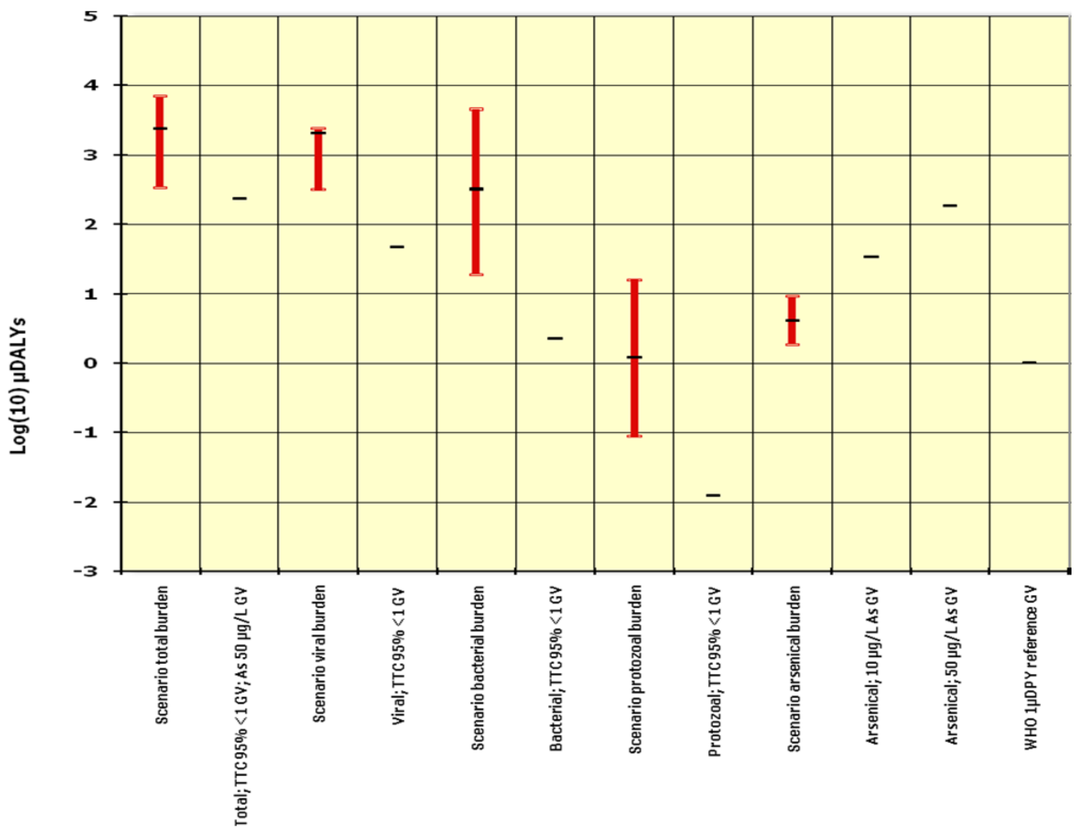



Figure 10: Illustration of disease burden using APSU QHRA model for residential area 1.

Similarly, using the model and observing the output graphs following results were obtained. Residential area 2, both slum areas and vending water had viral, bacterial and protozoal burden greater than the guideline value (GV).Bacterial burden was found to be the main contributor in the total DALYs. Viral burden was higher than protozoal burden in residential area 2 and slum 1. Bottle mineral waters were free from both microbial and arsenic hazard. Arsenic burden was too low in all the samples than GV. It ensures people in Dhaka are free from common diseases due to arsenic like Melanosis, Keratosis, hyperkeratosis and depigmentation, skin and other cancer. So, it can be seen that the most common and wide spread health risk associated with drinking water in Dhaka city is microbial contamination leading to Diarrheal diseases. In this study $P^H$, turbidity, conductivity, color values were within the range given by BS, which ensured no adverse effects. In all mineral water brands the hardness was under the approved level. Even the brand 'SHANTI' which is the product of DWASA was found to have hardness 20ppm. Water with very low hardness might cause cardiovascular diseases, urolithiasis, cerebrovascular disease.

## 6. CONCLUSION

Quality of drinking water in Dhaka city is a burning issue now a day, Water samples collected from different consumer categories were found unsatisfactory as many of the parameters were found not conforming to the standards of BS. Even treated water is not present even in clinics as some samples of vending water was collected from clinics which showed the evidences of microbial contamination.

Although hardness values found in the slum and residential areas were below 200 ppm it does not create any problem for drinking water purpose. Hardness of mineral water was too low due to their treatment processes that may cause health problems. The highest risk associated is due to microbial contamination as arsenic concentration in Dhaka water supply was too low to cause hazard. By comparing the economic status of the consumers it was found that the slum dwellers consumes inferior quality water as maximum value of FC was found in the slum area . They have lesser opportunities to improve their condition and they are at the highest risk.

For improving the water quality, periodic estimation of some important parameters like bacterial load especially indicating fecal coliforms both at the source and at the consumers end must be carried out. Strong policy and law should be enforced to ensure the quality of the bottle mineral water and vending water. Urban poor deserve special attention as almost 25-30 % of the city population live in the slums and do not have the adequate access to the safe water

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# SEISMIC RESPONSE OF BRICK MASONRY STRUCTURES

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## ABSTRACT

The importance of structural masonry has not been matched by appropriate attention or action on the part of structural designers or building owners in Bangladesh as well as the engineering curricula in the various universities countrywide. The engineering aspects are seldom (if ever) applied or understood even by structural designers, not to speak of architects, builders or building dwellers in our country. As a result, masonry structures are often categorized as 'non-engineered' structures, implying very minor role of engineers in their structural design particularly for major lateral loads like earthquakes. Naturally, the lateral load resistance capacity of masonry construction is relatively low compared to the 'engineered' constructions made of steel or even Reinforced Concrete. The main objective of the present work is to evaluate the earthquake-resistant behavior and assess the seismic vulnerability of masonry systems. An actual masonry building is selected for the structural analyses and design. The study includes the analysis of the building primarily for strength of in-plane walls as well as the stability of out-of-plane walls, and also observes the effects of openings (doors/windows) in modifying the behavior of in-plane walls. The code-specified seismic design provisions of masonry structures are also checked with the structures under study.

**Key Words**: Earthquake, Brick Masonry, Inplane Stiffness, Out-of-Plane Stability, Wall Opening, Wall Pier, Seismic Retrofit

## 1. INTRODUCTION

Masonry buildings are widely used for housing construction in many countries including Bangladesh. A huge majority of the population in Bangladesh live in masonry buildings, which also include several important historical and public buildings that add to the heritage, emotion and pride of a city and even the entire nation. There are several advantages of masonry construction over both reinforced concrete and steel; e.g., thermal comfort, sound control, possibility of addition and alteration after construction, less formwork, easy and inexpensive repair, use of locally available materials, need of less skilled labor, less engineering intervention etc.

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But the importance of structural masonry has not been matched by appropriate attention or action on the part of structural designers or building owners in Bangladesh as well as the engineering curricula in the various universities countrywide. This lack of attention or action is a source of major concern, because mmasonry has some serious disadvantages particularly when built in extreme environmental or loading conditions. It has relatively high compressive strength but is much lower in tensile or shearing strength unless reinforced. Naturally, the lateral load resistance capacity of masonry construction is relatively low compared to constructions made of steel or even Reinforced Concrete.

## 2. SIGNIFICANCE OF PRESENT WORK

As mentioned, the structural efficiency of masonry construction is hindered by its poor performance under lateral and particularly earthquake loading. The increased frequency of small and medium-sized earthquakes in Bangladesh, prediction of a major earthquake in this region in the near future [1] and extremely poor performance of building structures (particularly masonry) in recent earthquakes in neighboring countries (including India, Pakistan, Afghanistan and Iran) have resulted in an increased awareness of the potential seismic hazard and vulnerability of structures. However, the increased concern for new or future structures has not been matched by the repair or retrofit efforts of innumerable structures that have already been built without much (if any) consideration for seismic resistance.

And since much of these existing buildings are potentially vulnerable masonry structures, this lack of attention or action is a source of major concern. This is despite the fact that there has been a separate chapter allotted for the structural design of masonry structures in Bangladesh National Building Code [2], which includes design provisions for lateral loads as well. These provisions are seldom (if ever) applied or understood even by structural designers, not to speak of architects, builders or building dwellers. Masonry structures are often categorized as 'non-engineered' structure, implying very minor role of engineers in their structural design particularly for earthquakes.

The main objective of the present work (based on [3]) is to evaluate the earthquake-resistant behavior and assess the seismic vulnerability of masonry systems. Moreover, the building dimensions are checked with code-based seismic design provisions.

## 3. STRUCTURAL MASONRY IN PAST EARTHQUAKES

Many developed nations have imposed certain restrictions on the use of unreinforced masonry constructions. However, in developing nations unreinforced masonry construction is still being used frequently. In Bangladesh, masonry constructions are generally made by using locally available materials like stone, brick, timber, adobe, mud and are constructed in a traditional manner without the earthquake resistant features. Their seismic performances are not satisfactory in general. Typical causes for failure of unreinforced masonry in earthquakes are failure of building corner, out-of-plane wall, inadequate beam-wall connection, wall separation, shear failure of in-plane walls. These are caused by the lack of connection or reinforcements between walls in perpendicular directions, insufficient wall thickness compared to height, presence of openings due to doors, insufficient width of wall-piers, insufficient separation between buildings, incompatible distortion at re-entrant corners, etc.

### 3.1. Earthquakes within Bangladesh

During the last 150 years, seven major earthquakes (of magnitudes greater than 7.0) have affected the zone that is now within the geographical borders of Bangladesh. Among them, the 1897 Assam earthquake (Richter scale magnitude of 8.7) and possible repeat of a similar earthquake now (in the vastly changed scenario more than hundred years later) has captured the imagination and dominated the discussions on possible earthquake damage particularly in Dhaka city and recommended preparations throughout the country. Fig. 1 shows selected pictures of extensive damage and collapse of masonry structures in the Assam Earthquake, highlighting the Armenian church in Dhaka and a bungalow-turned jute mill in Serajganj.

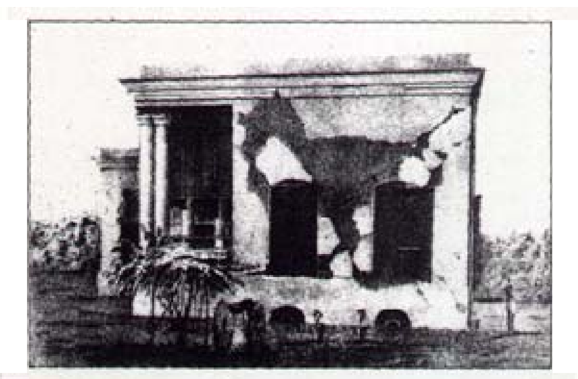

Fig. 1: Extensive damage of masonry structures in 1897 Assam Earthquake included
(a) Armenian Church in Dhaka, (b) Serajganj Jute Mill

### 3.2. Earthquakes outside Bangladesh

As mentioned, masonry structures have traditionally performed very poorly in earthquakes around the world. Some typical examples of such performances are shown in Figs. 2~5. Fig. 2 shows the trails of destruction left by the Assam earthquake of 1897. These include the complete collapse of the All Saints Church building [Fig. 2(a)] and a Girls School [Fig. 2(b)]. In both cases, the destroyed structure is left with very little semblance of the original. Figs. 3(a) and 3(b) demonstrate the total collapse of masonry in Bhuj earthquake [Fig. 3(a)] and the effectiveness of through lintel band in preventing such collapses. Fig. 3(b) shows similar buildings adjacent to each other, where one without through lintel was demolished completely, the one with through lintel remained almost undamaged. Fig. 4(a) shows a masonry structure left in the wake of the devastating Haiti earthquake of 2010, while Fig. 4(b) shows an office building in California, USA (1981). Pictures from an earthquake in Molise, Italy (2003) show the collapse of a historic citadel and a remarkable alternative providing nylon straps around the building keeping a masonry structure almost fully intact [Fig. 5(a), (b)].

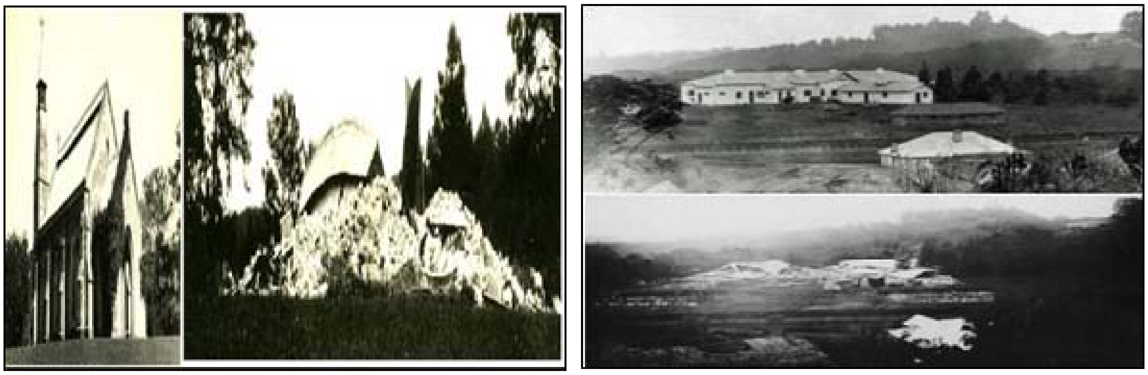
Fig. 2: Collapse of masonry (a) All Saints Church, (b) Girls School in Shillong (Assam 1897)


Fig. 3: (a) Total collapse of masonry building, (b) Lintel band preventing collapse (Bhuj 2001)


Fig. 4: Significant damage of structural masonry in (a) Haiti (2010) (b) California, USA (1981)


Fig. 5: (a) Collapsed Walls in historic citadel, (b) Little damaged building with Nylon straps (Italy 2003)

## 4. STRUCTURAL ANALYSIS

### 4.1 Structural Model

The structural analysis is carried out based on the Equivalent Static Force Method, following the steps described in [4] and [5]. This method is used to analyze a 5-storied masonry building, whose typical floor plan is shown in Fig. 6, while the details of various walls are shown in Fig. 7 and Fig. 8 for walls in the North-South and East-West direction. This is chosen as representing a typical masonry building in Dhaka city, which are designed (if at all) for vertical loads only, with no earthquake-resistant design measures taken.

The thickness of slab and wall are 120 and 250 mm respectively, while the dead loads carried by them are 3.0 and 5.0 kPa respectively. In addition, the slabs carry a live load of 1.0 kPa. The seismic parameters used for the analysis are $Z$ = 0.15, $I$ = 1.25, and $R$ = 6.0. The allowable axial and flexural stresses in the masonry are 2.5 and 3.125 MPa respectively.

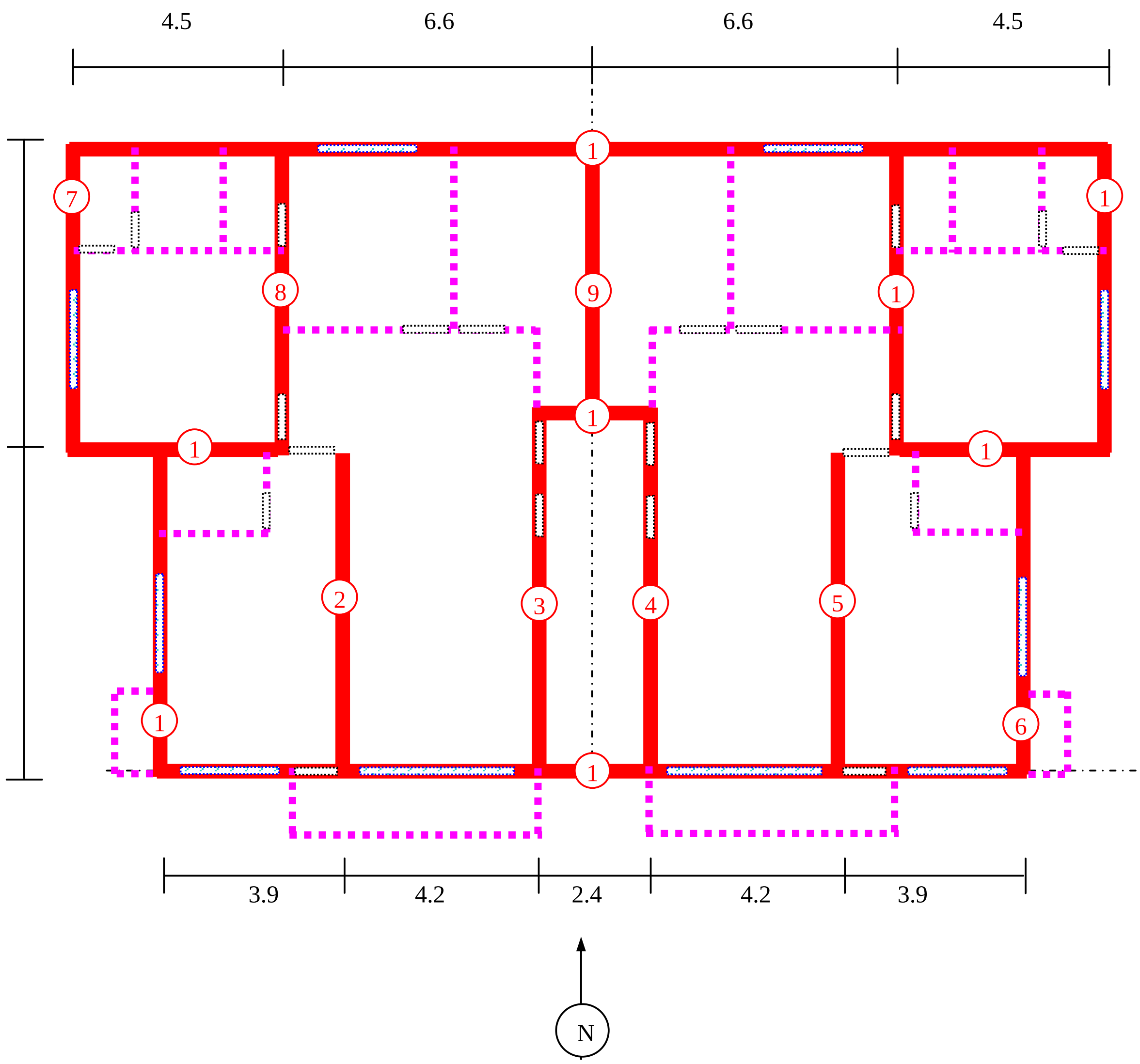


Fig. 6: Typical Floor Plan (All dimensions in meter)

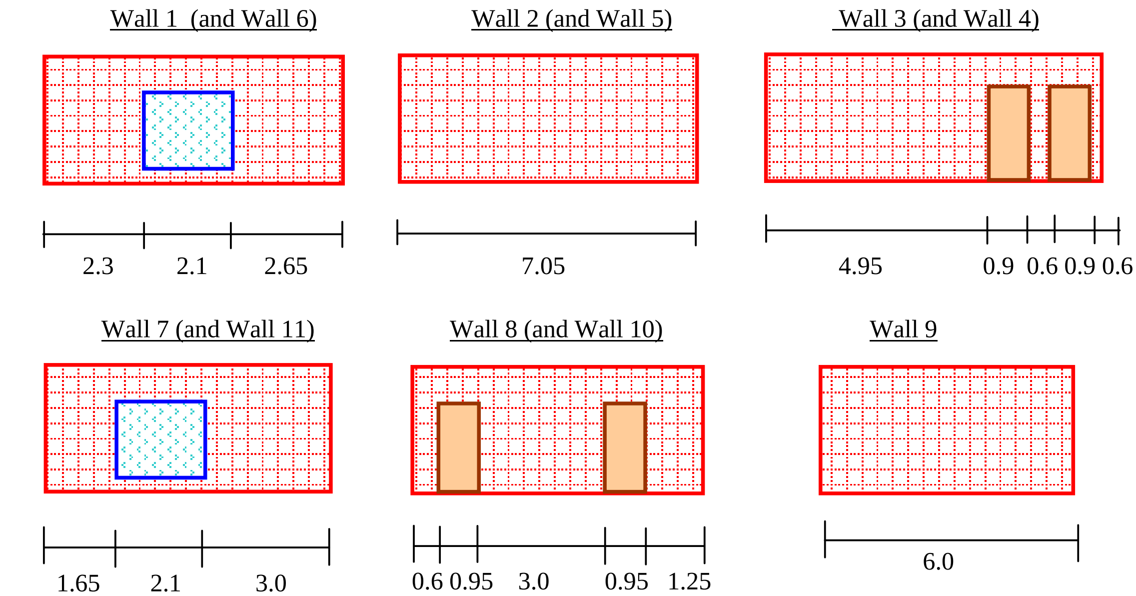


Fig. 7: Walls in North-South Direction

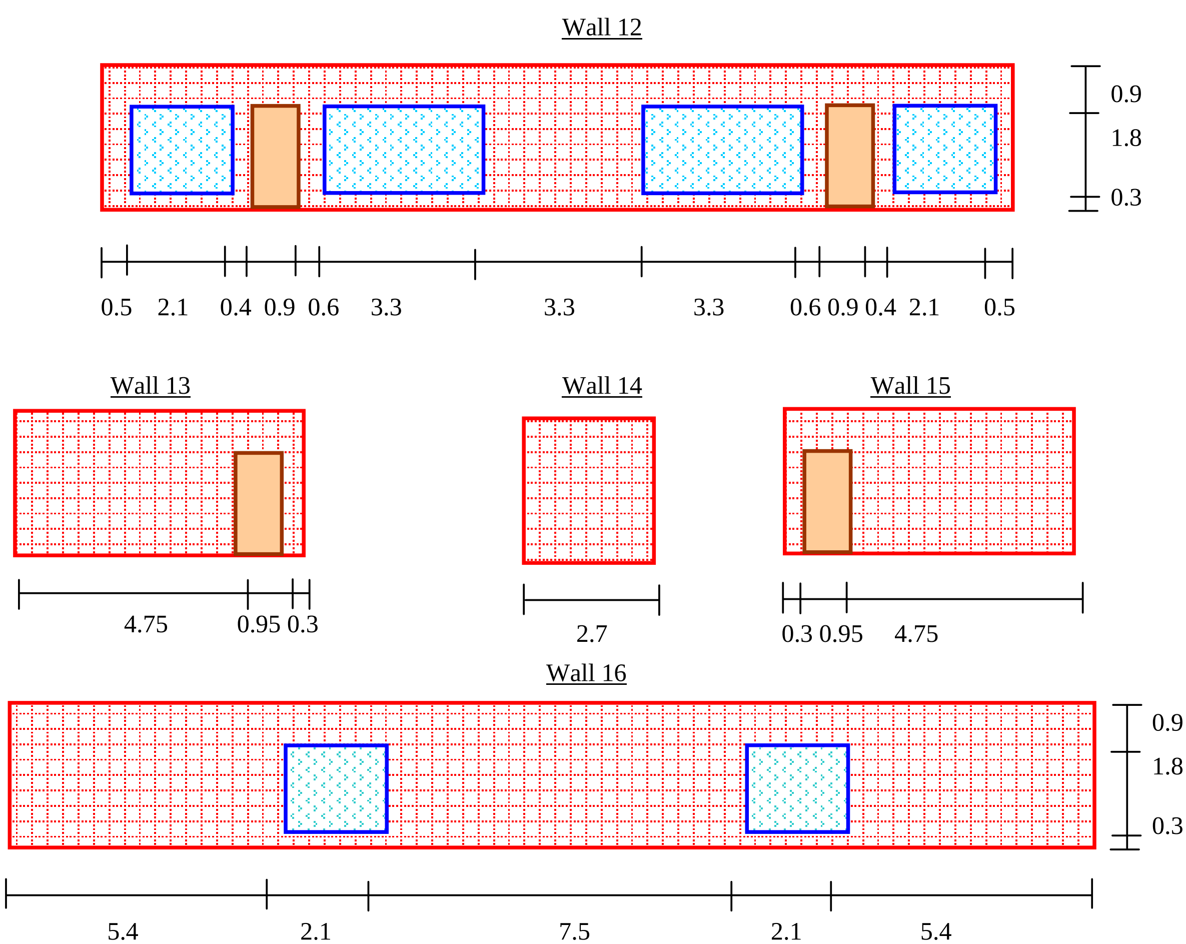


Fig. 8: Walls in East-West Direction

### 4.2. Results from Structural Analysis

#### 4.2.2. Distribution of Shear Forces

As mentioned before, results from this work include the relative rigidity of various walls, as well as the direct shear force, torsional shear force and combined shear forces in them. These results are presented in Table 1 for various Ground Floor walls, since they will be subjected to the maximum forces and are most vulnerable, as well as most important structurally.

Table 1: Distribution of Base Shear among Various GF Walls

| | Relative Rigidity | | Earthquake (NS-Direction) | | | Earthquake (EW-Direction) | | |
|---|---|---|---|---|---|---|---|---|
| Wall No. | $RG_x$ | $RG_y$ | $V_{Dir}$ (kN) | $V_{Tor}$ (kN) | $V_{Total}$ (kN) | $V_{Dir}$ (kN) | $V_{Tor}$ (kN) | $V_{Total}$ (kN) |
| 1 | 0.000 | 0.073 | 60.11 | -14.72 | 60.11 | 0.00 | 0.00 | 0.00 |
| 2 | 0.000 | 0.093 | 76.11 | -10.82 | 76.11 | 0.00 | 0.00 | 0.00 |
| 3 | 0.000 | 0.149 | 122.76 | -3.88 | 122.76 | 0.00 | 0.00 | 0.00 |
| 4 | 0.000 | 0.149 | 122.76 | 3.88 | 126.64 | 0.00 | 0.00 | 0.00 |
| 5 | 0.000 | 0.093 | 76.11 | 10.82 | 86.93 | 0.00 | 0.00 | 0.00 |
| 6 | 0.000 | 0.073 | 60.11 | 14.72 | 74.83 | 0.00 | 0.00 | 0.00 |
| 7 | 0.000 | 0.068 | 55.48 | -16.22 | 55.48 | 0.00 | 0.00 | 0.00 |
| 8 | 0.000 | 0.080 | 66.09 | -11.49 | 66.10 | 0.00 | 0.00 | 0.00 |
| 9 | 0.000 | 0.073 | 60.31 | 0.00 | 60.31 | 0.00 | 0.00 | 0.00 |
| 10 | 0.000 | 0.080 | 66.09 | 11.49 | 77.58 | 0.00 | 0.00 | 0.00 |
| 11 | 0.000 | 0.068 | 55.48 | 16.22 | 71.69 | 0.00 | 0.00 | 0.00 |
| 12 | 0.031 | 0.000 | 0.00 | 0.00 | 0.00 | 25.76 | -63.02 | 25.76 |
| 13 | 0.259 | 0.000 | 0.00 | 0.00 | 0.00 | 212.54 | -143.54 | 212.54 |
| 14 | 0.023 | 0.000 | 0.00 | 0.00 | 0.00 | 18.76 | -8.34 | 18.76 |
| 15 | 0.259 | 0.000 | 0.00 | 0.00 | 0.00 | 212.54 | -143.54 | 212.54 |
| 16 | 0.428 | 0.000 | 0.00 | 0.00 | 0.00 | 351.78 | 358.43 | 710.21 |

These results show that although the shear forces are quite well distributed among the North-South walls, Wall 16 takes a major proportion of the shear forces in the East-West direction. This is because of the large number of NS-walls, while Wall 16 is by far the largest and stiffest wall in the EW direction.

#### 4.2.3. Pier Design Conditions

Table 2 and 3 show the design conditions for various piers, based on normal stresses. These results show that Walls 3, 4, 8, 10 in the NS direction are most vulnerable mainly around the door openings, while the walls 12, 13 and 15 in the EW direction are similarly vulnerable around door openings. Among them, the walls 13 and 15 are particularly at risk because of the small pier-widths at the end of the walls. This is one of the major weaknesses of masonry structures, and is mainly due to the inevitable and necessary openings between closely spaced doors and windows, which are almost never compromised by architects or building owners and not considered by structural designers.

Table 2: Pier Design Conditions (Earthquake in the NS-Direction)

| Wall No. | Pier | $f_a$ (MPa) | $f_b$ (MPa) | $f_a/F_a + f_b/F_b$ |
|---|---|---|---|---|
| 1 | 1 | 0.75 | 0.253 | 0.381 |
| | 2 | 0.70 | 0.191 | 0.341 |
| 2 | 1 | 0.376 | 0.027 | 0.159 |
| 3 | 1 | 0.549 | 0.055 | 0.237 |
| | 2 | 1.391 | 3.723 | 1.748 |
| | 3 | 1.349 | 3.723 | 1.731 |
| 4 | 1 | 0.549 | 0.055 | 0.237 |
| | 2 | 1.391 | 3.723 | 1.748 |
| | 3 | 1.349 | 3.723 | 1.731 |
| 5 | 1 | 0.376 | 0.027 | 0.159 |
| 6 | 1 | 0.75 | 0.253 | 0.381 |
| | 2 | 0.70 | 0.191 | 0.341 |
| 7 | 1 | 0.878 | 0.492 | 0.509 |
| | 2 | 0.652 | 0.149 | 0.308 |
| 8 | 1 | 1.135 | 3.723 | 1.646 |
| | 2 | 0.561 | 0.149 | 0.272 |
| | 3 | 0.897 | 0.858 | 0.633 |
| 9 | 1 | 0.376 | 0.037 | 0.162 |
| 10 | 1 | 1.135 | 3.723 | 1.646 |
| | 2 | 0.561 | 0.149 | 0.272 |
| | 3 | 0.897 | 0.858 | 0.633 |
| 11 | 1 | 0.878 | 0.492 | 0.509 |
| | 2 | 0.652 | 0.149 | 0.308 |

Table 3: Pier Design Conditions (Earthquake in the EW-Direction)

| Wall No. | Pier | $f_a$ (MPa) | $f_b$ (MPa) | $f_a/F_a + f_b/F_b$ |
|---|---|---|---|---|
| 12 | 1 | 0.913 | 5.362 | 2.081 |
| | 2 | 1.829 | 8.377 | 3.412 |
| | 3 | 2.099 | 3.723 | 2.031 |
| | 4 | 0.756 | 0.123 | 0.342 |
| | 5 | 2.093 | 3.723 | 2.029 |
| | 6 | 1.823 | 8.377 | 3.410 |
| | 7 | 0.677 | 1.655 | 0.800 |
| 13 | 1 | 0.552 | 0.059 | 0.240 |
| | 2 | 3.155 | 14.893 | 6.028 |
| 14 | 1 | 0.376 | 0.184 | 0.209 |
| 15 | 1 | 3.155 | 14.893 | 6.028 |
| | 2 | 0.552 | 0.059 | 0.240 |
| 16 | 1 | 0.587 | 0.046 | 0.249 |
| | 2 | 0.482 | 0.024 | 0.200 |
| | 3 | 0.587 | 0.046 | 0.249 |

### 4.2.4. Check Code-based Design Criteria

For the building analyzed, the following criteria are checked with the code-based design provisions

* Total width of Wall Openings < 0.5 of Wall width, for one storied building
< 0.42 of Wall width, for two storied building
< 0.33 of Wall width, for three storied building
(not OK, because Wall 12 has much larger opening size)
* Spacing between Walls > 0.5 of Door/Window height, and ≥ 600mm
(not OK, because Walls 12, 13 and 15 have closer walls)
* Width of end Piers > 0.5 of Door/Window height, and ≥ 600mm
(not OK, because Walls 3, 8, 12, 13 and 15 have shallower end piers)
* Height of opening to ceiling > 600mm (OK)
* Wall Ratio = Total wall length/Floor area should be > 150 mm/m$^2$ on average
and > 210 mm/m$^2$ for upper stories (This is calculated to be OK)

## 5. CONCLUSION

This work combined some general study on the seismic behavior of unreinforced masonry with emphasis on a masonry building. Main conclusions from the study of general structural behavior of masonry include

- Masonry walls should be checked for out-of-plane criteria based on their (*h/t*) ratio. This is invariably the weakest link in their seismic resistance, because of the instability caused to them due to the large overturning moments from lateral loads like earthquake.
- Wall openings drastically reduce the stiffness and lateral load carrying ability of unreinforced masonry structures. In fact, very large walls that are expected to carry significant lateral loads are rendered very weak and vulnerable due to large openings due to windows and doors.
- Closely-spaced wall openings and the ones too close to wall boundary are very vulnerable to earthquake damage. Similar arguments lead to their weakness because of the narrow solid portions they are left with.

The building under study is also found to be particularly vulnerable to earthquake damage due to the some inherent weaknesses. In particular, it does not satisfy the following code-based seismic design criteria

- Thickness of the top-storey walls (for out-of-plane failure)
- Combined normal stress due to axial load and overturning moment (particularly for narrow piers near wall openings). In fact this weakness was found in several walls, more surprisingly in wide walls with large openings for windows and around the doors with vary narrow piers to the end of the walls.
- Structural dimensions and wall opening criteria are violated for several walls. These include the walls opening to height ratios, the height to width ratio and the pier width at the end of walls.

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# SEISMIC RETROFIT OPTIONS FOR RC COLUMNS AND FLAT SLABS

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## ABSTRACT

Seismic retrofitting of buildings is still a new subject for most structural engineers in Bangladesh. Conventional retrofit techniques usually involve costly and intrusive approaches that often deter building owners from retrofitting buildings for improved earthquake performance. Therefore the search for cost-effective and less intrusive seismic retrofit options is an essential element of earthquake resistant design. Bangladesh National Building Code (BNBC) suggests some detailing measures to improve the seismic behavior of new structures, but it is essential to repair and retrofit the large number of existing structures. Therefore, one main purpose of the present work is to evaluate various cost-effective retrofitting options to increase the strength and ductility of columns of existing RC buildings by confining them with low cost materials. The effectiveness of these options is tested in the laboratory by using them for concrete cylinders and subjecting them to compressive tests. It also includes a comparative study of the various options with the 'no-confinement' option. This work also evaluates the earthquake-resistant behavior of flat slabs with two types of shear reinforcements (e.g., vertical bars and shear studs). Known flat-slab building from previous study is used to numerically evaluate the effectiveness of different shear-reinforcement options in resisting earthquake-induced punching shear.

**Key Words:** Earthquake Retrofit, RC Column, Ductility, Confinement, Flat Slab, Punching Shear, Shear Reinforcement

## 1. INTRODUCTION

Earthquakes all over the world have repeatedly demonstrated their power and catastrophic impact upon man-made structures and urban cities. In such cases, the casualties and damage associated with older buildings, even if designed and constructed using prevailing codes, had been far worse than that for newer buildings which have been designed according to more stringent code requirements. Although updated design and detailing provisions are making building structures safer and more damage tolerant, the stock of older buildings is many times more than the number of newer buildings in most urban cities. These older buildings include the ones being inhabited by a huge majority of the population, as well as several important

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historical buildings that add to the history, heritage and pride of a city and even a nation. In case of serious earthquakes, the only safety option left is for those buildings to be repaired and retrofitted according to modern design provisions.

The seismic retrofitting of a building requires an appreciation for the technical, economic and social aspects of the issue in hand. New innovations and changes in construction and retrofit technologies present added challenge to engineers in selecting a technically, economically and socially acceptable solution.

## 2. SIGNIFICANCE OF PRESENT WORK

In the backdrop of the possible scenario in case of a major earthquake in and around a major city, some urgent countermeasures are necessary. The national building code (BNBC) suggests some detailing measures to improve the seismic behavior (mainly ductility) of new structures, but it is essential to repair and retrofit the large number of existing structures.

Conventional upgrading techniques usually include the addition of existing walls and foundations and strengthening of frames. Most of these techniques often lead to costly consequences such as heavy demolition, lengthy construction time, reconstruction, and occupant relocation. Such expensive, environmentally hostile and intrusive approaches associated with conventional techniques often deter building owners from retrofitting buildings for improved earthquake performance.

Therefore the search for cost-effective and less intrusive seismic retrofit options is an essential element of earthquake resistant design. This is particularly true for RC columns and flat slabs, which are two of the main sources of seismic vulnerability of RC buildings. They have been the reasons of poor performance of RC structures all over the world.

The main purpose of the present work is to evaluate various retrofitting options to increase the strength and ductility of column of existing buildings, and also increase their structural stability by the help of cost-effective options with low cost materials. The necessity for seismic retrofit is even more applicable for the ever-growing number of flat-slab structures, whose behavior during past earthquakes had been quite unsatisfactory. The present work also evaluates the earthquake-resistant behavior of flat slabs with two different types of shear reinforcements (e.g., vertical bars and shear studs) as per ACI codes.

The following steps are followed for this purpose

* Develop various cost-effective options to confine RC columns to improve their ductility and strength. These include nylon wires, scotch tapes, straps, tin sheets, plastic mesh and steel rings.
* Test the effectiveness of these options in the laboratory by using them for concrete cylinders and subjecting them to compressive tests. This would include a comparative study of the various options with the ‘no-confinement’ option.

* Use a known flat-slab building from previous studies to numerically evaluate the effectiveness of different shear-reinforcement options, including vertical bars and shear studs.

## 3. SEISMIC RETROFIT OPTIONS

Seismic retrofitting is to upgrade the earthquake resistance of the structure up to the level of current building code provisions by appropriate techniques. The concepts of retrofitting include repairing and remolding, thereby upgrading of the structural system to improve the performance, function or appearance.

### 3.1. Retrofit Options for Beam-Column Systems

There are two general types of earthquake retrofitting strategies available for RC structures; i.e., global strategies, modifying the overall behavior of the entire structures, and local strategies that improve the member properties making them better prepared to withstand the internal forces and deformations. The global strategies include addition of shear wall, infill wall, wing wall, bracing, wall thickening, mass reduction, supplemental damping, base isolation, while local strategies include jacketing of beams, columns, beam-column joints, strengthening of individual footings.

Since this particular work focuses more on the ductility of RC columns, and some confining options are used to improve its ductility and strength, a brief outline of the effect of lateral reinforcements on column ductility is provided. Confinement is one of the most important features influencing the seismic behavior of Reinforced Concrete. It refers to the favorable effect on ductility and strength that lateral reinforcement (in the form of hoops or spirals) has on concrete. Several workers have demonstrated the significant increase in the ductility and strength of concrete by confining the compressive zone with closely spaced lateral steel.

The importance of enhancing the ductility capacity of RC sections became well known after the 1971 San Fernando earthquake. Kent and Park [1] developed a stress-strain model of concrete accounting for the effect of lateral confinement, which was followed by thorough research on confinement effect on concrete properties. Among them, the works by Sheikh & Khoury [2], Cusson & Paultre [3], Bayrak [4] are mentioned here as more recent references. This particular work was also inspired by works by Foster [5], Kuang & Wong [6], Bhattacharya [7], Li et al. [8], Chapman & Driver [9], Husen & Pul [10], Benzaid et al. [11].

Despite growing awareness about the risk of a possible major earthquake around a major city, provisions of seismic repair and retrofit are known very little and practiced even less by the structural designers of Bangladesh. This paper is based on work by Das [12], which is the second of its kind at The University of Asia Pacific (UAP) following on a work on concrete cylinder (confined by steel rings) and RC beams by Akand [13].

### 3.2. Retrofit Options for Flat Slabs

Different measures can be used in flat plate slab to increase shear resistance capacity to survive the shear demand that comes from earthquake. Some of them constitute increasing the slab thickness around the punching shear area (e.g., Drop Panel, Column Capital), while others are shear reinforcements in the slabs like in a similar ways as RC beams. This work concentrates on two shear reinforcement options for this purpose; e.g., vertical bars and shear stud reinforcement. Several alternatives to increase shear capacity at the critical section have been suggested by Ghali & Hammill [14], Joint ACI-ASCE Committee [15], Megally & Ghali [16], Ebead & Marzouk [17], Bai [18], El-Salakawy et al. [19], Youakim & Ghali [20] and more recently by Broms [21]. However, neither the *Bangladesh National Building Code* [22] nor the *Earthquake Resistant Design Manual* by Bangladesh Earthquake Society [23] refers to these design options.

## 4. EXPERIMENTAL SETUP

The experimental works consist of confining a number of concrete cylinders (of 6″-diameter and 12″-height) with various metallic and non-metallic options and testing them for ultimate compressive strengths ($f_c'$) and crushing strains ($\varepsilon_{ult}$). Figs. 1(a)~(f) show the crushing of cylinders using non-metallic confining options, including 2-and 3-layers of Nylon Wire [Figs. 1(a), (b), (c)], Scotch Tape [Fig. 1(d)], Strap [Fig. 1(e)] and Plastic mesh [Fig. 1(f)], while Figs. 2(a)~(f) show similar pictures for metallic confinement; i.e., various layers of tin [Figs. 2(a)~(c)] as well as Steel Rings of 8-mm diameter and 1″ width [Figs. 2(d)~2(f)].

### 4.1. Experimental Results

Tables 1~4 show the results from the experiments narrated before. Four sets of results (of ultimate strength and crushing strain) are presented for the tests done in four phases. Table 1 shows the results for Set 1, i.e., the improvements achieved by 3 samples of Nylon Wires (2- and 3-layers), Scotch Tape and Strap. Among them, the improvements in ductility (increase of 92%, 55% and 73%) for the 3-layer Nylon, Scotch Tape and Strap are most significant.

Table 1: Ultimate Strength and Strain of Cylinder Tests (Set 1)

| | Open | | 2-Layer Nylon | | 3-Layer Nylon | | Scotch Tape | | Strap | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) |
| Avg | 1772 | 4.79 | 2003 | 4.87 | 1891 | 9.19 | 1844 | 7.41 | 2042 | 8.31 |
| Ratio | 1.00 | 1.00 | 1.13 | 1.02 | 1.07 | 1.92 | 1.04 | 1.55 | 1.15 | 1.73 |

Table 2 shows the results for test data Set 2, i.e., for 3-layers of Tin, Full Tin, Plastic Mesh and 3- layers of 8-mm Steel Rings. The increase in ductility is quite encouraging for almost all the cases (varying from 50% to 148% increase). However the effects of Full Tin and Plastic Mesh could not be properly measured, as the strain gauges could not touch the concrete surface. Therefore, these options were discarded after only one test, but the increase in strength seems to suggest their suitability.

Table 2: Ultimate Strength and Strain of Cylinder Tests (Set 2)

| | Open | | 3-0.5″ Layer Tin | | 11″ Width Tin | | Full Tin | Full Mesh | 3-Layer 8mm Ring | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $f_c'$ (psi) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) |
| Avg | 2140 | 3.57 | 3210 | 6.89 | 2386 | 7.11 | 3229 | 2412 | 2386 | 8.86 |
| Ratio | 1.00 | 1.00 | 1.50 | 1.93 | 1.11 | 1.99 | 1.51 | 1.13 | 1.11 | 2.48 |

(a) 2-layer Nylon wire (b) and (c) 3-layer Nylon wire

(d) Scotch tape (e) Strap (f) Plastic mesh

Fig. 1: Crushing of cylinders confined with non-metallic options

Tests 3 and 4 were performed to observe the prospects of promising retrofitting options more closely, using 6 cylinder tests each for every option. Table 3 shows the results for test data Set 3, i.e., for 3-layers of Nylon Wire and Scotch Tape. The improvements due to Nylon Wire seem much less this time (only 20% in strength and 6% ductility) while the improvements for Scotch Tape (17% in strength and 58% in ductility) is more significant.

Table 3: Ultimate Strength and Strain of Cylinder Tests (Set 3)

| | Open | | 3-Layer Nylon | | Scotch Tape | |
|---|---|---|---|---|---|---|
| Sample | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) |
| Avg | 1883 | 3.79 | 2264 | 4.02 | 2198 | 5.97 |
| Ratio | 1.00 | 1.00 | 1.20 | 1.06 | 1.17 | 1.58 |

(a) 3-0.5″ layer tin (b) 3-3.5″ layer tin (c) Full tin

(d) and (e) 3-layer 8mm ring (f) 3-layer 1″ ring

Fig. 2: Crushing of cylinders confined with metallic options

Table 4 shows the results for test data Set 4, which are a repeat of the tests performed on Tin Layers, as well as Steel Rings of 8-mm diameter and 1″ width. The improvements achieved by them are all significant; particularly the wide Tin and Steel Rings increase the ductility to more than six times their original values. The 80% increase of ductility achieved by 8-mm Steel Rings is also very encouraging.

Table 4: Ultimate Strength and Strain of Cylinder Tests (Set 4)

| | Open | | 3-3.5″ Layer Tin | | 3-Layer 8mm Ring | | 3-Layer 1″ Ring | |
|---|---|---|---|---|---|---|---|---|
| Sample | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) | $f_c'$ (psi) | $\varepsilon_{ult}$ ($10^{-3}$) |
| Avg | 1945 | 2.52 | 2272 | 15.87 | 2529 | 4.54 | 2482 | 15.58 |
| Ratio | 1.00 | 1.00 | 1.17 | 6.30 | 1.30 | 1.80 | 1.28 | 6.18 |

### 4.2. Numerical Results of Shear Reinforcement Design

#### 4.2.1. Structural and Material Properties

The structural models used in this work are the 6-, 12- and 24-storied residential buildings designed by Hossen [24] and Islam [25], with the structural layout plan shown in Fig. 3. The plan is quite regular in shape and column lines, and is chosen mainly to conform to the *Direct Design Method* used for subsequent vertical load analysis. No Drop Panel, Column Capital or shear reinforcements are used in order to study the behavior of ordinary flat plates.

The slab thickness is chosen equal to 8-in, while the floor is designed to carry typical loads like Floor Finish = 20 psf, Random Wall = 100 psf and Live Load = 40 psf. The reason for such high random wall load on the floor is because of the absence of any beam. The assumed ultimate compressive strength of concrete $f_c'$ = 3 ksi, tensile strength of concrete $f_t$ = 300 psi, yield strength of steel $f_y$ = 50 ksi, elasticity modulus of steel $E_s$ = 29,000 ksi. The Kent & Park model [1] for concrete and elastic-fully-plastic model for steel are used to derive the Moment vs. Curvature (or $M$-$\phi$) relationship for the slab and column sections. The strain at ultimate strength of concrete ($\varepsilon_0$) and the maximum crushing strain ($\varepsilon_u$) are assumed to be 0.002 and 0.0045 respectively.

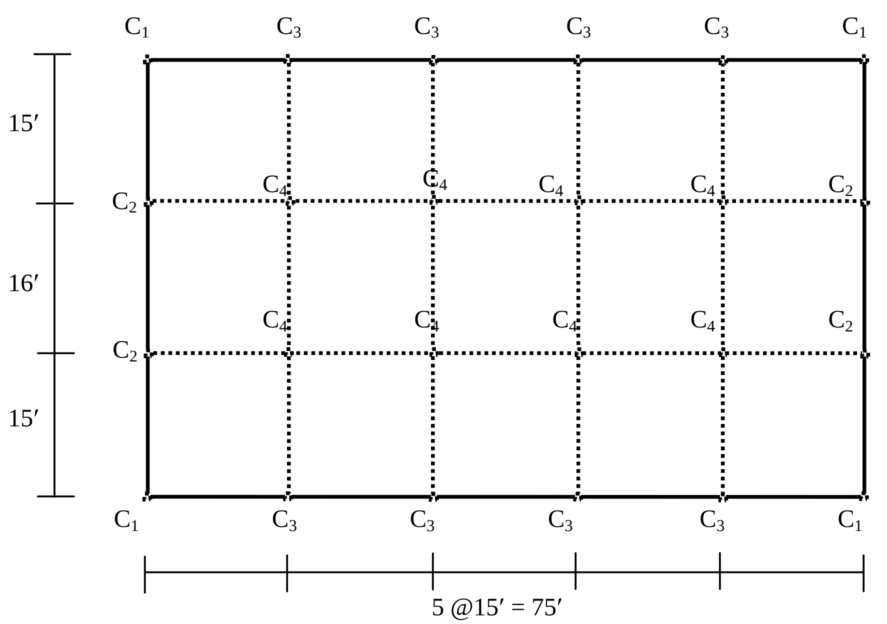


Fig. 3: Building Layout Plan (Hossen 2009)

#### 4.2.2. Design Results

Various strips of the slab around the columns (Column Strips B0 and B- in the long direction, D0 and D- in short direction) are reinforced with vertical shear reinforcement and shear stud. Two-legged #3 vertical stirrups and #4 shear studs are used in four directions around the columns. The punching shear forces calculated for the El Centro earthquake (1940) in Islam [25] are also used in this work for the reinforcement design. The design results are presented in Tables 6 (for vertical stirrups) and 7 (shear studs). They show that a uniform spacing of 3.5″ is adequate for vertical stirrups while shear studs are to be spaced at 4.5″ c/c.

Table 6: Design with Vertical Stirrups

| Stories | Slab Strip | Column | Size $c$ (in) | Shear Force | | | | Stirrup Spacing | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_u$ (kip) | $\phi V_{max}$ (kip) | $\phi V_p$ (kip) | $\phi V_c$ (kip) | $S_{req}$ (in) | $S$ (in) |
| 6 | B0 | $C2_{06}$ | 12.00 | 42.77 | 70.39 | 46.93 | 23.46 | 13.6 | 3.5 |
| | B- | $C4_{06}$ | 15.00 | 86.16 | 76.26 | 50.84 | 25.42 | 4.3 | 3.5 |
| | D0 | $C3_{06}$ | 12.00 | 41.36 | 70.39 | 46.93 | 23.46 | 14.6 | 3.5 |
| | D- | $C4_{06}$ | 15.00 | 86.16 | 76.26 | 50.84 | 25.42 | 4.3 | 3.5 |
| 12 | B0 | $C2_{12}$ | 15.00 | 42.45 | 76.26 | 50.84 | 25.42 | 15.4 | 3.5 |
| | B- | $C4_{12}$ | 21.00 | 85.37 | 87.99 | 58.66 | 29.33 | 4.7 | 3.5 |
| | D0 | $C3_{12}$ | 15.00 | 41.04 | 76.26 | 50.84 | 25.42 | 16.8 | 3.5 |
| | D- | $C4_{12}$ | 21.00 | 85.37 | 87.99 | 58.66 | 29.33 | 4.7 | 3.5 |
| 24 | B0 | $C2_{24}$ | 21.00 | 41.66 | 87.99 | 58.66 | 29.33 | 21.2 | 3.5 |
| | B- | $C4_{24}$ | 30.00 | 83.85 | 105.59 | 70.39 | 35.20 | 5.4 | 3.5 |
| | D0 | $C3_{24}$ | 21.00 | 40.25 | 87.99 | 58.66 | 29.33 | 24.0 | 3.5 |
| | D- | $C4_{24}$ | 30.00 | 83.85 | 105.59 | 70.39 | 35.20 | 5.4 | 3.5 |

Table 7: Design with Shear Studs

| Stories | Slab Strip | Column | Size $c$ (in) | Shear Force | | | Stud Spacing | |
|---|---|---|---|---|---|---|---|---|
| | | | | $V_u$ (kip) | $\phi V_{max}$ (kip) | $\phi V_c$ (kip) | $S_{req}$ (in) | $S$ (in) |
| 6 | B0 | $C2_{06}$ | 12.00 | 42.77 | 93.86 | 35.20 | 30.8 | 4.5 |
| | B- | $C4_{06}$ | 15.00 | 86.16 | 101.68 | 38.13 | 4.9 | 4.5 |
| | D0 | $C3_{06}$ | 12.00 | 41.36 | 93.86 | 35.20 | 37.9 | 4.5 |
| | D- | $C4_{06}$ | 15.00 | 86.16 | 101.68 | 38.13 | 4.9 | 4.5 |
| 12 | B0 | $C2_{12}$ | 15.00 | 42.45 | 101.68 | 38.13 | 54.0 | 4.5 |
| | B- | $C4_{12}$ | 21.00 | 85.37 | 117.32 | 44.00 | 5.6 | 4.5 |
| | D0 | $C3_{12}$ | 15.00 | 41.04 | 101.68 | 38.13 | 80.2 | 4.5 |
| | D- | $C4_{12}$ | 21.00 | 85.37 | 117.32 | 44.00 | 5.6 | 4.5 |
| 24 | B0 | $C2_{24}$ | 21.00 | 41.66 | 117.32 | 44.00 | -100.0 | 4.5 |
| | B- | $C4_{24}$ | 30.00 | 83.85 | 140.79 | 52.79 | 7.5 | 4.5 |
| | D0 | $C3_{24}$ | 21.00 | 40.25 | 117.32 | 44.00 | -62.3 | 4.5 |
| | D- | $C4_{24}$ | 30.00 | 83.85 | 140.79 | 52.79 | 7.5 | 4.5 |

## 5. CONCLUSION

The main conclusions of this work are

* All confining options used here including non-metallic options like nylon wire, scotch tape, strap, plastic mesh increased the ductility and strength of concrete. However, the options with scotch tape and straps were found to be most effective.
* 'Metallic' options (tin sheet, steel rod, and steel sheet) increased the ductility and strength more significantly. In fact for one set of experiments, the wide rings (made of tin or steel)

were found to increase the ductility of concrete to more than six times their original (unconfined) values.

* For the buildings studied (6-, 12- and 24-storied), both retrofit options of flat slab (vertical bars and shear stud) proved adequate in resisting the ultimate punching shear that is induced by a major earthquake (El Centro 1940). Two-legged vertical stirrups of #3 bars used in all four directions around columns were required at 3.5″ spacing, while 4.5″ spacing of #4 shear studs (also in all four directions) were also found adequate.

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# STUDY OF SURFACE WATER POLLUTION IN COASTAL REGION OF BANGLADESH

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## ABSTRACT

This paper deals with analysis of surface water pollution in terms of BOD and DO of Chittagong city. The measured values of pollution parameters were compared with the permissible values in order to estimate the extent of pollution. The BOD and DO levels for the water samples collected from 13 different locations at Chittagong along the Karnafuli River and connected Khals were analyzed and show that it varies from 2.6 mg/l to 74 mg/l. It was also observed that the DO levels in some locations have fallen to 0.1 mg/l, at which level fish and other aquatic organisms cannot survive. The Bangladesh Environment Conservation Act (ECA), 1995 states that the Inland Surface Water Quality Standard for BOD should be below 6-10 mg/liter and DO level should be above 5 mg/liter. According to the Coastal Environment Management Plan, at the normal physical condition of the Karnafuli River the BOD level should not exceed 5 mg/liter if the fisheries have to be survived.

**Key Words:** BOD, DO, surface water pollution, pollution parameters, extent of pollution.

## 1. INTRODUCTION

Bangladesh is situated at the apex of the Bay of Bengal and has a vast coastal plane of more than 47200 sq. km. Coastal zone refers to areas where land and sea meet (Islam, 2004). Coast of Bangladesh covers about 710 km in length and hosts a unique diversity of ecosystems. The population of coastal districts is about 23% of the total population of Bangladesh. The coastal zone is very important for economic, cultural and recreational activities. But due to increased population, industries and economic activities level pollution is also increasing and this in turn is affecting coastal environment and livelihood. The adverse effect of coastal pollution on human lives and environment is directly related not only in the coastal zone itself but also in the inland areas of the country. In order to save our coastal resources and to improve the economic condition of the country, it is necessary to identify the sources and extent of pollution. The study area was selected “Chittagong city” the hub of Bangladesh’s commercial and manufacturing industry. Since Chittagong is situated near the coast, there is the additional problem of coastal pollution from the increased development and industrial activities.

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## 2. SOURCES OF POLLUTION

The marine water of Bangladesh is threatened by pollution that washed down from lands and dumped directly near the coast. Most of the pollution in the form of municipal and industrial wastes, agro-chemical residues and pollutants discharge from ships and boats.

### 2.1. Solid Wastes

Times Like any other big city, Chittagong also generates a huge amount of solid wastes everyday. According to the Chittagong City Corporation, about 1,000 to 1,200 tons of solid wastes are generated in Chittagong per day( Sarkar, 2001) About 75% of this waste is collected and disposed off at two different waste disposal sites. 25% of this collected waste is dumped at Halishahar which is close to the sea and is actually connected to a water channel. Fig. 1 shows Halishahar land fill site. This site is about 2 hectares of land, but the waste is dumped on area of 6 hectares instead. The other 50% of the waste that is collected is dumped at Roufabad on 6.5 hectares of land. It should be noted that the major landfill site of the Chittagong City Corporation is very close to the Bay Bengal. The Total Waste Generation (TWG) in Chittagong urban area is 1,548.09 tons per day and about 70% of this waste is collected (Enayetullah, 2005). Often the waste created by a large number of people that live in slums and dumping of this waste on the bank of rivers and canals are overlooked and their contribution to the waste in urban areas are ignored. A large part of the solid waste is inorganic in nature, for instance, glass and plastic bottles, boxes, wood, metal pieces, Styrofoam etc. However, there is no doubt that a significant part of solid wastes including human wastes directly or indirectly (during rainy season and flood inundation) goes to the river system and then into the marine waters.

### 2.2. Sewage

The situation is becoming more serious due to increase of population in coastal districts and lack of proper sanitation as well as sewage treatment facilities. Since Chittagong metropolitan area does not have any sewage treatment plant, the raw sewage directly drains into the waterways in Chittagong. In fact, none of the coastal cities have any proper sewerage system or sewage treatment plant in place. All the urban cities are supported by septic tank and pit sanitation. Poor households use community latrines. However, these systems are directly or indirectly connected to canals or rivers through surface drains. Fig 2 shows sewage flow to the Bay of Bengal.

### 2.3. Industrial wastes

The major polluting industries such as ship breaking, pulp and paper, sugar, fertilizer, pharmaceuticals, metal, and chemical industries are mostly located in and around the major cities. Some of these are also located on the banks of major rivers and lakes. In fact, Chittagong alone is home to 8 industrial zones. It has been reported that around 720 industrial units and factories are situated on the banks of the river Karnafuli River, 217 of this have been identified as being very polluting and having a tremendous impact on river water quality. Islam (2004) shows that among other industries pulp and paper industry alone contributed about 47% of total water pollution in industrial sectors. Karnafuli Paper Mill

(KPM) releases 0.35 tons of china clay everyday (ADB, 2004). Fig 3 shows liquid waste flow from Chittagong EPZ area to the Bay of Bengal.

**2.4. Ship breaking industries**

Most of the steel in Bangladesh comes from the dismantling of the huge ocean liners at the ship-breaking yards. Vessels from all over the world come to Chittagong ship-breaking yard to be dismantled, due to absence of any sort of environmental laws and regulations. Ship-breaking is a highly toxic and hazardous industry where the scrap workers are exposed to extreme heat, toxic and flammable gases, and dangerous chemicals. Fig 4 shows ship breaking activity in Chittagong.

**2.5. Oil Pollution**

Inefficient systems of oil transfer from vessel to vessel, combined with old equipment and lack of compliance are responsible for wastage of oil and other hydrocarbons used in the dockyards. These wasted oil and polluting substances end up in the rivers and channels, to be washed out to the sea. Fig 5: shows oil spill from boat.

**2.6. Other Sources**

Over 4,520 tons of pesticides are used in the agricultural areas of coastal districts. Of them, 1,130 tons (25%) may reach surface water system as residue/ runoff during rainy season (ESCAP, 1994). Khan (1995) shows Organochlorine pesticide concentration in water of the Bay of Bengal which indicated the presence of Lindane, Aldrine etc. City Corporations playing a vital role in managing the medical wastes in Chittagong. They collect the waste from private clinics and hospitals. Saifiullah (2001). found that about 1090 syringes and needles were disposed of everyday in Chittagong by the City Corporation.

Fig 1: Halishahar landfill site

Fig 2: Sewage flow to the Bay of Bengal

Fig 4: Ship breaking activity in Chittagong

Fig 5: Oil spill from boat

**3. EFFECTS OF POLLUTION**

A large part of the solid waste is inorganic in nature, for instance, glass and plastic bottles, boxes, wood, metal pieces, Styrofoam etc. These often get washed up on to the banks of the waterways and are responsible for the clogging up of the narrow channels. This causes severe problems for marine ecosystem, and an estimated 100,000 marine mammals and turtles die annually worldwide through the ingestion of plastic and other solid waste materials.

Sewage improperly discharged to freshwater and coastal environments presents a variety of problems. The concentration of sewage pollution in the dry season is responsible for the spread of pathogens and diseases. Sewage pollution causes reduction of DO levels and also makes the water of Karnafuli unsuitable for fisheries and planktons to survive and also makes it unsuitable for irrigation, industrial and domestic uses.

Industries also release hydrocarbons in the form of oils and heated waste water (thermal discharges). The amount of these pollutants released and the extent of their damage have not yet been quantified. The water that is used to cool the boilers and other machineries in the industries when release contains chemical coolants. The release of water above normal temperature into river causes thermal pollution that damages the chemical and biological balance of the river. Both oil and heat adversely affects the aquatic organisms like fishes and plants.

Ship-breaking is a highly toxic and hazardous industry where the scrap workers are exposed to extreme heat, toxic and flammable gases, and dangerous chemicals. They dump huge amounts of wastes during the dismantling of ships, along with heavy metals, asbestos fiber and oil from the tankers. Due to ship breaking operation the metal concentration in both water and sediments of Karnafuli River increased considerably which causes adverse effects on fisheries as well as on human lives. Fig 6 : shows fish diseases due to pollution in river.

Fig 6: Fish diseases due to pollution in river

## 4. ANALYSIS OF CURRENT LEVEL OF POLLUTION (IN TERMS OF BOD AND DO)

Contribution of pollutants from different sources polluting the surface water of Chittagong, so it is necessary to have an idea about the present BOD and DO level of water. Among other water quality parameters, BOD and DO level indicates whether this water is safe for its living beings or not. Sampling of water was done in winter season when the condition was worse. Level of BOD and DO of the water samples of Chittagong sites were analyzed and the measured values were compared with permissible values. In Chittagong some locations were selected for water sampling to measure BOD and DO levels. Table1: shows DO and BOD measurements at different points in Chittagong (Date of sampling: 28-02-05) The locations were Naya Rasta Bridge, Chaktai Khal, Noya Hat Tola Bazar Ghat, Before Sadar Ghat (mid river), Fishery Ghat, (mid river) Outlet of EPZ, Karnafuli River Estuary (middle point), Noakhali Khal, Near Municipal Solid Waste Point.

**Table 1**: DO and BOD measurements at different points in Chittagong

| Location No | Name of Location | DO(mg/liter) | | BOD (mg/liter) | |
|---|---|---|---|---|---|
| | | Measured | Permissible Limit | Measured | Permissible Limit |
| 1 | Naya Rasta Bridge | 0.10 | | 40.0 | |
| 2 | Chaktai Khal (up) | 5.20 | | 45.0 | |
| 3 | Chaktai Khal (down) | 4.92 | | 52.0 | |
| 4 | Chaktai Khal (facing Karnaphuli River) | 0.07 | >5.0 | 68.0 | <10.0 |
| 5 | Noya Hat Tola Bazar Ghat | 5.55 | | - | |
| 6 | Before Sadar Ghat (mid river) | 5.95 | | 10.6 | |

**Table 2**: DO and BOD measurements at different points in Chittagong (Continued)

| Location No | Name of Location | DO(mg/liter) | | BOD (mg/liter) | |
|---|---|---|---|---|---|
| | | Measured | Permissible Limit | Measured | Permissible Limit |
| 7 | Fishery Ghat (mid river) | 5.04 | >5.0 | - | <10.0 |
| 8 | Outlet of EPZ | 0.10 | | 74.0 | |
| 9 | Karnafuli River Estuary (middle point) | 6.51 | | 27.0 | |
| 10 | Noakhali Khal (facing) | 4.55 | | 10.0 | |
| 11 | Noakhali Khal (up) | 4.87 | | 2.8 | |
| 12 | Noakhali Khal (down) | 4.44 | | 2.6 | |
| 13 | Near Municipal Solid Waste Point | - | | 15.4 | |

Source: BCAS, 2005

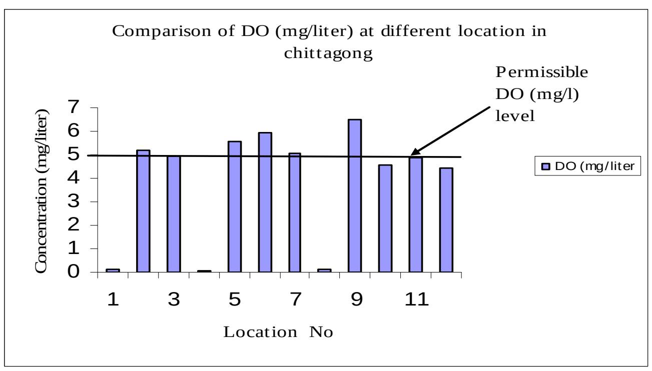


Figure 7: Comparison of DO (mg/l) level

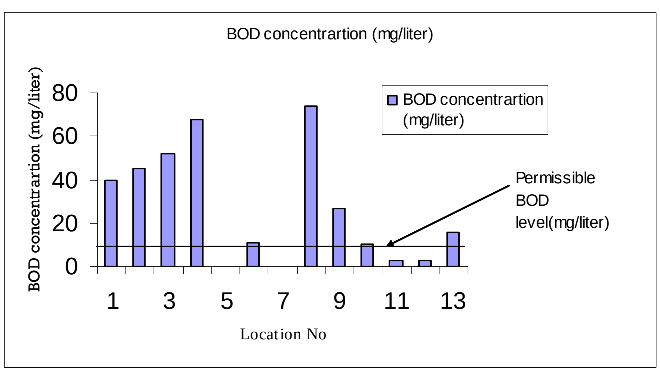


Figure 8: Comparison of BOD (mg/l)

The measured values of DO at the specified locations and the permissible DO levels are shown by a graphical representation in the figure 7. DO levels at Naya Rasta Bridge, Outlet of EPZ and Chaktai Khal are 0.10, 0.10, 0.07 mg/liter respectively which are very much lower than the required value DO 5.0 mg/liter.

The measured values of BOD at the specified locations and the permissible BOD levels are shown by a graphical representation in the figure 8. The measurement of BOD levels at Naya Rasta Bridge, Chaktai Khal (up), Chaktai Khal (down), Chaktai Khal (facing Karnaphuli River), Outlet of EPZ were 40.0, 45.0, 52.0, 68.0, 74.0 mg/liter respectively which are very much higher than the permissible limit of BOD 10.0 mg/liter.

## 5. RESULT AND DISCUSSION

The BOD level calculated from the water samples collected from selected locations in Chittagong shows that it varies from 2.6 mg/l to 74 mg/l. It is also observed that the dissolved oxygen (DO) levels in some locations have fallen to 0.1 mg/l, at which level fish and other aquatic organisms cannot survive. The Bangladesh Environment Conservation Act (ECA), 1995 and Environment Conservation Rules (ECR), 1997 states that the Inland Surface Water Quality Standard for BOD and DO should be 6-10 mg/liter or less and 5 or above mg/liter respectively (ECA 1995). This range refers to water used for industrial and irrigation purposes only. According to the Coastal Environment Management Plan, at the normal physical condition of the Karnafuli River the BOD level should not exceed 5 mg/liter if the fisheries has to be saved. For water used in pisciculture, the BOD and DO levels should range from 6 mg/liter or less and 5mg/liter or more respectively. On the basis of present DO and BOD levels comparison with permissible values in Chittagong, the mostly polluted areas are Naya Rasta Bridge, Chakti Khal ( fetching Karnafuli River), Outlet of EPZ.

Land-based coastal pollution has become an issue that needs immediate action for most of the countries in the world. For a country like Bangladesh, which has limited resources, the problems caused by land based pollution is a matter of concern. Our coastal and marine resources need protection on a priority basis. To protect our limited resources from further degradation, we have to monitor present land-based activities and need to take necessary measures. The study of pollution in major coastal city of Bangladesh has already highlighted the main issues that are responsible for the increasing pollution and degradation of water and other marine environments along the coastal belt.

## 6. SUGGESTION OF REMEDIAL MEASURES

Based on the analysis of present condition of pollution in the major coastal city Chittagong the following recommendations are given to improve the condition.

a) Solid waste should be disposed properly in the land fill sites located at safe distance away from natural water bodies of the exposed coastal cities.

b) Installation of industrial effluent treatment plants in the coastal cities.

c) Oil spill need to be properly contained and treated for disposal.

d) Relocation of hazardous industries such as ship-breaking industries from coastal areas.

e) Suitable monitoring systems should be developed and test of water samples to provide valuable information for taking preventive measures.

f) Awareness and training programmes for farmers, industrial and municipal workers.

g) Strict enforcement of existing environmental, agricultural, industrial and water resource management laws, policies and guidelines.

h) Implementation of Integrated Coastal Zone Management Plan (ICZMP), Coastal Development Strategy (CDS) and Coastal Zone Policy.

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# A STUDY ON AWARENESS LEVEL ABOUT FIRE HAZARDS AT HIGH-RISE BUILDINGS IN DHAKA CITY

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## ABSTRACT

Incident associated with fire is a common phenomenon in Bangladesh especially at densely populated Dhaka city. Urban fires have devastating impact on communities. Recently some grievous fire incidences in high-rise buildings have been experienced and fire engulfed lot of lives and properties. These incidents stimulate to conduct a detailed study on awareness about fire in high rise buildings of Dhaka city. For this study a questionnaire survey has been conducting to check the existing level of awareness and residents' evacuation plan. To have overall scenario regarding fire safety, 5% buildings (include residential, commercial, garments and institutional etc.) have been surveyed from 12 zones and all of them are above 8 stories. Study has been showed that 70% of total respondents know about severity of fire but only a little number of respondents has any evacuation plan about fire incidents. Among all the surveyed buildings, only 11 buildings have trained personnel and only 16 buildings which include garments and commercial building perform fire drill regularly. The respondents were asked about their evacuation plan during the fire incidence but only few people have their evacuation plan. Although the sample size was small, it represents the miserable condition of awareness level among the residents' of Dhaka city.

**Key Words:** Fire, Fire Hazards, High-rise buildings, Dhaka City, Colossal losses, Awareness level, Evacuation plan

## 1. INTRODUCTION

A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire. Urban fires have devastating impact on communities. Unplanned urbanization and rapid industrialization are the major causes of huge number of fire related accidents in Dhaka city and increase the vulnerability of the country's major population and economic centers. Dense building concentrations, narrow roads, flammable building materials and electrical system as well as the lack of resources to raise awareness and response skills have resulted in a growing risk of large scale, multiple structure fires.

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Fire incidents are very common in Dhaka city, especially in relatively densely populated areas. The damage of property and loss of human life are intensified by different factors. The extent of loss due to fire incidents has an increasing trend. The highest 3334 accidents took place in 2006, 2787 in 2005 and 2522 in 2004. [1] (See Figure 1).

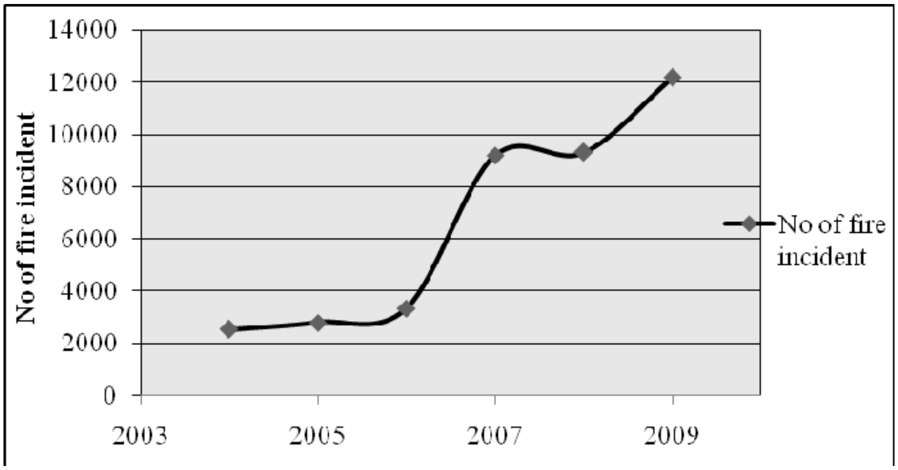



Figure 1: Trends of fire incident in Bangladesh (The New Age, 2009)

A developing country like Bangladesh cannot afford the huge amount of loss caused by fire accidents every year. Moreover, fire incidents in shops, industrial and commercial buildings cause heavy toll of life and property. The fire incidents are on an increase due to lack of awareness, almost no feeling for following safety measures and practicing fire fighting drills, violation of building codes[2] and non- compliance with the Fire fighting and Extinguishing Law [3]. Some recent flagitious fire incidents in Dhaka city have stimulated a detailed study on high rise buildings about fire safety and awareness. This study depicts an overview on awareness level among the occupants of high rise buildings in Dhaka city.

## 2. MAJOR CAUSES OF FIRE INCIDENT IN BANGLADESH

Common Causes of fire are smoking, welding or cutting operation and use of blow lamps, sparks from power unit, short circuit and over loading of electrical current, children playing with crackers, ignition by chemical action/spontaneous combustion, gross carelessness, malicious, deliberate during riot or strike, lightening, earthquake etc (see Figure 2). Fire at garments is very common in Bangladesh, major fire incidents take place due to unplanned construction of buildings being used by garment factory owners. Most of the buildings did not follow the building code and lacked arrangements for alternative staircases and emergency exits and firefighting equipment. Keeping collapsible gates under lock and key in the name of security is the main cause of increases casualties in the incidents. According to the statistics, the major accidents occurred due to electric shot circuits.

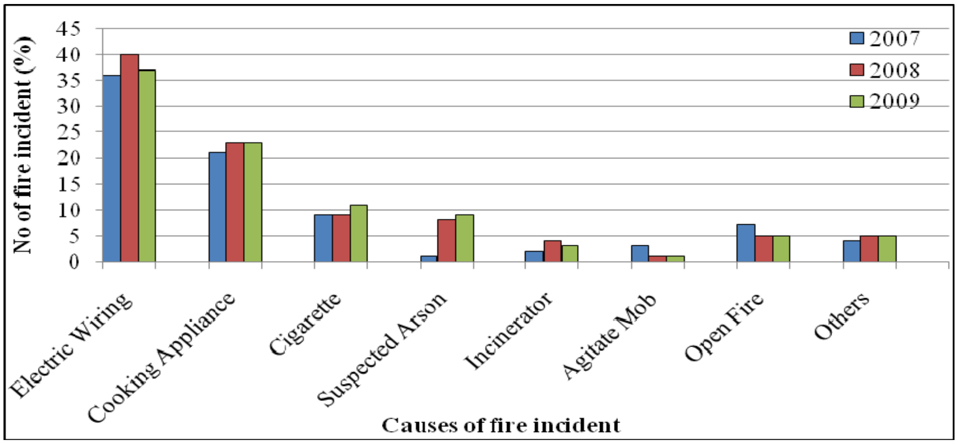



Figure 2: Causes of fire incident in Bangladesh

High-rise buildings now being constructed in different parts of the city is in lack of the minimum safety features and endangers both adjoining structures and public thoroughfares. Many of the high-rises have been constructed without proper planning, ensuring adequate structural strength, without taking the proper safety measures and considering environmental factor. Fire in BSEC Bhaban, in Bashundhara City and in Nimtoli at Old Dhaka prove the severity of fire incident in Dhaka City.

## 3. AWARENESS ABOUT FIRE HAZARDS

For the evaluation of awareness level among occupants of Dhaka city a questionnaire survey was conducted to assess the existing condition of awareness level of the respondent and their evacuation plan during fire catch up. To have overall scenario regarding fire safety, 2.5% buildings (includes residential, commercial, garments and institutional etc.) of 2150 (according to Dhaka City Corporation, total no. of high rise building) has been surveyed from 9 zones (Department of Fire Service and Civil Defense divided Dhaka City into 12 zones) and most of them are above 8 storied (see Map1). Figure 3 and Figure 4 show number of study buildings and existing use of the buildings in percentage respectively. 64% and 80% of total respondents know about earthquake and fire respectively but only a little number of respondents has any evacuation plan about fire incidents.

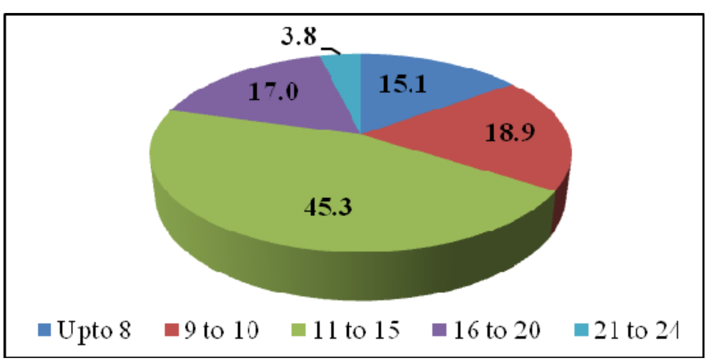



Figure 3: Number of study buildings by storey (in %)

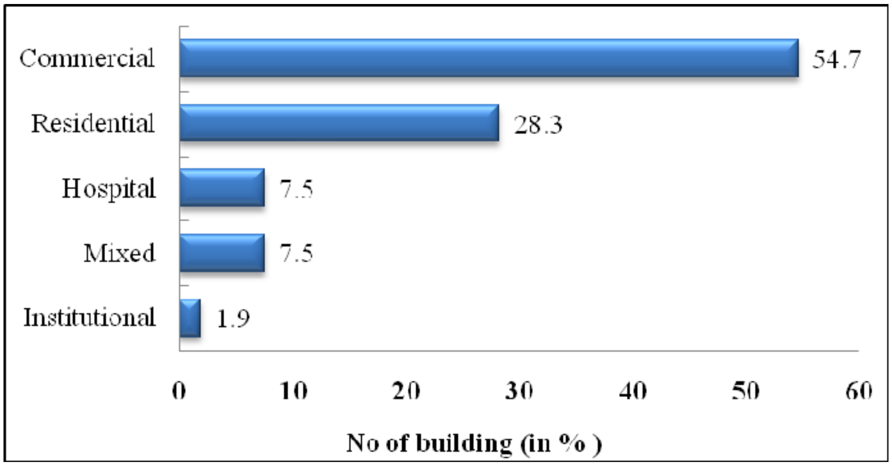
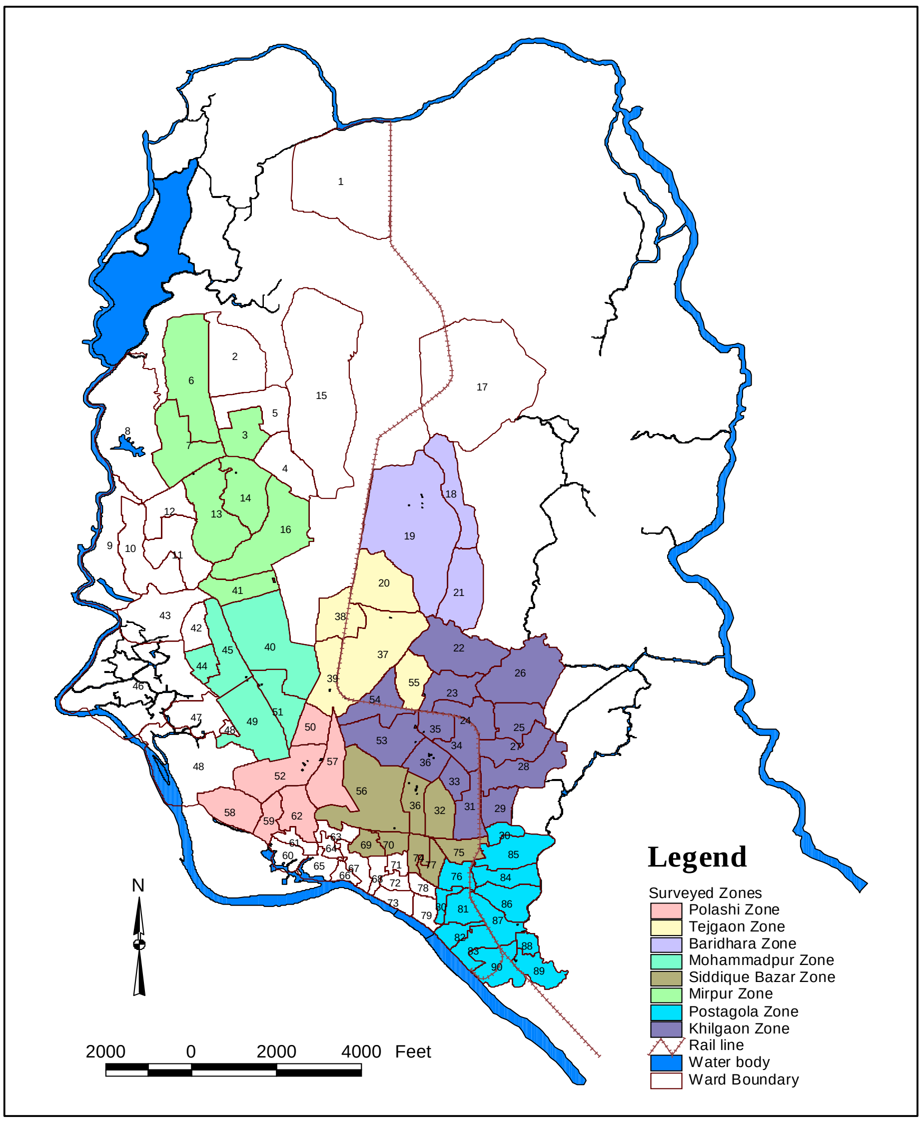



Figure 4: Use type of high rise building




Map 1: Study Area within Dhaka City

Study has been showed that 70% of total respondents know about severity of fire but only a little number of respondents has any evacuation plan about fire incidents (See figure 5).

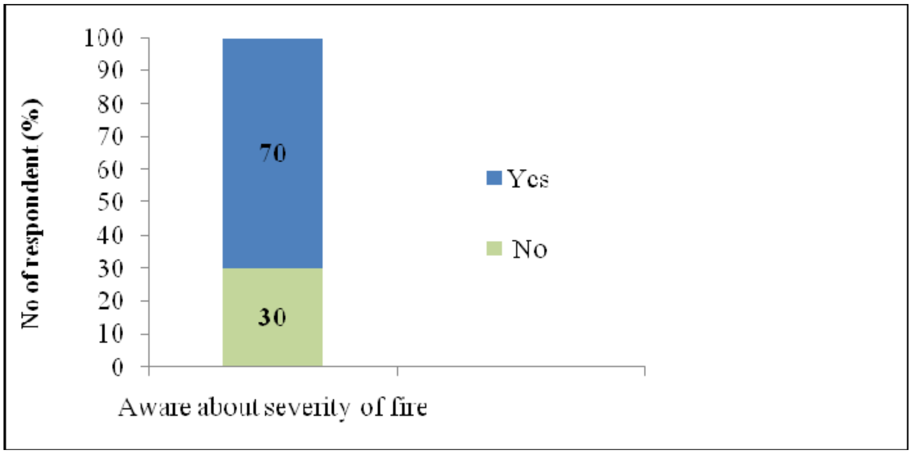



Figure 5: Aware about severity of fire

About 38% and 48% of respondent discuss about fire severity, fire evacuation plan, fire training with family member and community people respectively (See figure 6). Among all the surveyed buildings, only 11 buildings have trained personnel and only 16 buildings which include garments and commercial building perform fire drill regularly. Most surveyed garments workers were trained by Bangladesh Garment Manufacturers and Exporters Association (BGMEA). Usually they provide lectures, taken exam and lastly done evacuation drill in the premises of garments. In the surveyed commercial buildings which have trained personnel got training related to operation of hose reel and fire extinguisher and evacuation drill from Bangladesh Fire Service and Civil Defense. Mainly security guard and few care takers of the building have this training. The respondents were asked about their evacuation plan during the fire incidence but only few people i.e. 13% of total respondents have their evacuation plan. Evacuation plan consists use of firefighting equipment what they have, escape from the building through emergency exit and taking shelter in ground floor or any available open space adjacent to the building.

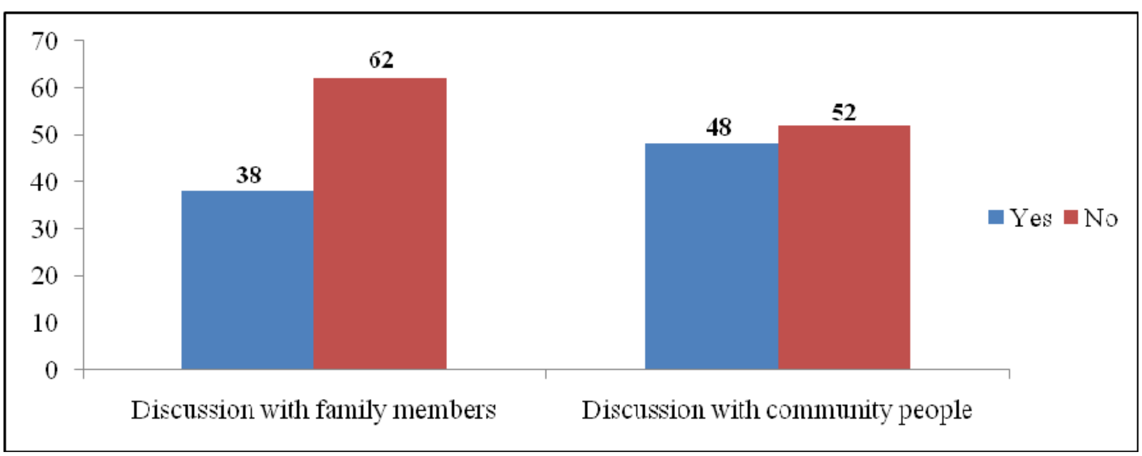



Figure 6: Aware about severity of fire

More than 49% buildings don’t have any emergency exit stair. In addition, exit signals for escape route are provided improperly and inadequately which poses a threat to the evacuation. In most of the cases escape routes remain blocked.

## 6. CONCLUSION

After analyzing a considerable amount of highrise building information in Dhaka city, it can be said that the overall condition of buildings are not suitable for fire fighting. People have ignorance about fire incident and they are not aware of this kind of accident. This study was not conducted on a large number of building samples. Although the sample size was small, it represents the miserable condition of Dhaka city buildings to fire hazards. For improving the condition, awareness of people should be increased. To create public awareness, workshops and seminars may be arranged. Electronic and printing media can play an important role for increasing awareness. A pragmatic fire safety plan may be developed for all the buildings with the help of Bangladesh Fire Service department. This study will help to understand the present scenario of Dhaka City in respect to awareness about fire and to take necessary steps for increasing awareness.

## 7. ACKNOWLEDGEMENT

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# ENVIRONMENTAL IMPACT ASSESSMENT FOR RURAL COMMUNITY INFRASTRUCTURE OF CHAR AREA (TUBEWELL, LATRINE, EVACUATION ROUTE): A CASE STUDY OF KURIGRAM DISTRICT

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## ABSTRACT

It is true that natural disaster like flood, river erosion, drought and monga are the common phenomena deviously annoying economy of Bangladesh especially on the northern districts. On the other hands these disasters are the main cause to lagging behind to development that yet not scourge to poverty. In that consequences, NGOs has been implemented many Community Infrastructure (Tube well, Latrine and Evacuation Route) in Northern part of Bangladesh. RDRS Bangladesh has started its journey of the project "Alleviating Poverty through Disaster Risk Reduction in North West Bangladesh". Under this project RDRS will be install 1000 tube wells, latrines and construct few numbers of evacuation route not more than 5km (total length 20km).

It can be observed from the matrix that major environmental components will be adversely affected by evacuation route are physio-chemical/ecological and will be positively affected its quality of life. From the water quality data of the study area suggested that water quality is good considering all parameter of water quality. In addition, installation of tube well and latrines created positive impact except ground water leaching. There will be a possibility to use topsoil during earth work (cutting and filling) of the evacuation route. However, it creates employment opportunity in transportation sector. It also creates opportunity to get services of education, health, transportation, crops harvesting, flood shelter etc. Moreover, installation of tube well/latrines provides safe drinking water and hygiene sanitation facilities. It improves the health condition of the local community. Increase health condition and income will helps to maintain better standard of life Mitigation measures can help to reduce and offset negative impacts and thereby enhance net positive benefit of the project. The road side plantation can give a high opportunity to reduce the environmental degradation of the area.

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Grass roofing of the route could ensure the management of soil erosion. Dust blowing from unpaved road during construction can cause health hazards due to dust pollution and cause damage to vegetation and trees along the road. Dust pollution can be reduced by controlling moisture content during construction by watering and providing vegetative cover on route surface and slope. Latrine should be constructed at least 30 feet far from the tube well to reduce ground water leaching.

**Key Words:** Environmental Impact Assessment, Community Infrastructure, Tube well, Latrine, Evacuation Route, Mitigation measures**.**

## 1. INTRODUCTION

### 1.1 Background

Bangladesh is a low-lying country comprising mainly the floodplain delta of the three major rivers, the Ganges, the Brahmaputra and the Meghna which originated outside of the country and meet inside before discharging to the Bay of Bengal through a single outfall. Floodplains occupy 80% of the country (Brammer, 1997). It has a tropical monsoon climate. About 44.7% populations are landless and below the poverty line (ADB, 2003). Apart from many other causes to poverty merely the dire cause of disaster is one of the most potential and prominent cause to set back to development. It is true that natural disaster like flood, river erosion, drought and monga are the common phenomena unscrupulously aggravating economy of especially northern districts of Bangladesh.

The environmental aspects of development activities must be taken into consideration and due attention must be paid to protect the environment. The first step in this direction is to evaluate the probable impacts of the project on the surrounding environment so that suitable measures could be taken during early stages of the project to minimize negative impacts. In the recent years there has been a remarkable growth of interest in the environmental issues in sustainability and better management of development in harmony with the nature. Associated with this interest, there has an introduction of new legislation that seeks to influence the relationship between the development and environment. Environmental Impact Assessment (EIA) is an import example of it. EIA is a policy and management tool for planning and decision making that conceived in the 1970s after the United Nations Conference on the environment in Stockholm. CARE Bangladesh initiated Environmental Impact Assessment in Bangladesh early Nineties in the rural road development project (Khan and Fitzcharies, 1998). The EIA methodology are prepared in this study based on the procedures described in EIA guidelines for industrial units published by DoE and provided in the ADB and WB manuals relating to IEE/EIA studies.

### 1.2 Objectives of the Present Study

The specific objectives of the study are to carry out Environmental Impact Assessment of Community Infrastructures on installation of flood resilient hygienic latrines and tube wells, construction of evacuation route as well as provide scientific recommendation to consider postulates of the study as one of the mandatory preconditions for sound environment friendly sustainable development initiations.

### 1.3 Description of the project area

The project will be implemented in the char area of Kurigram district namely Nama char, Joatindra Narayan and Shaka hathir char. The char area including the entire region of Kurigram district is considered to be the most neglected and deprived region of the country and excluded from mainstream development. The specific locations of evacuation route, tube wells and latrines are shown in Figure 1.

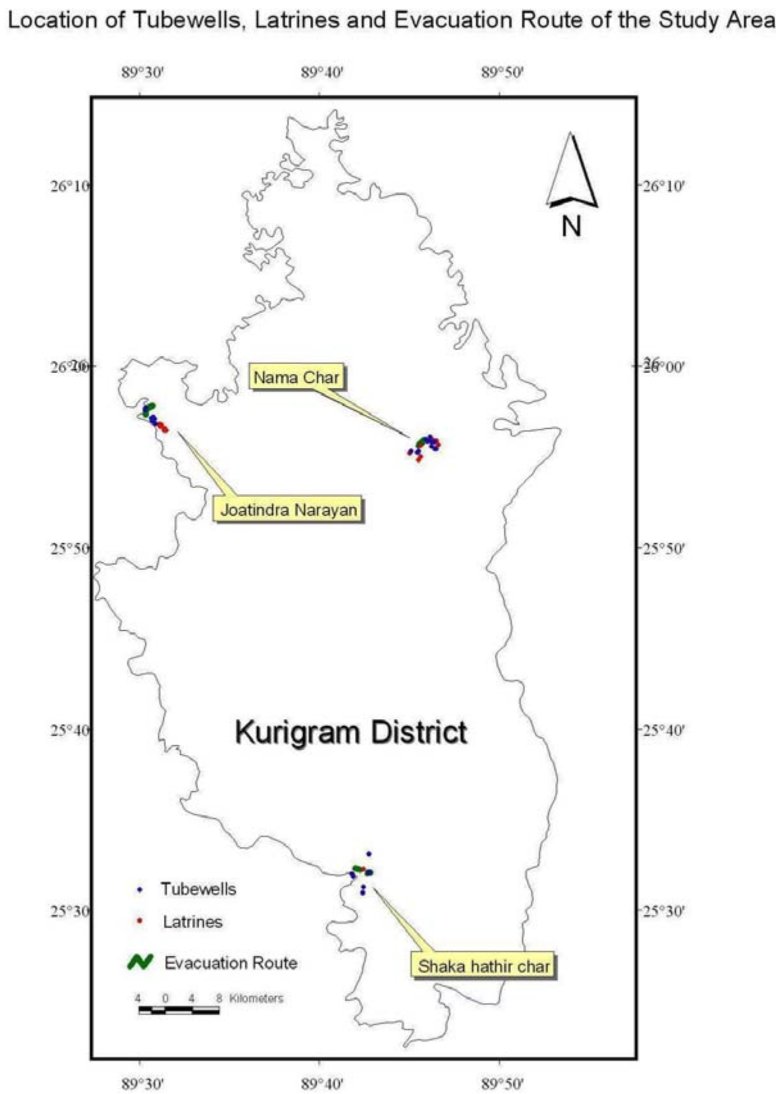


**Figure 1: Location of Tube wells, Latrines and Evacuation route of the study area**

## 2. METHODOLOGY

Local people's participation in the study process has been ensured by using Participatory Rural Appraisal (PRA) tools like Transect Work, Focus Group Discussion (FGD) of different male/female groups consists of beneficiaries, village disaster management committee (VDMC), Upazila disaster management committee (UDMC) and Local Leaders. The Key Informants were school teacher, Tube well Technicians, Local UP member. This interdisciplinary approach enables to gain in-depth understanding of the issues raised through the PRA practices.

Some physical and bio-chemical parameters of water were measured at the sampling sites during the period of sampling of water, and then brought to the laboratory for further chemical analysis. Collected data such as location of tube well, latrines, evacuation road are identified by Global Positioning System (GPS) from field surveys is processed by using Path Finder Software, and then projected in Bangladesh Transverse Mercator (BTM) projection.
All secondary data and information's were collected from different Government and Non-Government Organizations. The findings of the SEIA of this project had resulted in the identification and prediction of quite a number of key issues have been further studied and evaluated during the preparation of this EIA Report. Acting upon the collected data and information, identification, prediction and evaluation of likely significant impacts, their origin and potential extent arising from the project implementation have been determined using the 'Checklist and Matrix Method'. Thereafter, possible mitigation measures have been identified and on the basis of findings of impact appraisal comprising the key elements embodied in this EIA study.

## 3. BASE LINE ENVIRONMENTAL CONDITION

### 3.1 Physical Environment

In the present study the different environmental components examined for setting baseline conditions of the project areas are physico-chemical, biological and socio-economical. In physico-chemical component, parameters included are land, water quality, air quality, climate and noise.

#### 3.1.1 Land Conditions

The land as a whole has a gentle topography with a moderate slope of about 0.2 m per kilometer from northwest to southeast (FAP 2, 1993). There are occasional undulation with irregular relief due to low pockets, gulley and depressions. There are several defined channels in the district which are draining the local monsoon runoff. Land elevations ranges from about 21.9 m, PWD to 33.0 m, PWD with an average of about 24.8 m PWD (FAP 2, 1993). About 42% of the land of Kurigram district lies below the average ground level.

The stratatigraphy of the Permian Gondwana basins in the north-western part of the country was given by various authors (Ahmed and Zaher, 1963, 1965; Islam et al. 1987; Alam et al., 1990; Zaher and Islam, 1975). Alam et al. (1990) give a detailed description of the lithology and depositional models of the Barapukuria basin.The Khalaspir basin area is more or less plain land covered by Barind Clay Residuum and Alluvium. On the basis of drill whole data, the stratigraphic sequence of the area are divided into four major divisions which are correlated with four groups or formation of India and Bangladesh. These are Gondwana Group, Surma Group, Dupi Tila Formation and Barind Clay Residuum and Alluvium of Premian, Miocine, Pliocene, Pleistocene and Holocene ages respectively (GSB, 1992).

Kurigram district is generally classified into two major parts in respect of soil condition. These are Kiar (Barind tract) and Poli (alluvium). The Barind tract of the older Teesta meander Floodplains contains grey silt clay loam which is found in the north and also in the southern part of the district. Along the river valley the soil is formed by deposits of most recent origin from the Teesta, the Jamuna, the Dudkumar and the Dharla (BBS, 2006).

### 3.1.2 Atmospheric Conditions

Kurigram district experiences the sub-tropical monsoon climate typical of Bangladesh, with hot wet summers from May to September and cooler in dry winter months. Kurigram district does not have any climatic station. Rangpur is the nearest climatic station and therefore, its climatic data are considered applicable for Kurigram district. Maximum temperatures vary from 24.5°C to 34.5°C. Monthly minimum temperature can fluctuate significantly during the year, ranging from about 10.2°C to 26.4°C (MOEF, 1995).

### 3.1.3 Hydrologic Conditions

The hydrology of Kurigram district is mainly governed by local rainfall and runoff associated with cross boundary flows through Dharla, Dudkumar, Teesta and Brahmaputra, the four main perennial rivers surrounding the district area. The Brahmaputra, Teesta and Dharla are the principal rivers and main sources of surface water for Kurigram district. The physiography of Kurigram district mainly comprises a mixture of Teesta and Brahmaputra Floodplains. Majority of the district area (71%) belongs to Teesta Floodplain. The mode of ground development in these physiographic units is largely controlled by the thickness of the upper clay and specific yield of the sand that underlies the clay. In Kurigram district, the upper region is generally less than 5m thick in the Teesta Floodplain, while in Brahmaputra Floodplain, the upper clay layer is generally thin and permeable. Specific yield of underlying sand in these physiographic units is very high, in the range of 15 to 25%. This indicates a high recharge capacity and low sensitivity to drought conditions (LGED, 2009). Arsenic contamination in drinking water was not reported of the study area during FGD of local people and water quality analysis. Table 1 show the water quality of the study area and it recommended that water quality is good considering all parameter of water.

Table 1: The water quality of the study area

| **Upazila** | **Union** | **pH** | **Temperature (°C)** | **Iron (mg/l)** | **EC (µs)** | **TDS (mg/l)** | **Calcium (mg/l)** | **Chlorine (mg/l)** | **Sodium (mg/l)** |
|---|---|---|---|---|---|---|---|---|---|
| **DoE Standard (Drinking water)** | | **6.5-8.5** | **20-30** | **0.3-1** | **600-1000** | **1000** | **75** | **150-600** | **200** |
| **Fulbari** | Shimulbari (Joatindra Narayan) | 7.9 | 30.9 | 0.42 | 530 | 260 | 24.5 | 53.25 | 2.85 |
| **Nageswari** | Kaliganj (Nama Char) | 8 | 26.2 | 2.882 | 590 | 290 | 26.0 | 31.1 | 2.169 |
| Chilmari | Chilmari Sadder (Shaka hathir char) | 7.7 | 27.5 | 0.95 | 400 | 210 | 17.1 | 66.56 | 1.571 |

## 3.2 Biological Environment

The study area has high richness of flora and fauna due to the presence of the Brahmaputra-Jamuna and Teesta Rivers and some other rivers and their tributaries. Tree species mainly include Mango, Sisoo, Karai, Babul, Jarul etc. A few varieties of bamboo grow in plenty all over the area. Many kinds of birds are seen in the area. These include Doel (*Copssycus sanlaris*), Kokil, Oriole or Haide Pakhi, Babui, several species of pheasant, quails, pigeons and doves, herons and storks, and nightjar, king fishers and bee-eaters, barbets and woodpeckers, etc. Some migratory birds like Rajhans and Balihans are also seen during winter season. The most abundant fish species are Puti, Bacha, Gura icha, Guchi, Baim, Mola, Chela, Tengra, Magur, Air, Batashi and Kajori.

### 3.3 Socio-economic & Cultural Environment

Within the study area there are no sites of ancient monuments or other shorts of structure of archeologically importance. Most of the people are Muslim and the area is dominated by Muslim culture. The study area is under the monga prone areas well as char area. Rahman and Rahman (2011) identify that the per capita income of the Jamuna char area like Char Konabari village is about US$0.54. The people living in this area are dependent on agricultural activities. The main livelihood group here is farmers. The second largest group is agricultural labors. Collectively they comprise almost 70% of all livelihood groups. Other significant livelihood groups are fisherman and non-agricultural laborer.

## 4. IDENTIFICATION AND EVALUATION OF POTENTIAL IMPACTS

### 4.1 Environmental Impacts during Construction Phase

This evaluation concern adverse effect which are temporary, i.e. limited to the implementation period of the project. The project activities will have very insignificant adverse impacts on environmental quality.

#### 4.1.1 Impacts on Air Quality

The air quality impacts from the construction phase will mainly be restricted to the potential for dust generation from earth cutting activities. The dust will settle on the plants and the crops in surrounding agricultural field which will contribute to their demise.

#### 4.1.2 Impacts on Water Quality

During construction phase the possibility of deterioration of water quality is zero.

#### 4.1.3 Impacts on Soil and Land

There will be a possibility to use topsoil during earth work (cutting and filling) of the evacuation route. Improper drainage may cause erosion of road surface, side slopes of road and homestead during the rainy season. This could result in minor impacts on adjacent lands and flow discharge.

#### 4.1.4 Impacts on Biological Resources

As mentioned earlier that the project will be established on the char area and there will be no forest or any disturbance on existing biological resources in and around the site. But during construction period very negligible amount of small trees will be cut in the project site.

#### 4.1.5 Impacts on Socio-economic Environment

During construction, the project will create job opportunities for a large number of local skilled and semi-skilled labors especially for women during earth cutting. However, the impact will be a relatively short duration, being restricted locally to the construction period, which will typically be 6-8 months. In addition to this, all construction sites attract small traders, who supply food and other consumable items to the work force.

## 4.2 Environmental Impacts during Operation Phase

### 4.2.1 Impacts on Air Quality

During operation phase there will be a possibility to increase dust at the site of the evacuation route. Dust will be a nuisance created by all of these to a greater or lesser extent, and will affect air quality. The dust also will settle on the plants and the crops in surrounding agricultural field which will contribute to their demise. The vehicle movement at the evacuation route is very limited that's why vehicular emission is absence.

### 4.2.2 Impacts on Water Quality

The proposed evacuation route will not cross the natural channels. As a result it does not create water logging in the adjacent area and does not effect the lateral migration of fish. Installation of latrine may hamper ground water by leaching of leachate. The minute amount of ground water is extracted due to domestic use by installed tube well. On the other hand recharge ability of the local aquifer is good. So, there is no possibility of deterioration of ground water quantity and quality.

### 4.2.3 Impacts on Ambient Noise Standards

The project will not use any type of heavy machinery during project activates, so it does not produce excessive noise. As a result it does not hamper the quality of ambient noise standards.

### 4.2.4 Solid Waste Impact

The project will not generate any types of solid wastes which may create any environmental pollution in the area.

### 4.2.5 Impacts on Biological Resources

It is expected that the project will not affect homestead forestry, agriculture or the precious aquatic vegetation during its operation. As already mentioned that the project will not hampered the water body and does not create water logging problem. As a result it does not create any unfavorable situations in the river ecology and thereby cannot modify or destroy the existing condition of the aquatic habitat.

### 4.2.6 Impacts on Socio-economic Environment

The economic impact of this evacuation route will be positive. It provides benefits of fast communication; improve access to growth centers and commercial activities of the local people. Improvement in transport service in the project area will result in an increase in the value of land as compared to existing land value. Installation of tube well and latrines provides safe drinking water and hygiene sanitation facilities. It improves the health condition of the local community. Increase health condition as well as income will helps to maintain better standard of life.

### 4.2.7 Impact on Occupational Health & Safety

The project do not engaged any types of dangerous activities. So the possibilities of the occurrence of accident are minimal.

## 4.3 Impact Assessment – Application of Standard Methods

Identification of potential impacts due to implementation of project is done by using Matrix Method. Table 2 represents the matrix developed for the project. In this matrix, actions, which may affect at the various stages of the project activities, are listed and the degrees of Significant Environmental Impacts (SEIs) are shown. The terms none, major, minor; moderate and major are used in the matrix to evaluate the magnitude to SEIs. In the matrix, both the construction and operational phases of the project are considered in order to distinguish the short term and long-term impact. As can be observed from the matrix, major environmental components that will be adversely affected by evacuation route of the project are physio-chemical/ecological and will be positively affected is quality of life. However installation of tube well and latrines created positive impact except ground water leaching.

Table 2: Matrix table of EIA on Evacuation route, Tube wells and Latrines

| **Environmental Parameters** | **Potential Impact Assessment** | | | | | | **NMMN, NMMR, MMS** |
|---|---|---|---|---|---|---|---|
| | **Impact Without Intervention** No=0 Adverse=- Beneficial=+ | **Impact During Intervention** No=0 Adverse = - Beneficial=+ | **Impacts After Intervention** No = 0, Adverse= - Beneficial= + | **Magnitude / Intensity** Minor= 1 Medium=2, Major=3 | **Duration** Long=L Medium=M Short=S | **Nature** Direct (D) Indirect (IN) Cumulative (C) | |
| **PHYSICO-CHEMICAL** | | | | | | | |
| Soil characteristics | 0 | - | 0 | | M | IN | **MMS** |
| Soil erosion | 0 | - | 0 | | S | IN | **MMS** |
| Drainage/ water logging | 0 | 0 | - | 1 | S | D | NMMR |
| Solid Waste | 0 | 0 | 0 | | | | NMMN |
| Land use change | 0 | 0 | 0 | | | | NMMN |
| Agricultural land | 0 | - | - | 2 | M | D | **MMS** |
| Flood Plain | 0 | 0 | 0 | | | | NMMN |
| Water quality | 0 | 0 | + | 3 | L | C | NMMR |
| Ground water shortage | 0 | 0 | 0 | | | | NMMN |
| Ground water pollution/leaching | 0 | 0 | - | 1 | M | | **MMS** |
| Surface water pollution | 0 | 0 | 0 | | | | NMMN |
| Air pollution(dust,smoke) | 0 | - | - | 2 | M | D | **MMS** |
| **BIOLOGICAL/ ECOLOGICAL** | | | | | | | |
| Birds | 0 | 0 | 0 | | | | NMMN |
| Wildlife habitat | 0 | 0 | 0 | | | | NMMN |
| Wetland | 0 | 0 | 0 | | | | NMMN |
| Plantation | 0 | + | + | 3 | L | C | NMMN |
| Tree Removal | 0 | - | 0 | 1 | S | D | **MMS** |
| Fishery | 0 | 0 | - | 1 | S | D | NMMR |
| **HUMAN USE/ QUALITY OF LIFE** | | | | | | | |
| Crop production | 0 | 0 | 0 | | | | NMMN |
| Transportation | 0 | 0 | + | 3 | L | C | NMMN |
| Noise pollution | 0 | 0 | 0 | | | | NMMN |
| Trade, commerce | 0 | 0 | + | 3 | L | C | NMMN |
| Employment/ Livelihood | 0 | + | + | 3 | L | C | NMMN |
| Homestead displacement | 0 | 0 | 0 | | | | NMMN |
| Land price | - | + | + | 3 | L | C | NMMN |
| Accident risks | 0 | 0 | 0 | | | | NMMN |
| Cultural Heritage | 0 | 0 | 0 | | | | NMMN |
| Water & Sanitation | 0 | 0 | + | 3 | L | C | NMMN |

Note:

1) NMMN for No Mitigation Measures Needed; NNMR for No Mitigation Measures Recommended; MMS for Mitigation Measures Suggested.

2) Short term will generally mean immediate and for few months duration, Medium term means for up to five years and Long term means for over five year.

## 5. ENVIRONMENTAL MANAGEMENT AND MITIGATION

### 5.1 Mitigation Measures

Mitigation measures are to be incorporated in the planning and implementation stages of the project to reduce and offset negative impacts and thereby enhance net positive benefit of the project.

1. The road side plantation can helps to reduce the environmental degradation of the area.
2. Soil erosion could be initiated along the evacuation route. Grass roofing of the route could ensure the management of soil erosion.
3. The removal of tree species is a short duration impact. Planting trees along the proposed road side can minimize the loss of tree removal. It reduces soil erosion along route side.
4. Dust pollution can be reduced by controlling moisture content during construction by watering, stabilizing road surface with a suitable stabilizer and providing vegetative cover on road surface and slope.

In view of the above discussions the mitigation measures suggested in Table 3 may be adopted during and after the construction phase of the project.

Table 3: Recommended Mitigating Measures for Possible Adverse Impact

| Environmental Parameter | Impact | Mitigating Measures |
|---|---|---|
| Soil | Soil erosion | Grass roofing of the evacuation route could ensure the management of soil erosion and slope protection. |
| | Soil characteristics | Use of top soil should be prohibited and use barren soil |
| Ground water leaching | Contamination of ground water due sewerage water to leaching | Latrine should be constructed at least 30 feet far from the tube well |
| Air pollution, dust, smoke | Emission of dust from construction processes | Spray water during construction of route |
| Agricultural land | Permanent loss of productive agricultural land | Payment of compensation to land owners and provide alternative job opportunities. |
| Tree Removal | Losses of some trees | Route site plantation will manage the loss |

### 5.2 Environmental Monitoring/Management

The prime objectives of these monitoring program is defined as a process of making systematic observation, collection, examination, measurement and evaluation of both Physical view and Chemical aspects of Environmental Quality Key Parameter’s pollution levels in water in Tube wells. The project will carry out monitoring of the following Environmental & Workplace Quality Key Indicators as and when required: 1) Water Quality, 2) Public Complaints regarding adverse environmental impacts on Ecological Flora and Fauna. The above mentioned ‘Quality Key Indicator’s Parameters & Monitoring Program Format’ has been prepared and depicted at Table 4.

**Table 4: Quality Key Indicator's Parameters Monitoring Programme Format**

| Key parameters to be Monitoring: (I) Water Quality | | | |
|---|---|---|---|
| *Water from tube well* | *Every year after construction of tube well* | *pH, Temperature, EC, TDS, Fe, Cl, Ca, Na, As etc.* | *Report compilation.* |
| Key parameters to be Monitored: (II) Public Complaints Regarding adverse environmental Impacts concerning ecological effects on flora and Fauna will be handled appropriately. | | | |

## 6. CONCLUSION

This EIA has been prepared for the project through identification and evaluation of sources and nature of pollution and environmental impacts and recommendation of possible mitigating and enhancing measures for negative and positive impacts, respectively. The findings of this Environmental Impact Assessment suggest that there are no environmental issues of sensitive nature, which might have any potential of serious ill effects due to the project in this area. The project will provide beneficial impact in terms of employment opportunities. In conclusion, it can be said that the project would be an environmental friendly and its activities will not damage the surrounding environment in the long-term impact point or view subject to adoption of necessary and effective environmental management measures, environmental management systems (EMS), regular and effective environmental monitoring.

## 7. ACKNOWLEDGEMENT

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# RESPONSE OF THE JAMUNA MULTIPURPOSE BRIDGE TO 28TH AUGUST 2008 EARTHQUAKE

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## ABSTRACT

Jamuna Multipurpose Bridge is located in a seismically active region. The bridge is instrumented with sensors to record and collect ambient, traffic and earthquake vibration data. The objective of such installation is to observe and predict the dynamic behavior of the bridge structure. There are seven structural modules in the bridge. The FE model of one single module can be analyzed without much hardle and model with three modules offers a bit more complicacy, whereas model with more than three modules is too time consuming and exhaustive in memory requirement. A model considering the whole bridge, however, could help to predict the dynamic behavior of the bridge. The current study focuses on verifying to what extent a one-module model may provide useful information.

**Keywords:** Jamuna Multipurpose Bridge, Seismic responses, Bridge modules, earthquake on 28th August, 2008.

## 1. INTRODUCTION

Jamuna Multipurpose Bridge is located in a seismically active region. The bridge is instrumented with sensors to record and collect ambient, traffic and earthquake vibration data. The objective of such installation is to observe and predict the dynamic behavior of the bridge structure.

There are seven structural modules in the bridge. The FE model of one single module can be analyzed without much hardle and model with three modules offers a bit more complicacy, whereas model with more than three modules is too time consuming and exhaustive in memory requirement. A model considering the whole bridge, however, could help to predict the dynamic behavior of the bridge. The current study focuses on verifying to what extent a one-module model may provide useful information. Different approaches can be followed in this regard.

The following are the scopes of the study

- The isolation device is considered in the finite element model of the bridge.
- The horizontal and vertical curvatures of the bridge have been considered.
- The variation in the depth and width of the deck along its length is considered parabolic as per the actual condition

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The following can be detected as the major limitations

- The prestressed condition of the structural members is not considered.
- Only the stiffness effect of adjacent modules is considered, no effect of mass is taken in action.
- Material non-linearity is not considered.
- Soil-structure interaction is ignored.

## 2. COMPARISON OF THE RECORDED DATA AND DATA OBTAINED FROM FINITE ELEMENT MODEL

### 2.1 Modes for Analysis

Modal analysis was done with the help of different models of the bridge. (Rahman, 2008)
The different FE models are described bellow:

1) Model-1. The model does not consider prestressing in the bridge deck, pier system, diaphragm, exterior rail girder and longitudinal curvature. Vertical curvature is considered in this model. Supports and restraints are provided by hinge and roller as per actual condition.
2) Model-2. The model does not consider prestressing and the pier system. Supports and restraint are provided by hinge and roller as per actual condition. Internal diaphragm and Exterior rail girder are modelled with shell element.
3) Model-3. The model does not consider prestressing and the pier system, Supports and restraints provided by hinge are not as per actual condition, i.e. the direction of restrains are not considered in this model. Internal diaphragm and exterior rail girder are modelled with shell element.
4) Model-4. The model does not consider prestressing in the deck. Pier system is modelled with solid elements. Hollow sections at the top of the piers are not considered. Internal diaphragm and Exterior rail girder are modelled with shell elements.
5) Model-5. The model does not consider prestressing in the deck. Pier system is modelled with solid elements. Hollow sections at the top of the piers are also considered. Internal diaphragm and Exterior rail girder are modelled with shell elements.
6) Model-6. The model does not consider prestressing in the deck. Pier system is modelled with shell elements Hollow sections at the top of the piers are not considered. Internal diaphragm and Exterior rail girder are modelled with shell elements.
7) Model-7. The model does not consider lateral prestressing in the deck. Pier system is modelled with solid element. A hollow section at the top of the piers is also modelled. Internal diaphragm and Exterior rail girder are modelled with shell element.
8) Model-8. The model considers lateral prestressing in the deck. Pier system is modelled with solid element. A hollow section at the top of the piers is also

modelled. Internal diaphragm and Exterior rail girder are modelled with frame element.

The results gathered from modal history analysis from the model are compared with the recorded data on the bridge deck during the earthquake. These comparison leads to the applicability of the model and the need to update the model to estimate the actual response of the bridge during earthquake. The following data were compared to estimate the responses:

1. Actual data at for sensor at deck at Pier 10.
2. Finite element model with three modules assigning fixed supports with pier and springs at overhanging ends.
3. Finite element model with one module where the adjacent modules are replaced by springs of different sets of values. The spring values were altered at percentile of the value obtained from elementary stiffness analysis such as 25%, 50% etc.

### 2.2 The Time History Analysis

***Acceleration on Pier 10 along three directions:***

From the Figure 1 to 3 it is seen that, the patterns of time history obtained from the time history analyses and the recorded data are similar on deck on Pier 10 during an earthquake.

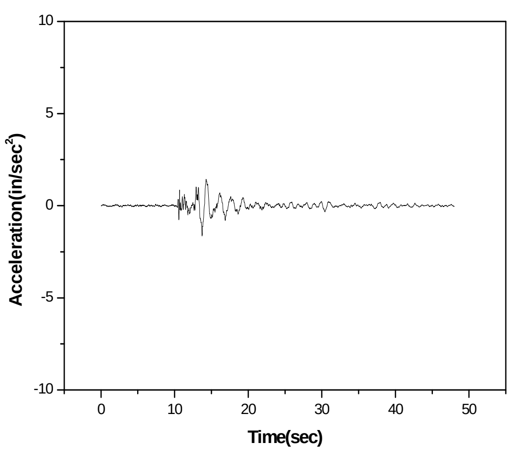



Fig 1(a): Acceleration obtained from actual response along longitudinal direction.

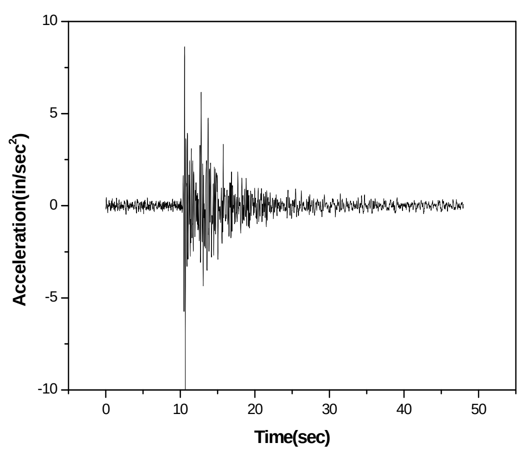
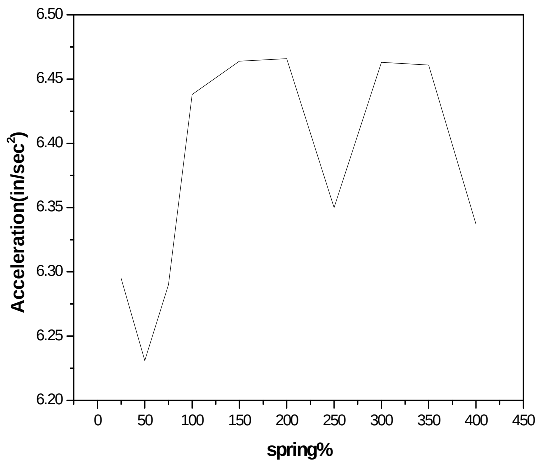



Fig 1(b): Acceleration obtained from FEM model with three modules along longitudinal direction.



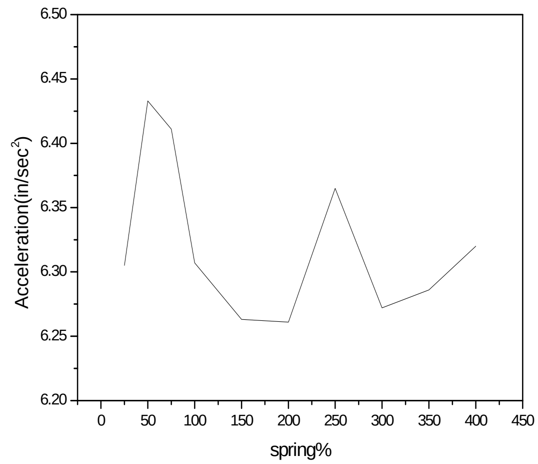
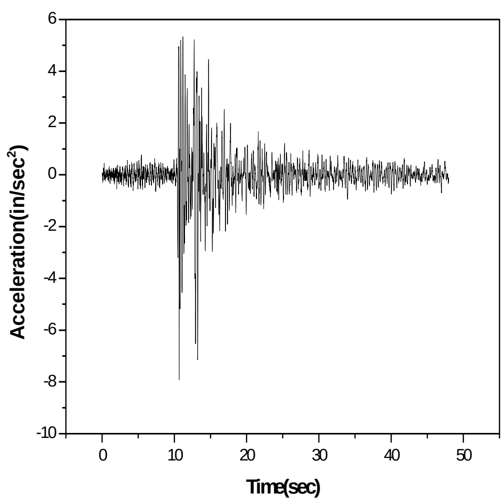




Fig 1(c): Peak values of acceleration along longitudinal direction obtained from FEM model with one module and spring assigned at overhanging edges along transverse direction only.

Fig 1(d): Peak values of acceleration along longitudinal direction obtained from FEM model with one module and spring assigned at overhanging edges along both transverse and vertical direction.



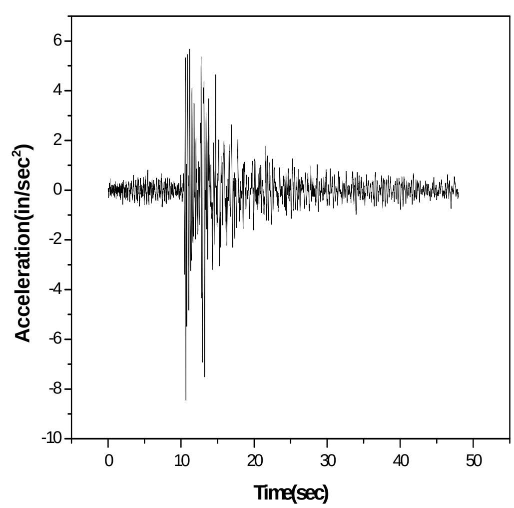




Fig 2(a): Acceleration obtained from actual response along transverse direction.

Fig 2(b): Acceleration obtained from FEM model with three modules along transverse direction.

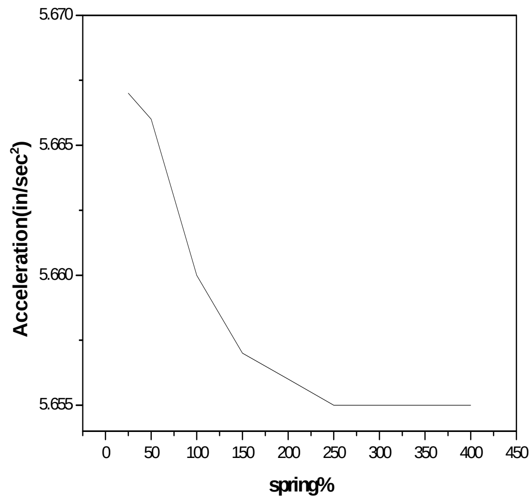



Fig 2(c): Peak values of acceleration along transverse direction obtained from FEM model with one module and spring assigned at overhanging edges along transverse direction only.

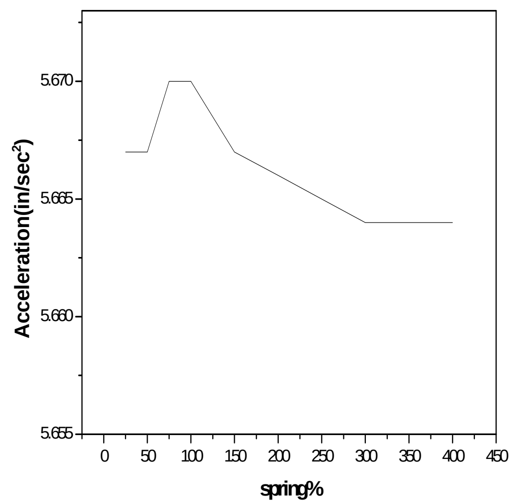



Fig 2(d): Peak values of acceleration along transverse direction obtained from FEM model with one module and spring assigned at overhanging edges along both transverse and vertical direction.

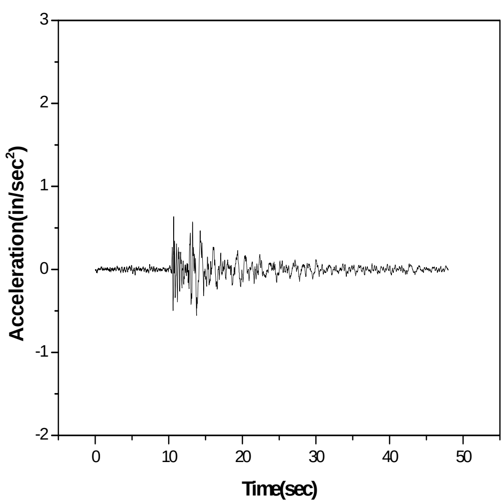



Fig 3(a): Acceleration obtained from actual response along vertical direction.

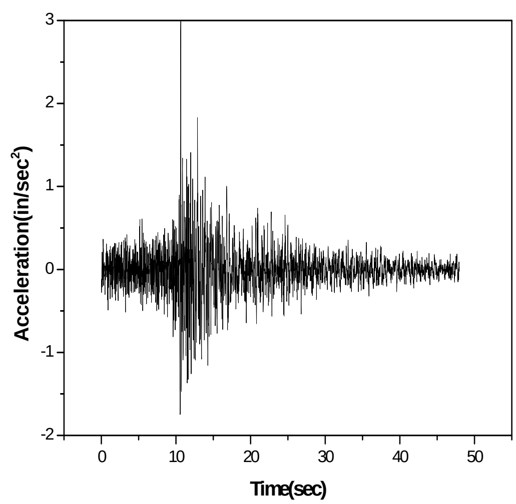
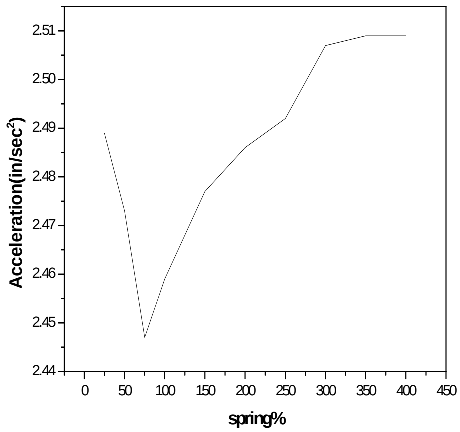



Fig 3(b): Acceleration obtained from FEM model with three modules along vertical direction.



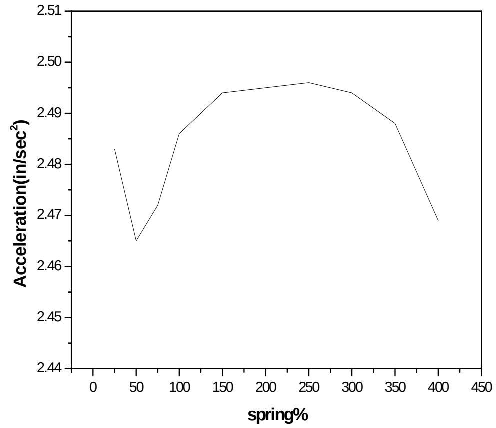




Fig 3(c): Peak values of acceleration along vertical direction obtained from FEM model with one module and spring assigned at overhanging edges along transverse direction only.

Fig 3(d): Peak values of acceleration along vertical direction obtained from FEM model with one module and spring assigned at overhanging edges along both transverse and vertical direction.

From the above graphs the variation of values can be shown as follows:

Table 1: Summary of the output values of acceleration

| | | Peak Acceleration (in/sec$^2$) | | | Time to peak (sec) | | |
|---|---|---|---|---|---|---|---|
| | | Longitudinal | Transverse | Vertical | Longitudinal | Transverse | Vertical |
| Actual response | | 1.66 | 8.32 | 0.47 | 13.74 | 10.66 | 10.66 |
| Three Modules | | 3.01 | 8.45 | 3.01 | 10.64 | 10.66 | 10.64 |
| One Module | With spring Along Y direction only | Varies from 6.231 to 6.466 | Varies from 5.667 to 5.655 | Varies from 2.447 to 2.509 | - | - | - |
| | With spring Along both Y & Z direction | Varies from 6.261 to 6.433 | Varies from 5.66 to 5.67 | Varies from 2.465 to 2.496 | - | - | - |

However, the acceleration magnitude of the output of numerical analyses are greater compared to the recorded data. The reason might be that in the numerical analysis no soil-structure interaction effect was considered.

## 3. CONCLUSIONS

Findings of the study as presented in the previous chapters are summarized bellow:

1. The results conclude that a 1 module model can be successfully taken to describe the actual response values. The effect of stiffness of other modules can be taken as insignificant.
2. It is observed that the peak response in acceleration, velocity and displacement of the bridge always comes later in the case of FE model than the recorded data on bridge.
3. Response from the FE model clearly shows the predominant frequency of the structure and also the predominant frequency of the earthquake but does not show the predominant frequency of the soil. This is because no soil-structure interaction was considered. On the other hand, the actual response shows the predominant peak of the soil and that of the structure but does not show for this particular earthquake because this earthquake is very low intensity earthquake as compared to the ambient vibration.

## 4. FUTURE RECOMMENDATIONS

1. In the study only three locations were selected for comparison. Other location can be selected for comparison study.
2. The results can be compared with results analyzing more modules.
3. I only considered the effect of only stiffness of other modules, the effect of mass of other modules can be added.
4. Responses can be studied for same bridge with different parameters.
5. Responses can be also studied for another types of bridges.
6. Earthquake data was used as loads in this study. This earthquake data was recorded at the free field station and used as uniform input motions at all bridge supports throughout the model. But the input data needs to be modified for each support location. This modification can be considered for future study.
7. The base of the pier was considered as a fixed support and soil-structure interaction was not considered. But in reality a complex support system exists below each pier. Soil-structure interaction should be considered for future study.
8. Nonlinear behaviour of the material can be used for further study.
9. Longitudinal prestressing has not been incorporated in this model it can be incorporated in a future study.
10. In future study superimposed dead load and moving load for vehicle may be applied and static analysis can be done for staged construction for this with this model.

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# POTENTIALITY OF RAINWATER HARVESTING IN DHAKA: A GREENER APPROACH

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## ABSTRACT

Dhaka is the most densely populated mega city of this world. Increasing demand of increasing population of Dhaka city puts pressure on energy consumption. As a result we are facing shortage of electricity, gas, water which is making the city unsustainable day by day. To ensure sustainable future we have to go for Green buildings. Green building focuses on energy conservation, materials (embodied energy and renewable), water (conservation and re-use). One aspect of green engineering and sustainable design is how man interacts with the hydrologic cycle. Rainwater harvesting is the process of intercepting storm-water runoff and putting it to beneficial use. It provides self sufficiency to water supply and to supplement domestic water requirement, recharges the groundwater, reduces the runoff which chokes storm drains and avoids flooding of roads. This will reduce water logging on the roadway of Dhaka city, the demand of water on WASA and power consumption for pumping of ground water. These sorts of schemes that result in eco-friendly environment in the city are being seriously considered by our present government (2009-2013). In this context, current technological scenario of the buildings constructed in Dhaka with regard to rooftop rainwater harvesting is investigated. This paper presents the outcome of this investigation and shows the potentiality of rainwater harvesting to make the city sustainable.

**Key Words:** Rainwater harvesting, Ground Water Recharge, Water Demand, Water Supply, Flush, Population

## 1. INTRODUCTION

The other name of water is Life. It is the most important element for our living. Other than, water is required in every aspect of life like cooking, washing, agriculture, industries etc. The sources mainly supply water for use is groundwater and surface water through treatment. Only 2.5% of the world’s water is fresh, while 97.5% is ocean. And of that freshwater, only 0.3% is available from rivers, lakes and reservoirs. Most freshwater is locked up in polar ice, glaciers or soil moisture. Unfortunately, more and more of that precious freshwater is contaminated each year.

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The demand of water is increasing exponentially with the huge increase of population. But the sauces are limited. Specially in Dhaka the situation is much more complicated. Dhaka City has a area of 1528 $km^2$ with a population of around 20 million. It is the most densely populated mega city. Moreover the population is increasing every day. As a result the demand for water is also increasing exponentially. To meet this demand water is supplied from two sources. One of the two sources is surface water treatment which contributes only 15% of the total supply. The major pressure for water supply is on groundwater. Due to the abandon use of groundwater and not enough recharge is causing the level of groundwater table to fall every year. As a result after few years groundwater table will fall so much that it will not be available for our use.

So, an alternative source for water supply or effective steps is required to recharge ground water. Rainwater Harvesting is a more likely alternative resource to supply a portion of water demand in Dhaka City. A portion of the harvested water can be used for groundwater recharge. So the potentiality of Rainwater Harvesting is high for Dhaka City.

## 2. RAINWATER HARVESTING

Rainwater harvesting is the mechanism of using rainwater before it reaches the surface water. The rainwater harvesting is considered as a possible answer to the global water use problem especially where rainwater is available but scope for development of surface and ground water based water supply system is limited or costly. The existing situation prevailing in both the surface and ground water gives us a sign of imminent danger if pragmatic measures are not taken in this regard. Rainwater harvesting systems are simple to install, operate, and maintain.

### 2.1. Advantages of Rainwater Harvesting

1. To meet the ever increasing demand for water. Water harvesting to recharge the groundwater enhances the availability of groundwater at specific place and time and thus assures a continuous and reliable access to groundwater.
2. To reduce the runoff which chokes storm drains and to avoid flooding of roads.
3. To reduce groundwater pollution and to improve the quality of groundwater through dilution when recharged to groundwater thereby providing high quality water, soft and low in minerals.
4. Provides self-sufficiency to your water supply and to supplement domestic water requirement during summer and drought conditions.
5. It reduces the rate of power consumption for pumping of groundwater. For pumping amount of electricity required 1000-1400kw/day/pump by DWASA.
6. Reduces soil erosion in urban areas
7. The rooftop rainwater harvesting is less expensive, easy to construct, operate and maintain.
8. In saline or coastal areas, rainwater provides good quality water and when recharged to ground water, it reduces salinity and helps in maintaining balance between the fresh-saline water interface.
9. In Islands, due to limited extent of fresh water aquifers, rainwater harvesting is the most preferred source of water for domestic use.

10. In desert, where rainfall is low, rainwater harvesting has been providing relief to people.

## 3. CURRENT WATER SCENARIO OF DHAKA CITY

Bangladesh is categorized as a developing country whose economy is rapidly growing. Dhaka is the capital of Bangladesh. All the activities regarding any development is Dhaka centered. As a result for a better and safer living people from all districts are moving towards Dhaka. This makes Dhaka the most densely populated mega city of this world. With the growing population and development of Dhaka city, the demand for water is also increasing. Dhaka WASA is finding it difficult to meet this exponential demand. The statistical data showing the relation between population growth, water demand and shortfall of water supply is given below the Table-1 and Figure-1:

Table-1: Prediction of population and water demand in Dhaka urban area

| Year | Population(million) | Water Demand(mld) | Shortfall(mld) with present water supply (2200 mld) |
|---|---|---|---|
| 2010 | 12.27 | 2400 | 200 |
| 2015 | 14.93 | 3050 | 850 |
| 2020 | 18.04 | 3686 | 1486 |
| 2025 | 21.63 | 4419 | 2219 |
| 2030 | 25.87 | 5286 | 3085 |

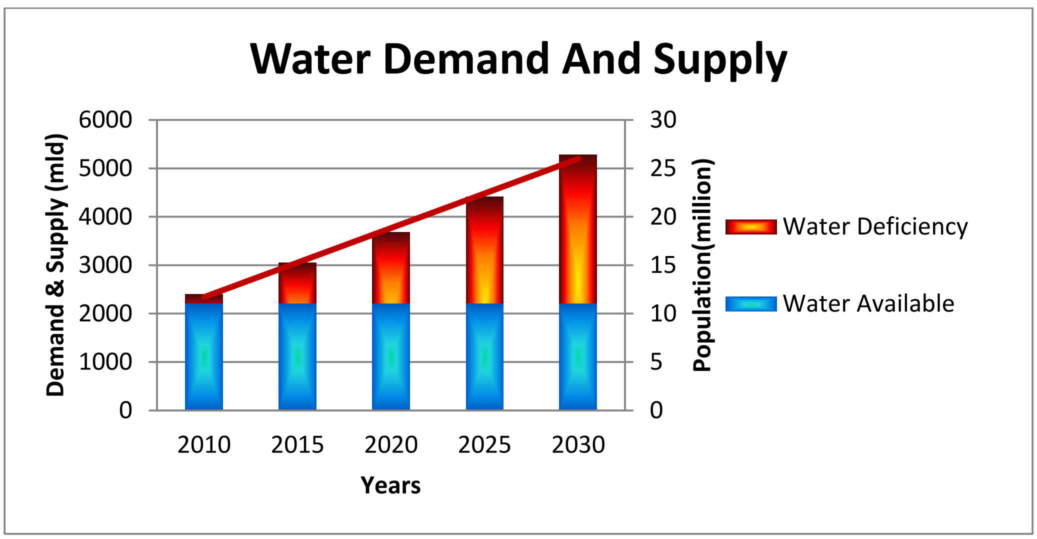



Figure-1: Showing water demand and supply with growing population

Currently, with the help of some 546 water-supply pumps, DWASA supplies about 2.2 million cubic meters (MCM) of water a day against city's daily demand of 2.4 MCM. Only 15% of the water is supplied from the two surface water treatment plants at Chadnighat and Syedabad. DWASA is dependent on groundwater for the rest 85% water demand. This is resulting the groundwater to drop by 3 meter every year. According to the Dhaka Water and Sewerage Authority (WASA), the Ground water table was at 11.3m below the surface in the 1970s and at 20m in the 1980s. Dhaka's groundwater table has gone down by 35m in the past 11 years. However, water level has drastically fallen since 1996. The continuous dropping of groundwater table over the past 14 years is graphically shown in Figure-2:

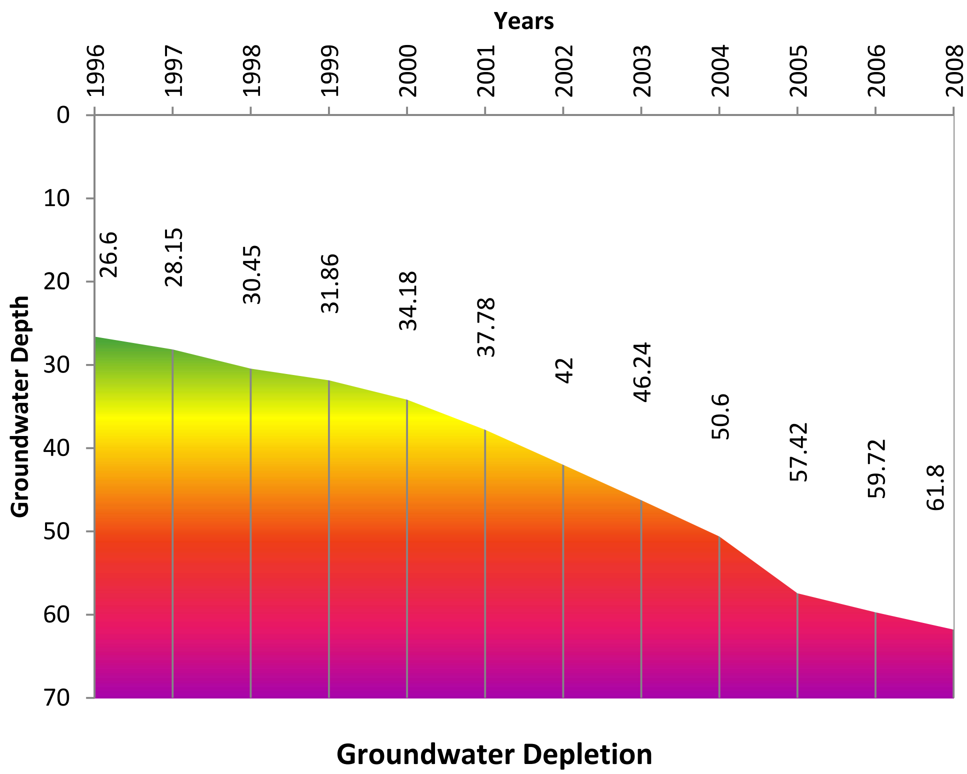



Figure-2: Groundwater depletion with time (years)

This is mainly because the estimated mean annual recharge for Dhaka city is 300 – 350 MCM, which is much less than the annual abstraction of 700 MCM. After every few years the pumps has to be relocated or new deeper installation has to be installed. If this process continues then within few years groundwater depth will not be any more within pumping depth. From the past history with the growing demand for water supply was increased which caused the Deep Tube Well to go from deep to deeper as shown below Table-2:

Table-2: Historical data of water supply (Source: Dhaka WASA)

| Year | Supply ( MLD ) | DTW |
|---|---|---|
| 1963 | 130 | 30 |
| 1970 | 180 | 47 |
| 1980 | 300 | 87 |
| 1990 | 510 | 140 |
| 1996 | 810 | 216 |
| 1997 | 870 | 225 |
| 1998 | 930 | 237 |
| 1999 | 1070 | 277 |
| 2000 | 1130 | 308 |
| 2001 | 1220 | 336 |
| 2002 | 1550 | 394 |
| 2004 | 1437 | 382 |
| 2005 | 1460 | 423 |

The demand will surely not decrease but due to the shortage of groundwater, supply will surely decrease. One of the major threats to the city due to declining groundwater levels is land subsidence, which can be triggered by earthquakes of greater magnitudes. So, an alternative source of water or a method to recharge groundwater is of utmost importance in Dhaka city for preserving environmental balance along with meeting human demand.

## 4. CONDITION OF RAINFALL IN DHAKA CITY

Dhaka has a climate. It has a distinct monsoonal season with an average 2075 mm (1953-2009) of rain every year. Nearly 88% of the annual average rainfall of 1,826 millimeters occurs between May and October. Water logging occurs after 2-3hrs of continuous raining.

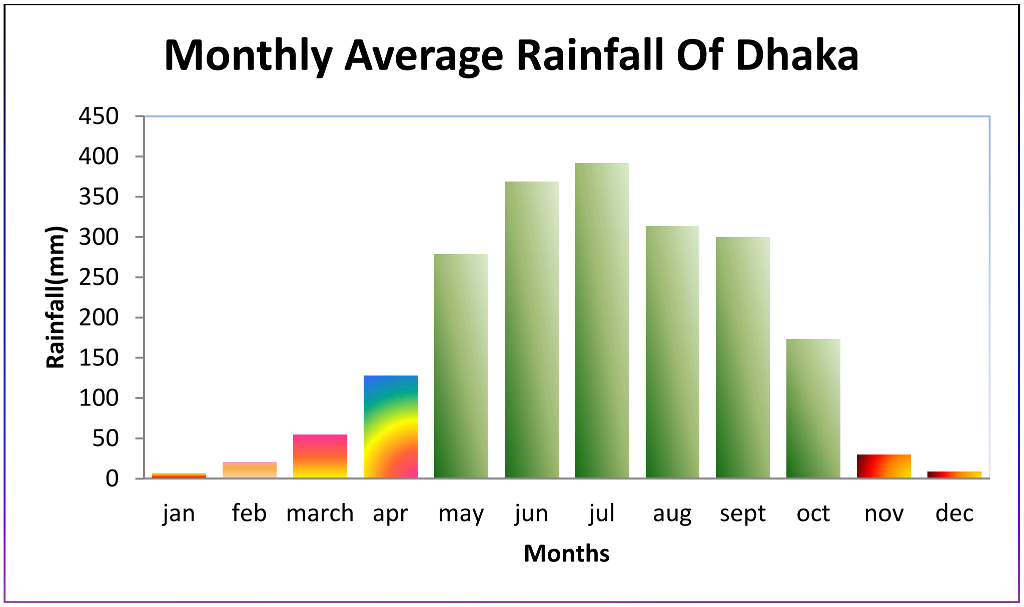
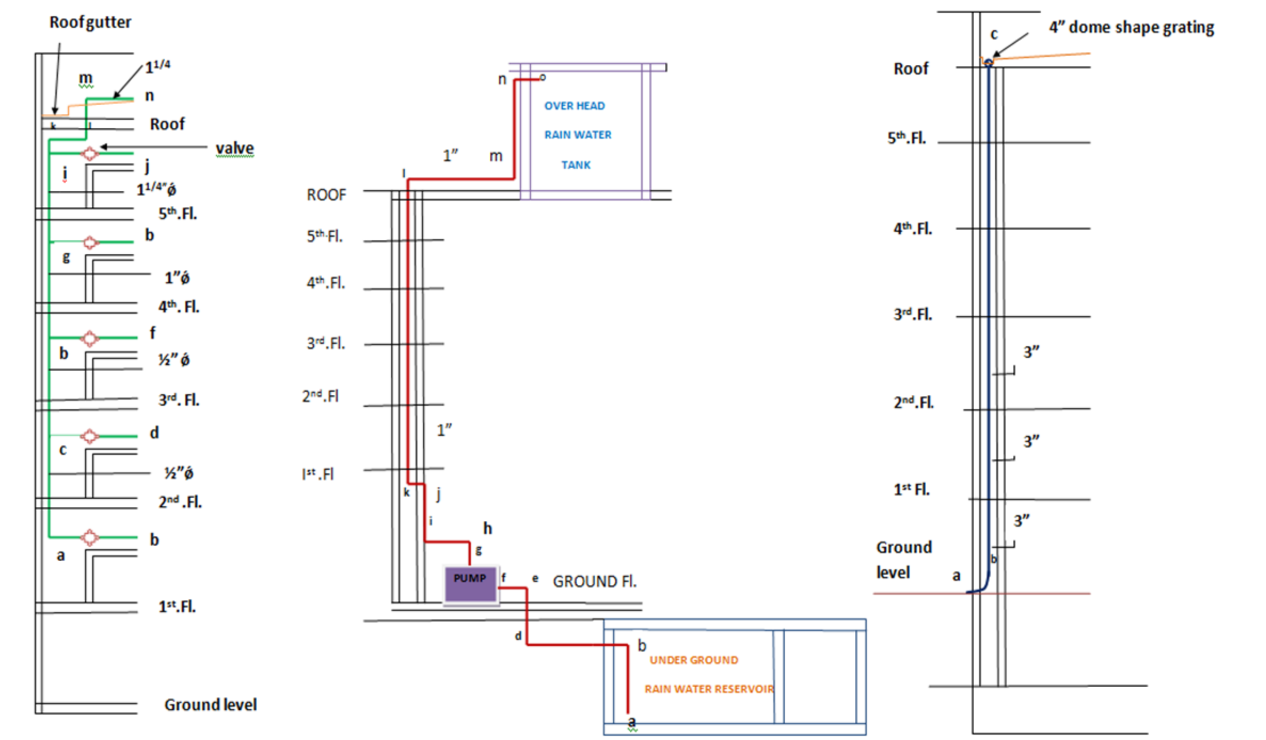



Figure-3: Monthly average rainfall of Dhaka

## 5. A CASE STUDY

A five storied residential building situated in Uttara of Dhaka city has been considered for our study. This building is designed in a manner so that rain water can be used for flushing in toilet for the entire building.


Figure-4: Layout of building




(c) Supply Pipe (b) Lifting Pipe (a)Rainwater Downpipe

Figure-5: Rainwater harvesting system

Rain water downpipe pipe:
Total length of 3"dia pipe = bc(vertical) + ab(horizontal)= 62' + 5'= 67'
Cost/meter for 3" dia pipe = 450tk
So, total cost = 67'x0.3048x450 =9190tk

Rain water lifting pipe:
Total length of 1" dia vertical pipe = ab+de+gh+ij+kl+mn = 12'+5'+5'+5'+50'+10'= 87'
Total length of 1" dia horizontal pipe = lm+kj+ih+fe+bd = 10'+3'+5'+5'+5' = 28'
Total length of pipe = 87'+28' = 115'
Cost/meter for 1" dia pipe = 391tk
So, total cost = 115'x0.3048x391 = 13706tk
Supply pipe:

| Direction | Length | Diameter | Cost/ meter | Total cost |
|---|---|---|---|---|
| Vertical(ac) | 10' | 0.5" | 225 | 686 |
| Vertical(ce) | 10' | 0.5" | 225 | 686 |
| Vertical(eg) | 10' | 1" | 391 | 1192 |
| Vertical(gk) | 10' | 1.25" | 650 | 1982 |
| Vertical(lm) | 10' | 1.25" | 650 | 1982 |

| Direction | Length | Diameter | Cost/ meter | Total cost |
|---|---|---|---|---|
| Horizontal(ab) | 5’ | 0.5” | 225 | 343 |
| Horizontal(cads) | 5’ | 0.5” | 225 | 343 |
| Horizontal(ef) | 5’ | 1” | 391 | 596 |
| Horizontal(gh) | 5’ | 1.25” | 650 | 991 |
| Horizontal(ij) | 5’ | 1.25” | 650 | 991 |
| Horizontal(kl) | 2.5’ | 1.25” | 650 | 496 |
| Horizontal(mn) | 2.5’ | 1.25” | 650 | 496 |

Total cost = 10784tk/-

As, we have selected 6 storey building of one unit with four toilet at each floor each having different pipe line so the total cost will be = 10784 x 4 = 43136 tk/-
Total gate valve = 20
Cost per valve = 500tk/-
So, total cost for valve = 20 x 500 = 10000 tk/-
Underground tank volume = 200 cft
Cost /cft for underground tank = 570 tk/-
Cost for underground tank = 570 x 200 = 1,14,000 tk/-
Over head tank volume = 50 cft
Total cost for over head tank = 50 x 570 = 28500 tk/-
Total costing for rainwater harvesting process for 6 storied building (one unit)
= 9190 + 13706 + 43136 + 10000 + 114000 + 28500
= 218532tk/-
Additional costing per flat for rainwater harvesting = 218532/5 = 43706.4 tk/-
Area of per flat = 1800 $ft^2$
Assuming the cost per square feet = 5000 tk/-
So, the cost per flat = 1800 x 5000 = 90,00,000 tk/-
So, the increasing percentage per flat = (43706.4/9000000)*100 = 0.5%
For each flush water required = 4 ltr
Each day water requirement for flush per person= 4* 6 = 24 ltr
Assuming, no. of people per flat = 6 persons
No . of people in the building = 5 x 6 = 30 persons
So, total water required for flushing per day = 30 x 24 = 720 ltr
We can save rainwater minimum for 5 months in a year
In 5 months (150 days), total water required for flushing for this building = 720 x 150
= 1,08,000 ltr

### 5.1. Cost-Benefit Analysis

Price of water = 6tk/1000ltr (from WASA)
Hence, the price of total water required for flushing for 5 months for this building

= (108000/1000) x 6
= 648 tk/yr

## 6. CONTRIBUTION TO GROUNDWATER RECHARGE

If the system can be used for ground water recharge then a significant amount of water can be recharged.

Total area of Dhaka City = 1528 $km^2$
Total population of Dhaka City = 20 million
Total Annual Rainwater = Annual rainfall x Area
= 2.1 m x 1528 x $10^6$
=3208.8 x $10^6$ $m^3$/yr
Assuming 25% of the total rainwater is used in recharging groundwater.
Total water recharge naturally = 0.25 x 3208.8 x $10^6$
= 802.2 x $10^6$ $m^3$/yr
Considering 65% of the area of the Dhaka City is covered by concrete as a continuous roof.
Actual water recharge in Dhaka = .35 x 802.2 x $10^6$
= 280.77 x $10^6$ $m^3$/yr
= 280.77 MCM/yr
= 769.23 mld
If half of the covered area can be used for the rain water harvesting and 50% of the rain water can be recharged,
Additional ground water recharge = 769.23 x $10^6$ x 0.65 x 0.5 x .5 x 0.85
= 106.25 x $10^6$ $m^3$/yr
= 106.25 MCM/yr
= 291.1 mld

## 7. CONCLUDING REMARK

The current water availability and supply condition of Dhaka city is very vulnerable which will deteriorate in future. This is alarming for both government and private sector, and this crisis will question the survival of mankind at some point of time in future. So dependency on groundwater has to be decreased and the possibility of surface water treatment plant for Dhaka City is also not that bright. So right now the only and most potential alternative is Rain Water Harvesting. This will meet the water demand of the community during severe crisis. The installation of rainwater harvesting will increase only 0.5% of the cost of the building which is very much affordable as water is one of few important elements for human survival whose availability is of more importance than its cost. Rainwater Harvesting will recharge 108 MCM per year which is equal to 31% of the deficit Dhaka faces every year. This also increases the sustainability of groundwater by recharging it. So, for the sake of our survival in Dhaka, a revolution of rainwater harvesting has to be adapted which will involve all the roofs of the city catching water in every possible way.

## 8. ACKNOWLEDGEMENT

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# SOLAR PHOTOVOLTAIC (PV) TECHNOLOGY: GREEN ELECTRICITY CAN MITIGATE POWER CRISIS IN BANGLADESH

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## ABSTRACT

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for utilization of solar energy. Daily average solar radiation varies between 4kWh/m$^2$ to 6.5kWh/m$^2$. Average annual solar irradiance is nearly 1900kWh/m$^2$ which is sufficient to operate a solar photovoltaic (PV) power system. At present Bangladesh has a requirement of about 6,000 megawatts electricity but production hovers around 4,000 megawatts. The electrification rate is about 42%.The rural areas which are not as developed as the urban areas have an electrification rate of only 23%.Still nearly three-fifths of the population are not covered by electricity and 40,000 villages remain outside the power grid. The country almost entirely depends on conventional sources of energy like oil and gas to meet its energy demand which are depleting fast. As a result the issue of sustainable development is gaining steady momentum. Nowadays in Bangladesh approximately 40 MW of power is being produced form solar and wind energy which is only 0.9% of total generation. As there is no fuel cost in PV generation and it produces pollution free green energy with nominal maintenance cost, it can be an attractive choice to mitigate the power crisis in Bangladesh. Solar technology can also play a vital role in off grid rural electrification as grid expansion is a difficult task. Solar water pumping can also save approximately 800MW power during the season of irrigation. So it is high time to take necessary steps for green energy electrification in Bangladesh to cope with acute power crisis. In this paper we have described the prospect of solar photovoltaic power in Bangladesh along with technical and economical factors.

**Key Words:** Photovoltaic; solar radiation; power grid; green energy; power crisis; conventional source; rural electrification.

## 1. INTRODUCTION

In the long term, renewable energies will dominate the world's energy supply system. The reason is at the same time very simple and imperative: there is no alternative. Mankind cannot indefinitely continue to base its activities on the consumption of finite energy resources. Renewable sources of energy are in line with an overall strategy of sustainable development. They help reduce dependence on energy imports, thereby ensuring a sustainable security of supply. Furthermore, renewable energy sources can help improve the

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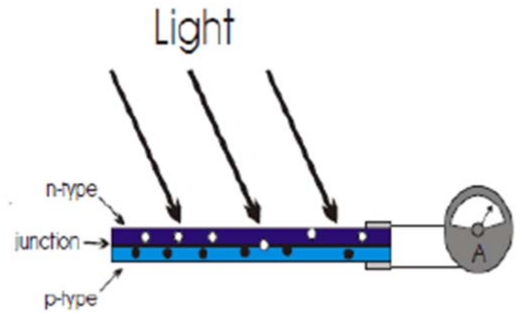


Fig 1 : Photovoltaic electricity generation

competitiveness of industries and have a positive impact on regional development and employment. Renewable energy technologies are suitable for off-grid services, serving those in remote areas of the world without having to build or extend expensive and complicated grid infrastructure.

As a renewable energy, the sunlight is a potential resource for generating electric power. In recent years, it is being increasingly used to generate power all over the world.

The fossil fuels used for generation of electricity are depleting fast. This is more applicable in case of Bangladesh. Thus the issue of sustainable development is gaining steady momentum. The renewable energies being inherently sustainable and environment friendly, are gaining popularity. Many countries are planning to develop renewable energies (PV, wind, hydro) to cover 10% to 40% of their energy needs within couple of decades. However, no such effort is seen in Bangladesh although Bangladesh has a good prospect in the field of solar photovoltaic technology.

## 2. PV TECHNOLOGY

### 2.1. Working Principle

Solar energy is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaics and heat engines. Photovoltaic solar power is the energy created by converting solar energy into electricity using photovoltaic solar cells. A solar cell or photovoltaic (PV) cell is a device that converts light into electric current using the photoelectric effect.

### 2.2. Worldwide PV Technology Use

As of 2010, solar photovoltaic generates electricity in more than 100 countries and it is the fastest growing power-generation technology in the world. Photovoltaic production has been increasing by an average of some 20 percent each year since 2002.At the end of 2010; the cumulative global PV installations surpassed 4.8 TW. [1]

### 2.3. Why PV Technology

There are several reasons why solar energy is the most promising alternative energy resource for our future. Scientists estimate that our sun will continue producing solar energy for another 5 billion years! We definitely do not have to worry about running out of solar energy. It is the ultimate renewable energy available to us. In one hour enough sunlight reaches the

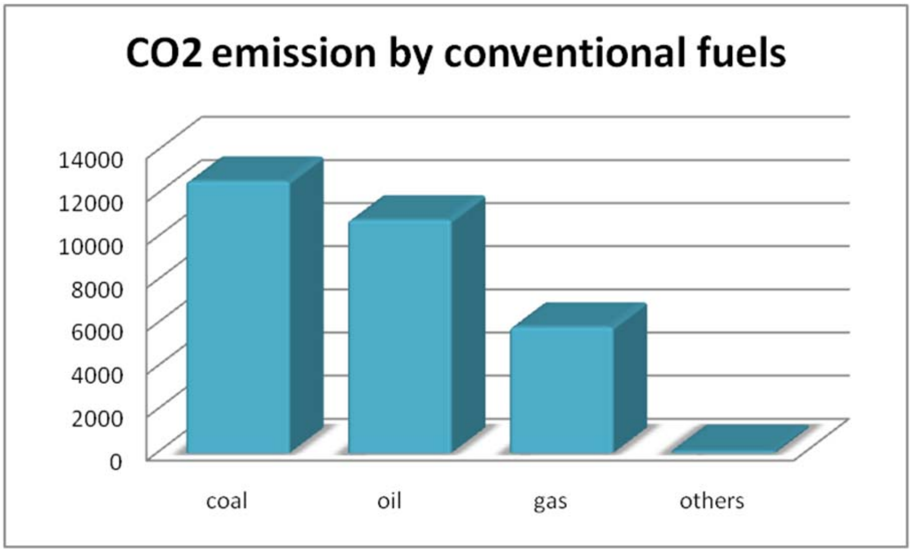


Fig 2: $CO_2$ emission by different fuels in 2008 (total $CO_2$ emission 29382 Mt) [3]

earth to supply its energy needs for an entire year. So not only is it sustainable, but it provides more than enough energy for our needs. We just need to continue improving our solar technology so that we can capture more of this energy and put it to productive use.

### 2.3. Green Energy

The usage of conventional energy resources in electricity generation leads to environmental damages by polluting the atmosphere. Each different source of energy, from fossil fuels to nuclear, pollutes in a different way and to a different degree. Global warming is caused by the tendency for some gases like carbon dioxide which trap heat in the earth's atmosphere. But solar photovoltaic electricity is the cleanest and the most convenient of all forms of energy.

## 3. PRESENT POWER STATISTICS IN BANGLADESH

### 3.1. Electricity Generation

At present Bangladesh has a requirement of about 6,000 megawatts electricity but production hovers around 4,000 megawatts. In the Eastern Zone, electricity is generated from indigenous gas and a small percentage through hydro power. In the Western Zone, Coal and imported liquid fuel is used for generation of electricity. Bangladesh as a developing country has lowest coverage of electricity. The rural areas of Bangladesh, where 76 per cent of the population lives, are seriously deprived of the electricity facility. The electrification rate of the country is now 42% but the rural areas are not as developed as the urban areas seeing that their electrification rate is only 23% (against 79% or urban areas).[4]The country almost entirely depends on conventional sources of energy like oil and gas to meet its energy demand. But imported oil is too costly while proven gas reserve that now fuels some 80 percent of power generation is likely to exhaust within three to four years. This situation demands harnessing other energy resources among which solar energy is a vital one. As there is no fuel cost in PV generation and it produces pollution free green energy with nominal maintenance cost, this can be an attractive choice to cope with the present power crisis in Bangladesh.

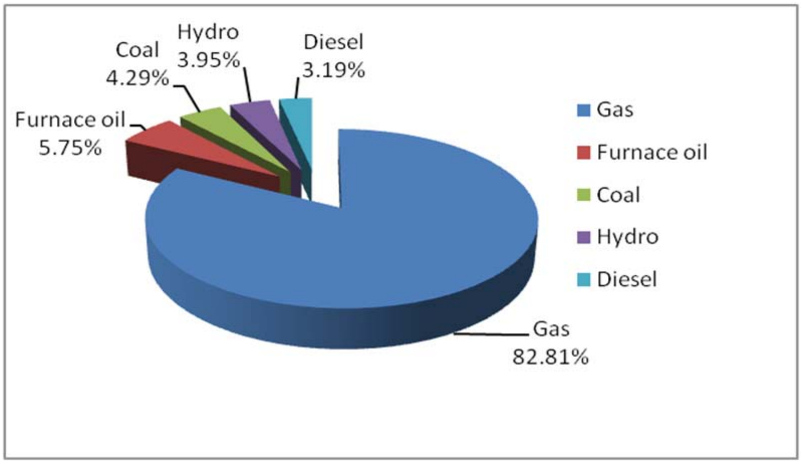


Fig 3: Generation capacity according to fuel type [5]

**3.2 Transmission & Distribution**

BPDB is responsible for distribution of electricity in most of the areas in Bangladesh except Dhaka Metropolitan City and its adjoining areas under DESA and DESCO, areas under West Zone Power Distribution Company Limited (WZPDCL) and some of the rural areas under Rural Electrification Board ( REB). At present only 47% of the population is served with electricity and per capita electricity consumption is only 156 kWh. [5]

**3.2 Renewable Energy Use**

In Bangladesh every month more than 30,000 Solar Home Systems (SHS) are being installed in a bid to reduce greenhouse emissions and ensures sustainable development in the energy sector. Every month those solar home systems are adding one and a half MW of electricity. [6]
At present more than 3, 00,000 houses of 465 upazilla of all the districts and 16 islands are getting the light of solar energy. The beneficiaries of this system is about 3 millions.44 megawatt electricity is produced everyday from the solar projects in Bangladesh. [7]

**4. PROSPECT OF GREEN TECNOLOGY**

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. [8]
The solar energy system can provide reliable, clean and environment friendly electricity supply in the different areas of Bangladesh. At present contribution of solar in electricity generation is only 0.9% which includes solar home system(SHS), centralized ( AC) system, centralized(AC) market electrification, water pumping, roof top PV mini-grid system, telecommunications, railway signaling, refrigeration, cyclone shelters, community places etc. Grid-connected PV power systems are being installed in cities in different countries of the world. Government policies are being framed to encourage and popularize this system by providing necessary regulations and incentives. The Government of Bangladesh should also take such steps to spread green electricity throughout the country.

Table 1: Comparative study between PV & other generation [8]

| Type | Total Generation | Remarks |
|---|---|---|
| Conventional Fuel | 4698.5 MW | PV generation is only 0.95% of total generation |
| PV generation | 45MW | |

From the gradual decrease of prices and increased rate of installation of the systems in the cities all over the world it can be easily comprehended that this system will become an important source of electricity in a very short time in the urban areas. Currently Bangladesh is experiencing the acutest load shedding in its history. Solar PV power plant can minimize this crisis by producing green energy.

## 5. OFF GRID ELECTRIFICATION

### 5.1. Existing Grid Network

Different types of power plants generate electricity and synchronize it with the national grid. PGCB owns and operates the high voltage grid network throughout Bangladesh. The national grid operates at 230 KV, 132 KV and 66 KV and controls and manages the second to second operation of electricity transmission system, balancing electricity generation to meet the demand.

About 50% of the populations in Bangladesh are not connected to the electricity. Most people in rural villages depend on kerosene for lighting, and biomass fuels such as agricultural residues and fuel wood for cooking. This absence of reliable power remains a significant barrier to economic development and reducing poverty in Bangladesh. Lack of access to electricity is disempowering on many levels – it deprives people of opportunities for education, productive activities and rural economic development.

### 5.2 Grid Expansion & Limits

Although the grid spreads on a relatively great part of the country, but still leaves many regions out of it. Furthermore, the grid is concentrated on the main cities of the country. Supplying energy from the traditional grid system will be difficult because of infrastructure problems and the lack of economic resources in our countries.

### 5.3 PV technology for off grid rural electrification

Photovoltaic system use solar energy for generation of electricity. This system does not require any kind of conventional fuels. Since solar energy is available everywhere, this new technology may serve as a great booster for rural electrification. This technology is being utilized in many countries to supply electricity in a decentralized mode. With all the possible attempts on the part of PDB and REB it will not be possible to reach electricity to all villages, islands, coastal areas, hilly areas and other inaccessible parts of the country because of the scattering of households in the rural areas resulting into low consumer density, transmission and distribution cost from a central grid will be prohibitively high. The only way to overcome this difficulty is the decentralized mode of power distribution which can be conveniently provided by PV systems. This is a unique advantage of this new technology. This off grid PV generation can improve the quality of life of the rural people and ultimately can lead the socio-economic development of the country.

Fig 4: Solar water pumping demonstration project in Savar, Dhaka

## 6. SOLAR WATER PUMPING

There are some 1.3 million irrigation pumps across the country, which consumes about 800MW of electricity everyday during irrigation season. Bangladesh has diesel-based irrigation system and only 12.5 per cent of the pumps are electricity-driven while 2.5 per cent pumps are driven by both electricity and diesel. [9]

It is also estimated that replacement of only one per cent of the country's total diesel pumps with the solar pumps could help save US$ 12 million. At present, there are 1,015,000 low-lift pumps, 145,000 shallow pumps and 29,000 deep tube wells in the country being used for irrigation. Of the total pumps, 85 per cent are diesel-driven, consuming 800,000 tons of diesel annually. [10]

Thus the government should take initiative to diversify the use of solar power for agriculture irrigation that now consumes around 800 mw of electricity from the power-hungry grid. The initial cost of the solar irrigation system would be much higher but the experts believe that it would be a cost effective alternative to diesel-based irrigation.

## 8. OBSTACLES & RECOMMENDATIONS

### 8.1. Obstacles

In many developed and developing countries Government policies are being framed to encourage and popularize PV system by providing necessary regulations and incentives. From the increased rate of installation of the systems in the cities all over the world it can be easily comprehended that this system will become an important source of electricity in future. The major obstacles to rapid expansion of PV generation in Bangladesh are as follows:

- The main hindrance is the high installation cost of PV system due to high price of the PV module in international market. But it is hopeful that, there is a historical trend of capital cost reduction for PV technology all over the world. This is expected to happen globally within the next decade.
- Lack of awareness about the PV technology
- Absence of proper planning and design
- Less financial incentives from the government
- Lack of domestic manufacturing
- Lack of information about renewable energy resources, technical/economic information about RETs, equipment suppliers, and potential financiers
- Unfavorable utility regulations to renewable energy development

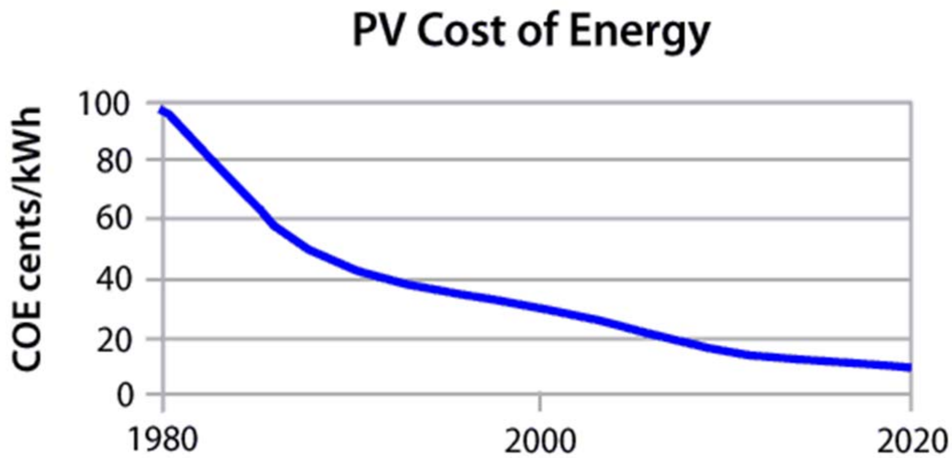


Fig 5: PV cost decreasing [11]

### 8.2. Recommendations

For rapid expansion of PV technology following steps should be taken:

- PV system marketing organizations should develop more flexible and easy financing schemes for the system buyers
- A successful national solar energy program should be launched. Government should also give financial incentives to private and non-governmental organizations to come forward with innovative PV programs for rural areas
- Incentives & consumer credit schemes should be introduced
- Consumer awareness should be increased through demonstration projects

## 9. CONCLUSION

Electricity does not travel alone. When it makes its advent in a country, speedy changes take place concomitantly in many areas of life and living. Not only homes are lit, life is transformed. This transformation must be accelerated. The more than half of the population unlit by power must be covered speedily. Photovoltaic technology can play a significant role in this field. Again there are more than 87,000 villages in Bangladesh and most of them are not connected to the national grid. In such cases off grid PV generation can improve the quality of life of the rural people and ultimately can lead the socio-economic development of the country. The instruments that can be applied to encourage PV technology promotion are incentives, consumer credit schemes, capacity building and to establish a renewable energy service authority. So it is high time the Government should take necessary steps for green electrification in Bangladesh.

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# MORPHOLOGICAL STUDY AROUND THE INTAKE REACH OF THE OLD BRAHMAPUTRA RIVER

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**ABSTRACT**

A study has been conducted to investigate various aspects related to morphology of the intake reach of the Old Brahmaputra River. The study considered use of satellite images covering the period from 1973 to 2007. The cross-sectional data around the mouth, water level, and discharge data covering the period from 1973 to 2005 were collected. In addition, sediment discharge data were collected for the years from 1988 to 1993. The length of the Intake Reach was considered 26 km and was divided into sixteen sections. All bends were considered for determining meandering parameters.

Study of satellite images shows that the change of plan form of this river is significant. The maximum migration rate at the mouth of the Old Brahmaputra River was found during 1973-1984 with average migration rate of 158 m/yr towards north-west direction. The study indicated that the river has become dominantly narrower although both narrowing and widening of the channel have been observed in the area. The average widening of the Intake reach for the last 34 years is 36 m/yr and narrowing is 44 m/yr. Increase in sinuosity was associated with larger amount of land erosion in the bends. Both the banks of the Old Brahmaputra river are dynamic but the frequency of bank line movements were different at different sections due to erosion and accretion along the respective reaches The maximum migration along left bank was found as 2150 m while the minimum migration was 33 m. The maximum migration along right bank was 2297 m while the minimum was 31 m. The cross-sectional area was found to vary considerably and the study showed that sedimentation was dominant over the period. In 1973, percentage of Jamuna River flow to the Old Brahmaputra River was 7% and in 2007 this percentage of flow reduced to 0.70%. This reduction of flow accelerated the siltation process at the Intake reach of the Old Brahmaputra River.

**Key words**: Old Brahmaputra River, morphology, cross-section, sedimentation, erosion, thalweg, sinuosity

## 1. INTRODUCTION

The Old Brahmaputra, a left bank distributary of the Jamuna river takes off at Kholabarichar, approximately 10 km upstream from Bahadurabad and follows a south easterly course via Mymensingh and Toke up to Bhairab Bazar at the confluence with the Upper Meghna river(Fig.1). The river length between the off take and outfall is approximately 225km. The mouth of the river is not stable and changes when the left bank anabranch of the Jamuna River has a changing discharge [1]. The length of the Intake reach considered for the study is about 26km starting from Kholabarichar to Jhenai offtake. The culture and cultivation practice of people of the region has influenced due to erosion & sedimentation of the river.

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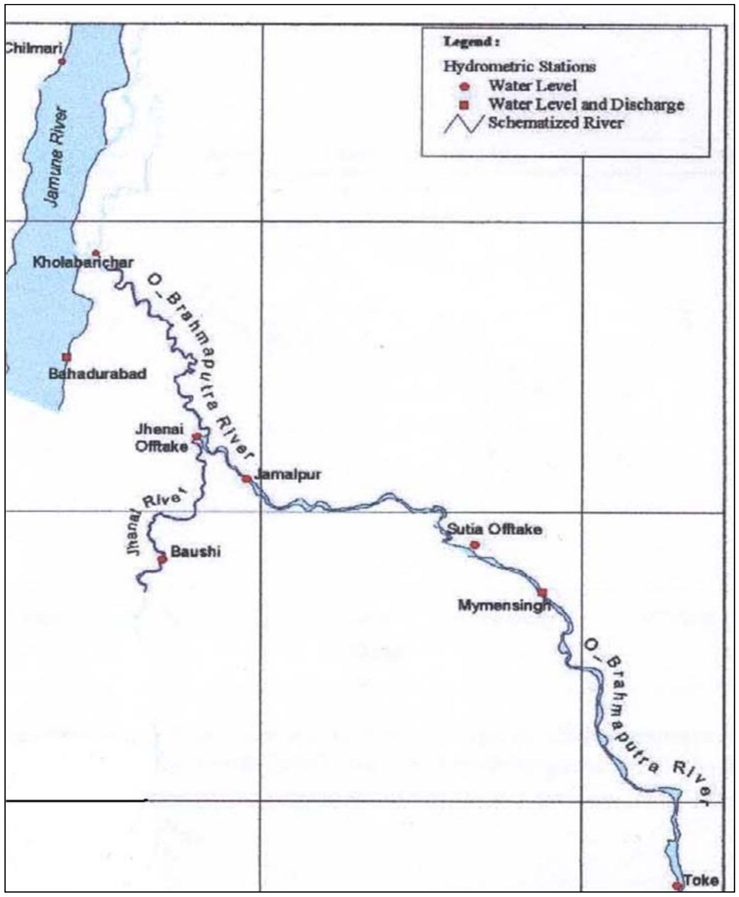


Fig. 1 Location of the study area

A number of studies have been carried out in the past, particularly concerning the morphological processes in the large rivers around the world including the Jamuna, the Ganges and the Meghna ([2]; [3]; [4]; [5];[6];[7]; [8]; [9]; [10]; and [11]). These researchers investigated various aspects related to morphology including plan form characteristics, geometry and sediment loads of the rivers system. Holeman reported an annual sediment load is about of 2.4 billion tons per year [12]. Coleman found the value of annual sediment load for the Ganges as 500 million tons and for the Brahmaputra 750 million tons per year [13]. The most rigorous analysis for assessment of sediment loads in the major rivers of Bangladesh was carried out by Hossain [14] and he concluded that the Ganges and Jamuna system carry a maximum sediment load of about of 1.6 billion tons, average being in the range of 1.1 to 1.4 billion tons annually. BWDB [15] found that the Jamuna carries 541 million tons and Ganges carries 520 million tons sediment on average per year which was later confirmed by Alam and Hossain [16]. The sediment load and water flow in the Brahmaputra-Jamuna has a direct influence on the morphology of the Old Brahmaputra River.

Preliminary reviews of published reports reveal that the Old Brahmaputra River appears to be going through a process of aggradations and degradation. The river at present has reduced to a spill channel of the Brahmaputra- Jamuna River, and active only during high river stage. Its hydrological regime is becoming flashier than perennial rivers. The average annual discharge of the river is showing a decreasing trend. Gradual silting of the mouth of Old Brahmaputra is creating obstruction of smooth flow from the Brahmaputra to downstream reaches. In addition migrations of off-take at various times have also effects on the shifting nature of the river downstream affecting the livelihood of the people of the region. In view of the above, a study has been conducted to study problems associated with the morphology at the Intake reach of the Old Brahmaputra River.

## 2. DATA AND METHODOLOGY

Secondary data from CEGIS, IWM, and BWDB were collected for conducting the research. The type of data is: satellite images, cross-sections, water level and discharge and sediment related data. Satellite images covering the period 1973-2007 were collected from CEGIS. All available data on cross-sections, water level, discharge and sediment loads covering a period from 1964 to 2008 of the Old Brahmaputra and Brahmaputra-Jamuna were collected from BWDB and IWM.
The software Arc View 3.3 was used for analyzing the images. The variation of the width of Intake reach was assessed. Year-wise cross-sectional data were used to calculate various geometric parameters. Intake reach of the Old Brahmaputra River was divided into sixteen sections for calculation of variation of width, bank line, thalweg shifting etc. Thirteen bends were selected along the intake reach of the river for determination of meandering parameter.

## 3. RESULT AND DISCUSSION

### 3.1 Analysis of Satellite Images

Twelve satellite images of the Old Brahmaputra River for the years 1973, 1976, 1980, 1984, 1987, 1989, 1992, 1995, 1997, 2000, 2002 and 2007 were utilized. Up to 1987 LANDSAT, MSS images are available and from 1989 LANDSAT, Thematic Mapper (TM) images are available. The MSS images have ground resolution of 80m x 80m, whereas the TM images have ground resolution of 30m x 30m. Over the past decades, Old Brahmaputra River is showing a deterioration of hydraulic and morphologic conditions. It is widely believed that silt accumulation at the intake reach of the old Brahmaputra due to gradual decline of flow from the parent river Brahmaputra is responsible for developing the situation. The shifting of the old Brahmaputra in the intake reach was considered on the basis of shifting in BTM coordinates in terms of Easting and Northing. Separate computations were made in this respect. The resultant shifting of the mouth of the old Brahmaputra River is shown in Fig. 2.

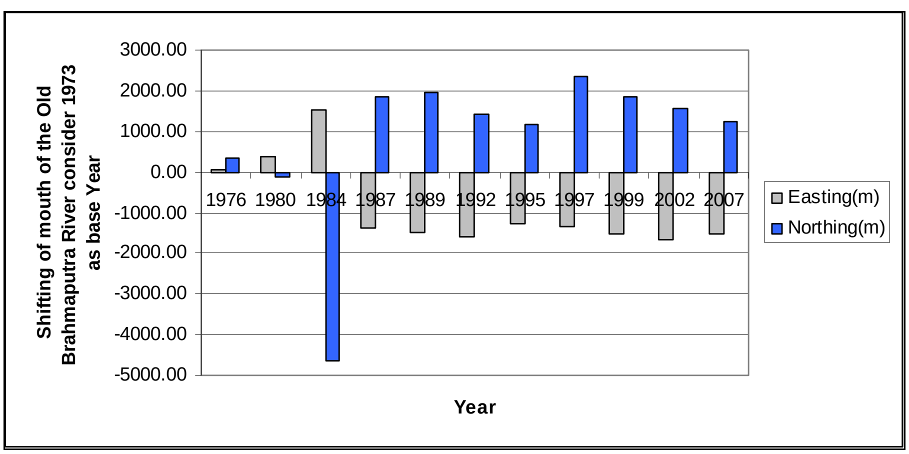


Fig. 2 Resultant shifting of the mouth of the old Brahmaputra River

From 1973 to 2007, the average difference in northing is 989.12 m and easting is 868.48 m. The overall trend line of northing is increasing and easting is decreasing, which indicates that the mouth of the Old Brahmaputra River is shifting towards north-west ward. A close examination of the figures shows that the shifting magnitude varies in various years from 1973 to 2007 and that the maximum migration rate around the mouth reach of the Old Brahmaputra River is found during 1973-1984. The average migration rate is during the study period was about160 m/yr.

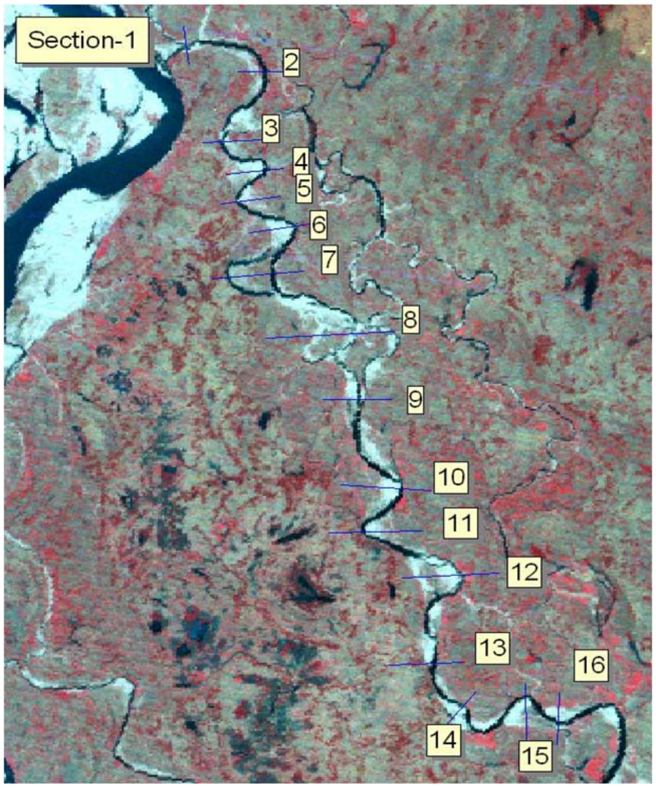


Fig. 3 Intake reach transects on the satellite images

**3.2 Variation of Width**

The width of the river is defined as the distance between two banks as drawn from satellite images. Here width of the river measured from the images considering the point bars and active corridors, which go under water during monsoon. Fig. 3 shows the 16 intake reach transects for calculation purpose on the satellite image. Typical variation of width at various transects from section-1 to 4 is shown in Figs. 4. For average width calculation, the Intake reach was divided to three reaches. This variation is shown in Fig. 5

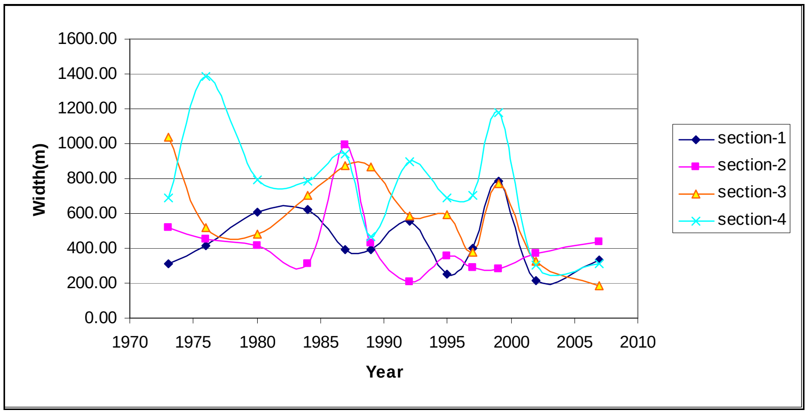


Fig. 4 Variation of width for section 1 to 4, of the old Brahmaputra

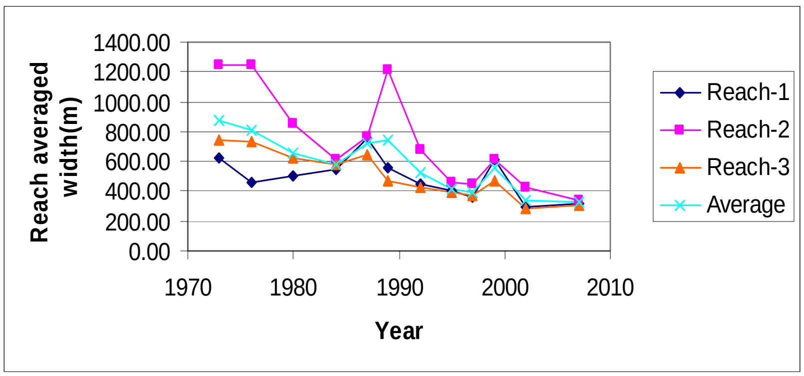


Fig. 5 Reach-averaged width of the Intake reaches of Old Brahmaputra River

Analysis of graphical plots shows that the width in general has a decreasing trend. From 1973 to 2007 both narrowing and widening of the channel have been manifested in all sections but the channel narrowing process appears to be a dominant. The maximum widening rate was 307.55 m/yr at section-7 and minimum widening rate was 60.09 m/yr at section -8. The maximum narrowing rate was 467.39 m/yr at section-3 and minimum narrowing rate was 78.74 m/yr at section-16. The average widening of the channel for the last 34 years is 36.49 m/yr and narrowing is 44.16 m/yr.

### 3.3 Bank Line Migration

Analysis of the satellite imagery over the last 34 years from 1973 to 2007 shows that both the banks of the Old Brahmaputra river are dynamic but the frequency of bank line movements were different at different sections due to erosion and accretion along the respective reaches. Time series satellite images of intake reach were utilized in order to carry out the analysis. Bank line shifting of the Intake reach of the river from both left and right bank was determined using the satellite images. Typical bank line shifting of the left bank with respect to 1973 bank line is shown in Fig. 6. The analysis shows that the maximum migration from left bank was 2149.29 m at section-15 during 1973-1999 and minimum migration was 33.14 m at section-9 during 1973-2002.The maximum migration from right bank was 2297.12 m at section-4 during 1973-1995 and minimum was 30.55m at section-11 during 1973-1995. Massive changes occurred in bank line shifting after the flood of 1988 and 1998.

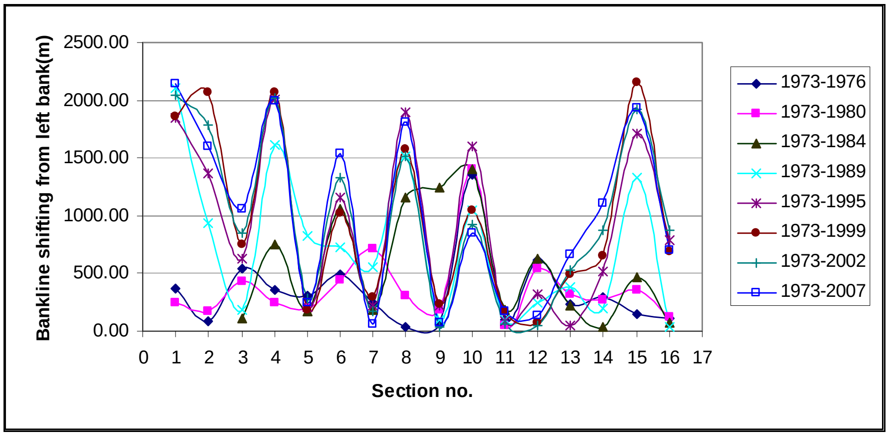


Fig. 6 Bank line shifting of the left bank of the Old Brahmaputra River

### 3.4 Variation of Cross-sectional Area

River morphology and research circle (RMRC) of BWDB surveys 36 cross sections on the Old Brahmaputra at a number of standard transects designated as OB-1 to OB-36 spaced approximately at 6.5 km, starting from the off take with the Brahmaputra (OB-1) to the confluence with the upper Meghna at Bhairab bazaar (OB-36). The variation of cross-sectional area for different years was determined by superposition of cross-section of various years. A typical plot is shown in Fig. 7 & Fig. 8.

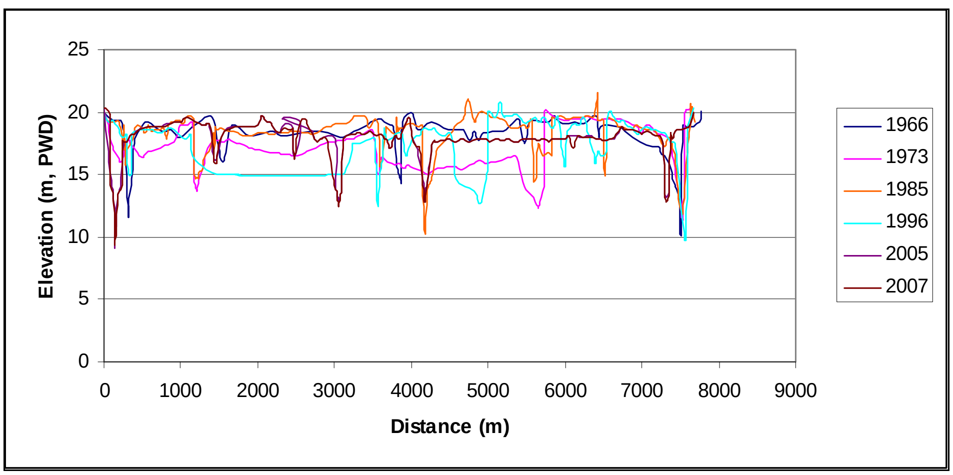


Fig. 7 Variation of Cross-sectional area at Section-2 near mouth of the Old Brahmaputra

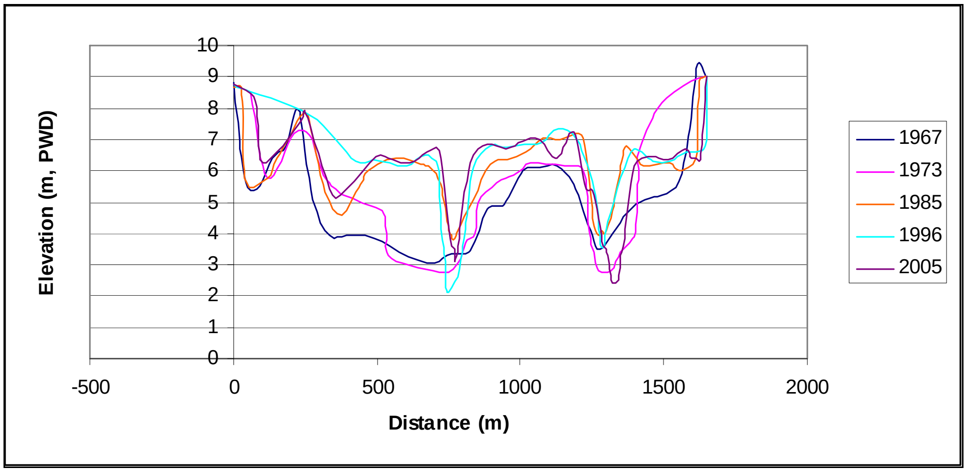


Fig. 8 Variation of Cross-sectional area at Section-34 near outfall with the Meghna

### 3.5 Mean Bed Level

Analysis on erosion and deposition has been carried out for Old Brahmaputra River by comparing the mean bed profiles over the years. The computation of the mean bed level was carried out at bank full stage condition. To observe and evaluate the effects of erosion and deposition on mean bed level, mean bed level of the selected 11 sections for different year were computed and is presented in the Fig. 9. It may be observed from Fig. 9 that the maximum mean bed level is happened in the cross section OB-1 and minimum bed level is at OB-34 section. It may be apparent from the figure that the mean bed level of the Old Brahmaputra River is dynamic and it varies significantly over the years.

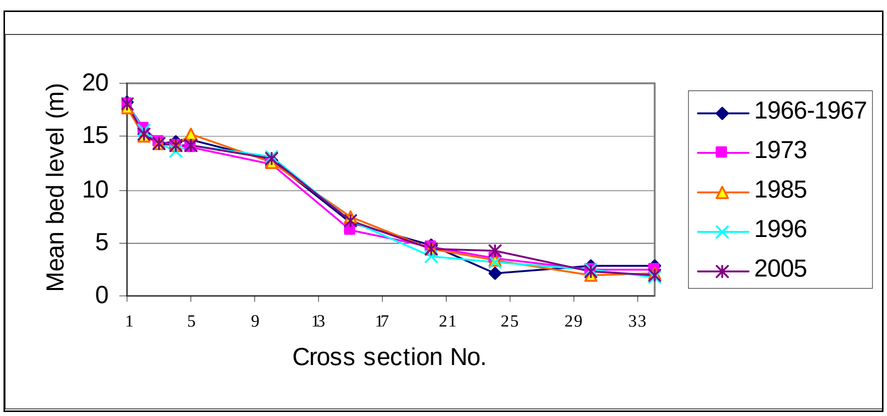


Fig 9: Mean bed level variation of Old Brahmaputra River

Although the exact amount of erosion and deposition occurred all over the river was not possible due to the limited data, however, an indicative value of the erosion and sedimentation activities prevailing in that river was obtained. One very important aspect that was reveled is that there is a gradual rise of mean bed level of about 2.10 m during 1996 to 2005. This raising of bed level is clear indication of sedimentation. The bed slope is very steep at the upstream reach of the river; the slope is moderately steep at the middle reach of the river. The slope is relatively flat at the downstream reach of the river.

### 3.6 Thalweg Profile

In a river highly charged with sediment, the bed configuration changes drastically under different flow regimes. Deposition of sediment in one place causes deepening by scour in another place. Thus the thalweg tends to wander continuously from one position to another within the river bank lines. Deepest points of all available cross-sections from 1966 to 2005 are shown in Fig.10

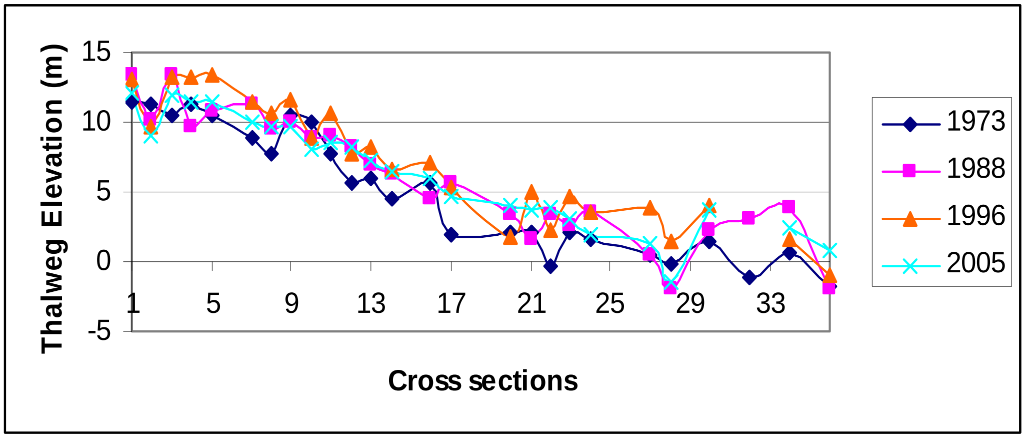


Fig. 10 Thalweg elevation of Old Brahmaputra River in different years

Fig. 11 shows that there is a decreasing trend in percentage of Brahmaputra flow to Old Brahmaputra. From 1973 percentage of Jamuna river flow to the Old Brahmaputra river was 7% and in 2007 this percentage of flow is reduced to 0.70%.This reduction of flow accelerated the siltation problem at the mouth.

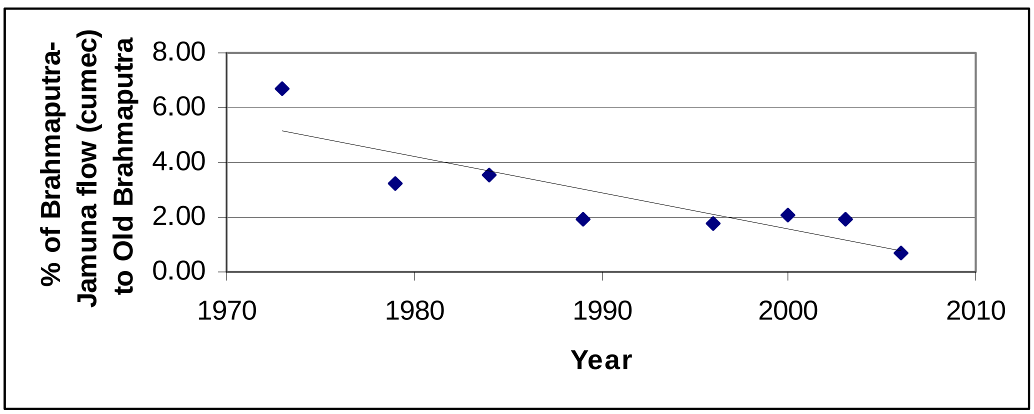


Fig. 11 Percentage of Maximum Discharge of Brahmaputra to Old Brahmaputra River

## 4. CONCLUSION

From 1973 to 2007, the mouth of the Old Brahmaputra River is shifting towards north-west ward. The width of the river was found to vary randomly from section to sections and from year to year; both narrowing and widening of the channel have been observed in all sections but the channel narrowing process appears to be a dominant process.

The study revealed that both the banks of the Old Brahmaputra river are dynamic but the frequency of bank line movements were different at different sections due to erosion and accretion along the respective reaches. Massive changes occurred in bank line shifting after the large flood of 1988 and 1998. Increase in sinuosity was associated with larger amount of land erosion in the bends.
Mean bed level rise was about 2.10 m on average during 1996 to 2005.The bed slope is steeper at the upstream reach of the river; the slope is moderately steep at the middle reach of the river and is relatively flat at the downstream reach of the river.
There is a decreasing trend in percentage of Brahmaputra flow to Old Brahmaputra. The maximum flow entry decreased from 7% to 0.70% from 1973 to 2006. The declining discharge from Parent River to Old Brahmaputra river caused accelerated sedimentation around the mouth.

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# A MICROCONTROLLER BASED AUTOMATIC SOLAR TRACKING SCHEME

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## ABSTRACT

A solar energy collecting surface performs best whenever it is faced to the sun. In this research, studies have been carried out to develop a microprocessor based automatic solar tracker locally with least cost. The system has been programmed to detect the intensity of sunlight by a differential arrangement of two photoresistors and subsequently actuate the motor to position the solar panel where it can receive maximum sunlight. This permits the solar panel moving from east to west and returning from west to the east, within the angle regulation range of 0-180° forward and reverse. The designed system can track the better sunlight position within 1 sec. This microcontroller based system with its auxiliaries and stepper motor drive arrangement made it interactive with high degree of dynamic and steady state stability.

**Key Words:** Renewable energy, photovoltaic, solar tracking system, microcontroller, stepper motor, maximum power capture, closed-loop control.

## 1. INTRODUCTION

Energy is one of the key building blocks of sustainable development. Even today one third of the world population does not have access to electricity and are not connected to the national grid. Solar, wind, and hydroelectric power not only produce minimal carbon emissions once the generating systems are in place, they also help reduce poverty through improved energy access in underserved areas. Photovoltaic (PV) system will need to play a significant role in the world's energy mix in 2050 to help achieve global climate change goals at the lowest cost [1]. The International Energy Agency estimates that nearly 50% of global electricity supplies will need to come from renewable energy sources in order to halve carbon dioxide emissions by 2050 and minimize significant, irreversible climate change impacts [2].

Solar panels are generally statically aligned at lattitude tilt angle, they have a fixed position at that certain angle towards the sky; the time and intensity of direct sunlight falling upon the solar panel is greatly reduced, it results in low power output from the PV cells. In order to have maximum power capture throughout the day it is necessary that the photovoltaic panels change their orientation throughout the day following the path of the sun in the sky, this is

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possible by means of an automatic solar tracking system. A solar tracker improves the efficiency of solar electric or thermal energy conversion system [3]. The main reason to use a solar tracker is to reduce the cost of the energy captured by the solar panel and other criterion for solar tracker is the efficiency. A tracker produces more power over a longer time than a stationary array with the same number of modules.

From the past decades, several techniques and experiment has been developed for solar tracking device for an alternative source of energy. In this work we present a single axis tracker. It helps maximizing the investment in a PV system. Embedded controlled solar tracker like [4] needs statistical data over a long period of time. Conversely presented prototype avoids all the complex calculations. This scheme can be easily converted to a dual axis tracker. Actually trackers need not point directly at the sun to be effective, and if the aim is off by ten degrees the output is still 98.5% of the full-tracking maximum. Dual axis tracking is effective only for seasonal tracking; therefore single axis tracking is sufficient for effective energy transformation. It has better accuracy. It has less dependence in hardware. It is more feasible than [5, 6]. It is very user friendly, easily reprogrammable and numerous features can be added to it, if required.

## 2. SOLAR TRACKERS

A Solar tracker is a device for orienting a solar photovoltaic panel or concentrating solar reflector or lens toward the sun. The sun's position in the sky varies both with the seasons (elevation) and time of day as the sun moves across the sky. Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position, at the cost of additional system complexity. The additional output or "gain" can be quantified as a percentage of the output of the stationary array. Gain varies significantly with latitude, climate, and the type of tracker one chooses- as well as the orientation of a stationary installation in the same location. (The energy required to move the tracker is insignificant in these calculations.)

Climate is the most important factor. The more sun and less clouds, moisture, haze, dust, and smog, the greater the gain provided by trackers. At higher latitudes gain will be increased due to the long arc of the summer sun. In the cloudiest, haziest locations the gain in annual output from trackers can be in the low 20 percent range. In a given area the annual gain on any given day may vary from almost zero to nearly 100 percent. In general, a tracker adds most to output during the hours when a stationary array produces the least power.

There are several types of classification of solar tracker. Considering movement capability, three main types of sun trackers can be found-fixed surfaces [7], one axis trackers [8] and two axes trackers [9].The amount energy they produce is varied due to the ability of reducing the pointing error, increasing the daily irradiation that the solar cells receive. Different studies have been made to do a comparative study between the energy available to a two axes tracker, an east–west tracker and a fixed surface [10].

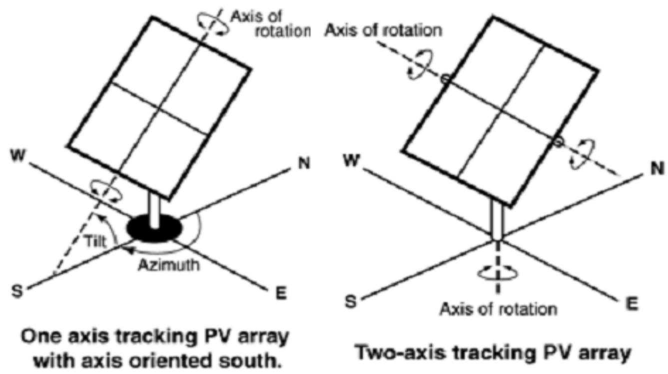


Fig 1: One and two axis tracking PV array [4, 11]

As main results, it concluded that the annual energy available to the ideal tracker is higher by 5–10% and 50% than the east–west tracker and the fixed surface, respectively. Another classification can be made regarding control units, the major types of solar trackers are [12]: passive, microprocessor and electro-optical controlled units. In the first one there is no electronic control or motor [13]. The second ones use mathematical formulae to predict the sun's movement and need not sense the sunlight. An example of this kind of unit can be found in [9]. And in the last one, the electro-optical controlled units that use the sensing information from sensor like auxiliary bifacial solar cell panel, pyrheliometer to estimate the sun's real position and use in the control algorithm [8, 14].

### 2.1 Closed-loop types of sun tracking systems

Closed-loop types of sun tracking systems are based on feedback control principles. In these systems, a number of inputs are transferred to a controller from sensors which detect relevant parameters induced by the sun, manipulated in the controller and then yield outputs (i.e. sensor-based). From performance test of sun-tracking systems [15] gain in energy production comparing with a non-tracking systems and error is compared between open-loop and close-loop control sun-trackers. Using open-loop control sun tracker maximum 41% gain has been achieved than the non-tracking modules. Energy production gain can be 10-75% for different type close-loop control sun trackers.

## 3. FRAMEWORK OF THE SOLAR TRACKER PROTOTYPE

**The design we present is based on the following criterions-**

- Simplicity
- Low cost
- Easy to construct
- Minimum maintenance
- Reliability
- Less steady state error
- Dynamic output
- High Convergence Speed
- Availability of components
- Independent of PV characteristics

### 3.1 Working methodology of designed solar tracker

This design is developed and implemented using a simplified horizontal-axis and active tracker method fitted to a solar panel. It is able to navigate to the best angle of exposure of

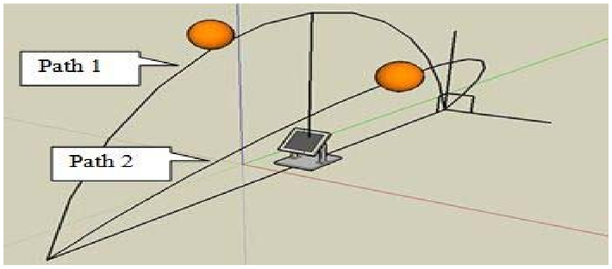


Fig 2: Sun path

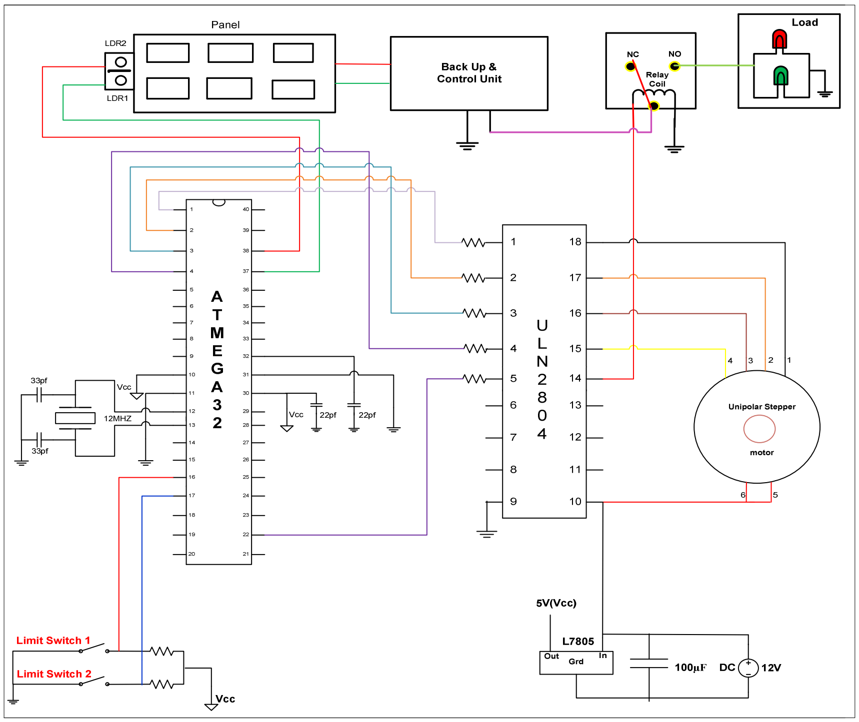


Fig 3: Schematic diagram of single axis high precision solar tracker circuit

light, entailing control of one angle. This tracker implies tracking only in path 1 but not Path 2 (Fig 2); to comprise tracking in path-2 facilitation to control the azimuth and latitude angle is necessary.

The eyes of the Solar Tracker are taken care by the photo resistor. The photo resistors are imperative to detect the amount of illumination; two Cadmium Sulphide (CdS) light sensors are used as comparator of light intensity. When one of the sensors has higher intensity of light, the position of the sun is on the side of that light sensor. In this prototype, the two photocells have been positioned on a small straight piece of plastic; an additional small piece has been placed perpendicular to the straight piece to divide both the sensors. The purpose of doing so is that- if both the photocells are equally illuminated by the sun, their resistance level will be same; if one of the sensors comes under shadow, then the controller of the tracking system will sense the deviation of signal and it will generate actuating signals for drivers to correct misalignment between sun's ray and the surface normal. The microcontroller is programmed so that it can attain signal from the two light dependent resistors (LDR) and to move motor either clock wise or anti clock wise depending on which LDR is under shadow, to a position where equal light is being illuminated on both of them.

Obviously in real world solar trackers are not so simple. A solar tracker must be able to reset itself at sunset so it is ready for sunrise.For this two limit switches are placed at both sides of the stand. When the tracking is going on then the motor will rotate in one direction and when the sun goes set the stepper motor will rotate in reverse direction as one of the limit switch will be touched. This is done for tracking the sun for next day morning. The other limit switch is used to give signal when the panel touches it so that the microcontroller can generate a pulse to halts rotation until next sunrise is sensed by the light sensors.

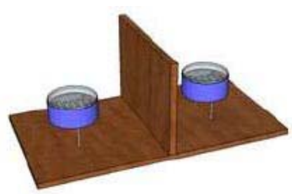

Fig 4: Sensor module

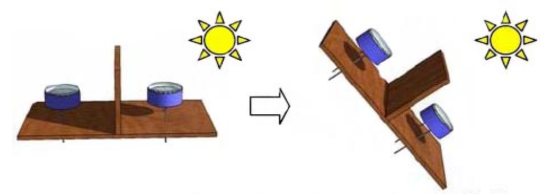

Fig 5: Operation of sensor module once an LDR comes under shadow

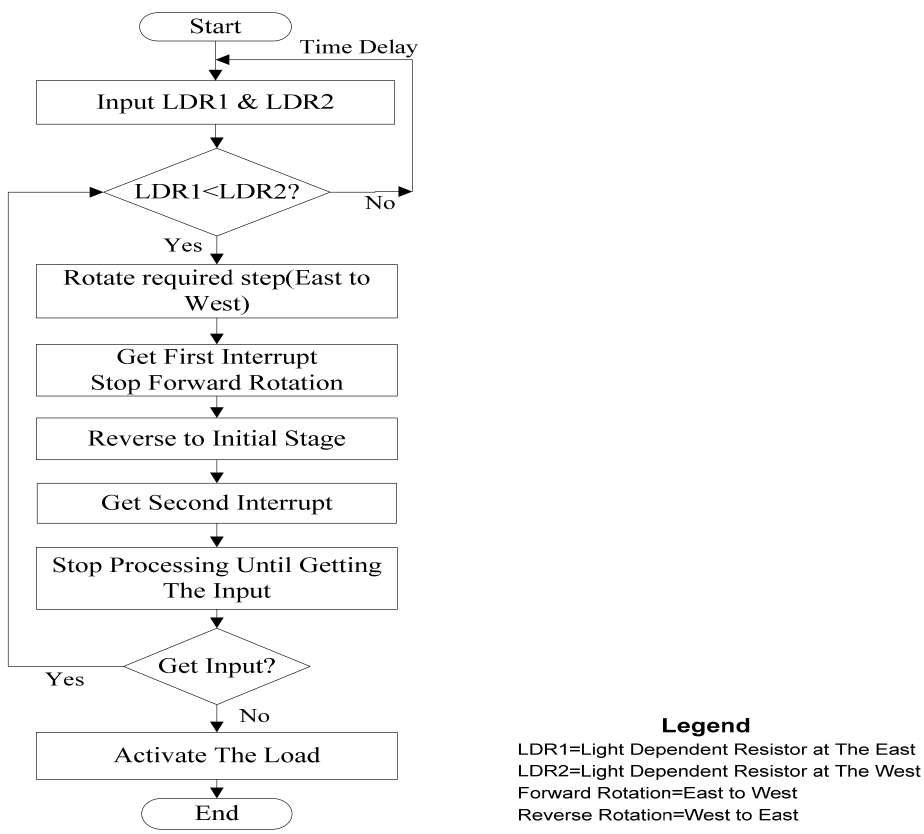


Fig 6: System implementation flowchart

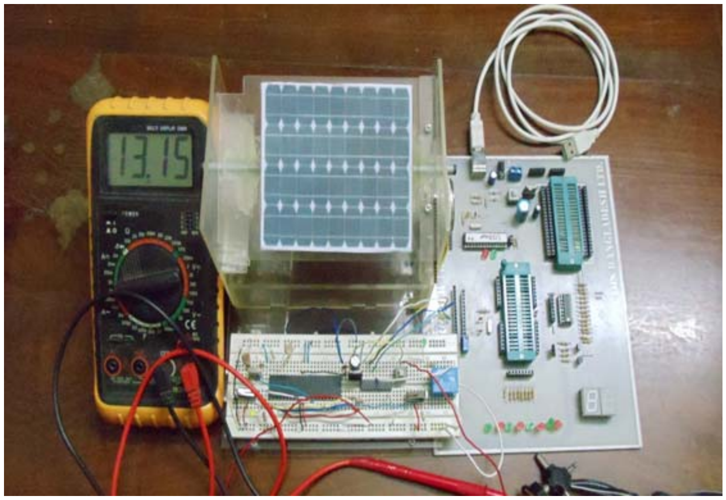

Fig 7: Proposed solar tracker prototype

### 3.2 Overall design considerations

In terms of optimal functionality, the barrier between two LDRs should be adjusted based on the location where to implement. To protect the photovoltaic array from damage, protection diodes were used. Two lead acid battery banks may be utilized- only one battery bank will be charged at a time, the other may be employed to run other components of the circuitry. In order to tickle charge the batteries, a voltage within cut off points must be fed to the bank. Voltage regulators may need a proper heat sink to operate smoothly.

## 4. DESCRIPTION OF MAJOR COMPONENTS

### 4.1 ATmega32 architecture detail

The ATmega32 [16] is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The AVR core combines a rich instruction set with 32 general purpose working registers.

### 4.2 Configuring ATmega32

The AVR Microcontroller chosen for the system, has sufficient memory to meet the requirements of the design. The analog to digital converters (ADC) is integrated in the AVR which reduced the amount of additional external parts. As program compiler AVR studio is used and Extreme Burner is used to burn the microcontroller.

To configure the microcontroller unit (MCU), 5 Volt digital supply from the voltage regulator is fed to Vcc (Pin 10). Pin 32 is the analog reference signal for the A/D converter. Analog input from LDR-1 and LDR-2 is received by Pin 37 and Pin 38 of port A respectively and converted to digital signal. Port A receives supply voltage through AVCC and a low pass filter is used in this case to use port A as ADC. Built-in compare [5] is there to compare the input values. PB0- PB4 is connected with the driver to provide signaling information to the motor. Port D is configured to conduct the limit switches through interrupt signals via PD2 (INT0) and PD3 (INT1). Inverting oscillator amplifier receives input signal from XTAL1 (Pin 12) and XTAL2 (Pin 13) of MCU and is configured to be employed as an On-chip Oscillator. Few delays are purposely introduced in order to avoid gratuitous assessment, tracking, rotation and signaling.

### 4.3 Relay

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts [17]. In this design a relay is used as an automatic switch which enables the current flow from the battery at night and in the day when the sun light is available then the PV output is fed into the battery for charging [18].

### 4.4 High-voltage, high-current Darlington arrays

This is two transistors connected together so that the current amplified by the first is amplified further by the second transistor. The overall current gain is equal to the two individual gains multiplied together: Darlington pair current gain, hFE = hFE1 × hFE2 (hFE1 and hFE2 are the gains of the individual transistors).This gives the Darlington pair a very high current gain, such as 10000, so that only a tiny base current is required to make the pair switch on. A Darlington pair behaves like a single transistor with a very high current gain. In this work ULN2804 [19] is used. The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open–collector outputs and freewheeling clamp diodes for transient suppression. The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS.

### 4.5 Voltage regulator

A Voltage Regulator (also called a "regulator") has only three legs and appears to be a comparatively simple device but it is actually a very complex integrated circuit.

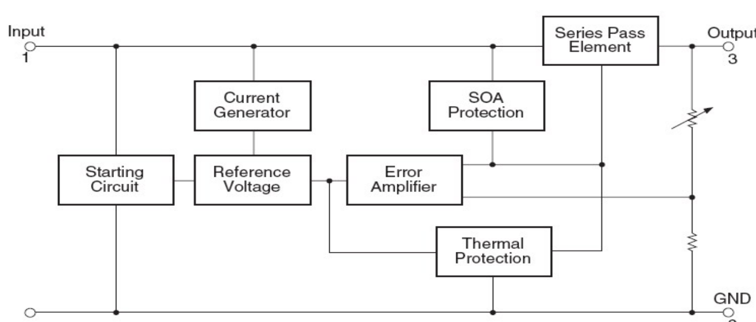


Fig 8: Schematic diagram of voltage regulator

A regulator converts varying input voltage and produces a constant "regulated" output voltage. Voltage regulators are available in a variety of outputs, typically 5 volts, 9 volts and 12 volts. Voltage regulators are very robust. They can withstand over-current draw due to short circuits and also over-heating. In both cases the regulator will shut down before damage occurs. The only way to destroy a regulator is to apply reverse voltage to its input. In this work LM7805 is used for its excellent thermal overload protection, short circuit protection and output transition so a protection.

### 4.7 Light detection theory

A light sensor is the most regular electronic equipment. The simplest optical sensor is a photo resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs) [20]. The sun tracker system designed here uses the cadmium sulfide (CdS) photocell for sensing the light. This photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor. The photocell to be used for the tracker is based on its dark resistance and light saturation resistance. The term light saturation means that further increasing the light intensity to the CdS cells will not decrease its resistance any further [20, 21]. In this work VAC54 [19] is used.

## 5. TEST AND RESULT

From the experiment testing section, we varied the bulbs in four directions; 15, 35, 55 and 75° respectively. The result of time response and speed are as shown in Table 1.

Table 1: Experimental Result

| Position of lamp (°) | Time of positioning to the target (sec) | Response time of the system (sec) |
|---|---|---|
| 15 | 1 | .25 |
| 35 | 1 | .35 |
| 55 | 1 | .45 |
| 75 | 1 | .55 |

Even for variation of small angle this system can response dynamically and no dead band is found. The speed of it position tracking is 1 sec. In order to verify light sensing ability an evaluation is done from the LDR outputs by means of digital display oscilloscope. Figure 9 shows the result when one of the Two LDRs is under shadow. Channel 1 and 2 represent the PA3 and PA4 of ATmega32 respectively. The indication of channel 1 illustrates that LRD1 is under shadow. The signal shown in the figure is sent to the motor drive from the ATmega32. The motor is therefore actuated, and it runs until the resistance on both LDRs is the same. Fig 10 illustrates that, when LDR 1 and LDR 2 both are under shadow i.e. equal sun light is received by both light detector microcontroller puts no comparative output to fed the motor to generate the next pulse. Thus the panel remain in the same position.

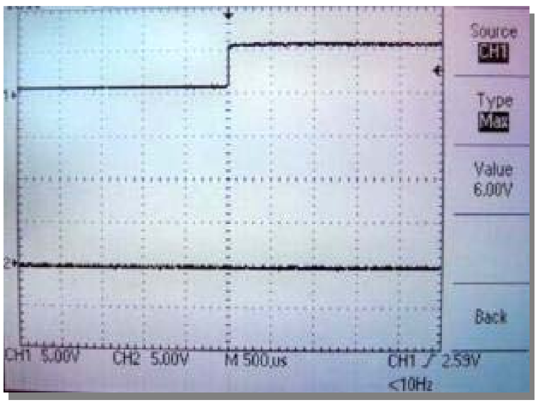


Fig 9: Generated Signal when one LDR is under shadow

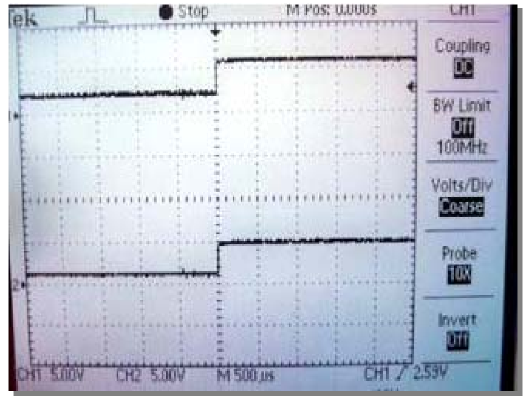


Fig 10: Generated ssignals while both LDRs are under shadow

## 6. FUTURE WORK

The goals of this project were purposely kept within what was believed to be attainable within the allotted timeline. As such, many improvements can be made upon this initial design. That being said, it is felt that this design represents a functioning miniature scale model which could be replicated to a much larger scale. The following recommendations are provided as ideas for future expansion of this project:

• Remedy the motor binding problems due to the photosensor leads. This could be done with some sort of slip ring mechanism, smaller gauge wire, a larger motor with more torque, or a combination of some or all of these ideas.

• Increase the sensitivity and accuracy of tracking by using a different light sensor. A phototransistor with an amplification circuit would provide improved resolution and more précised tracking.

• Utilize a dual-axis design instead of a single-axis to increase PV output to at least 40%.

## 7. CONCLUSION

Different study shows that the factors that influence the performance of the Solar Home System (SHS) in developing countries e.g. Bangladesh indicates that the overall efficiency is quite low. It makes energy cost significantly high and discourages rapid dissemination of the idea of green energy via solar PV modules.

The sun tracking system which is proposed in this article is able to track the sun under clear sky and partly cloudy sky. In worse case, this tracking system disable when there have not a sun under the overcast sky. Presented sun-tracking scheme results in a considerable saving in energy; use of the step-tracking scheme instead of continuous tracking keeps the motors idle for most of the time which also helps to save energy. It is easy to assemble, portable, light and long-lasting. Tracker’s competency depends upon the solar panel weight and the mechanical frame weight. The tracking system is slightly constrained by wind speed because of the lightness of overall scheme. Predetermining the necessary solar panel height from the base can avoid discretionary rotation of the solar panel. The system has 1 sec response time. But this response time can be reconfigured through programming. The short interval will utilize the full bright sunshine hours and will give better output of solar energy collectors. Its dynamic response, least steady state error and stability make the system a substantial one. A typical 100Wp module will give 21% more electricity as fixed at latitude tilt angle. This reveals that the proposed system is compatible with the additional energy production.

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# EFFECT OF FLY ASH ON RAPID CHLORIDE PENETRATION AND STRENGTH OF CONCRETE

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## ABSTRACT

Durability is one of the major design aspects for concrete structures exposed to aggressive environments. Improper selection of concrete materials or concrete mix proportions/ ingredients may cause the deterioration of Reinforced Concrete including the corrosion of embedded reinforcement and eventually lead to reduction of structural integrity and service life. The rapid chloride penetration test (RCPT) as recommended by ASTM method (C1202) virtually measures the electrical conductivity of concrete, which depends on both the pore structure characteristics and pore solution chemistry of concrete. This paper discusses the effects of cement replacement with supplementary cementitious materials on the electrical conductivity of concrete evaluated by RCPT and also the compressive as well as tensile strength development of concrete up to the curing period of 180 days. Cement was partially replaced with seven percentage levels (10%, 20%, 30%, 40%, 50%, 60% and 70%) of Class F fly ash by weight. RCPT was conducted at an age of 28 and 180 days whereas compressive and tensile strength of the concrete specimens were determined at 3, 7, 14, 28, 90 and 180 days. A total of 50 cylindrical specimen of size 100 mm diameter and 50 mm height for RCPT and other 300 specimens of 100 mm cube were cast for compressive and tensile strength test. Test results show that RCPT value decrease with the increase of fly ash level up to an optimum value and then increase. Among all the concretes studied, the optimum amount of cement replacement is reported to be 40%, which provides around 38% lower Coulomb charge passed through concrete specimens as well as around 17% higher compressive strength and 16% higher tensile strength at an curing age of 180 days. The study reveals that fly ash improves the resistance to chloride penetration which may inhibit the chloride induced corrosion of the embedded steel reinforcement.

**Key Words:** Cement, Chloride Permeability, Compressive Strength, Durability, Fly Ash, Tensile Strength.

## 1. INTRODUCTION

A sustainable industrial growth will influence the cement and concrete industry in many respects as the construction industry has environmental impact due to high consumption of energy and other resources. One important issue is the use of environmental-friendly concrete, which is termed as green concrete, to enable worldwide infrastructure growth without affecting the environment [1]. There are great concerns on the strength and durability

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of the concrete being produced with replacement material when used as construction materials in the construction industries. If it is proven that green concrete is durable and strong, this will lead to the use of supplementary material to replace the cement in concrete.

Durability is an important factor for reinforced concrete exposed to adverse environment including underground and on/offshore structures. Corrosion of reinforcing steel resulting from the ingress of chloride ion is one of the most important issues concerning the durability of concrete structures. When the chloride concentration of concrete at rebar level exceeds a certain threshold value, the reinforced steel would start to corrode. The main source of chlorides in concrete is chloride ions ingressing from outside. In the case of highway structures and bridges, de-icing salts ($NaCl$ and $CaCl_2$) act as the main source of chloride. Another source of chloride ions is seawater surrounding the concrete structure. Chlorides can also be deposited on the surface of concrete in the form of very fine airborne drops of seawater, carried by wind. Brackish ground water in contact with concrete is also the source of chlorides. Chlorides penetrate concrete by diffusion of the ions in the water, as well as by capillary action and by absorption. Prolonged or repeated ingress can, with time, result in a high concentration of chloride ions at the surface of reinforcing steel. The resistance of concrete to penetration by chlorides is an important factor in protecting reinforced concrete structures from premature deterioration. Because of the time needed to measure the resistance directly, a relatively rapid indirect test method is developed, which is commonly referred to as the RCPT [2].

Concrete is normally considered to be porous due to existence of capillary pores, gel pores and potentially porous cement-aggregate interface zones. Important traditional means to improve concrete durability are through reduction of water to cement ratio and/or increase of the moist curing period. Recently, many new materials and techniques have been developed to control corrosion by reduction of penetrable aggressive species. Partial replacement of Portland cement with supplementary cementitious materials has been used widely in aggressive environmental applications. It is generally recognized that the introduction of pozzolan in blended cements improves concrete protection against chloride-induced corrosion of steel reinforcement by reducing its permeability/diffusivity, particularly to chloride ion transportation and increasing the resistivity of the concrete [3]. According to ASTM C125, Pozzolan is a siliceous or siliceous and aluminous material which itself possesses little or no cementitious value but will in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Fly ash is the most common pozzolan and is being used worldwide in blended cements. The incorporation of fly ash increases the porosity of the hardened cement paste at early ages, but the average pore size is reduced, and this often results in a less permeable paste [4]. The dense interfacial zone between aggregate and the matrix is also a result of the use of fly ash. The concrete containing fly ash is, therefore, less susceptible to the ingress of the harmful chloride ions. Concrete mixes prepared by supplementary mineral admixtures such as Slag, Fly ash, Silica fume as partial replacement of ordinarily Portland cement gives a new idea to reduce the permeability of concrete [5]. These mineral admixtures may impart proper resistance to chloride and sulfate induced deterioration by modifying the chemistry of pore characteristics of the hardened concrete [6]. Mineral admixtures having high fineness react with the product liberated at early ages during hydration and form secondary C-S-H gel (also referred as tobermorite gel). This gel is less densed and has more volume than primary C-S-H gel. Therefore, it fills all the pores inside concrete and makes the concrete more impermeable thereby reducing the risk of chloride and sulfate induced deterioration.

Fly ash is comprised of the non-combustible mineral portion of coal. When coal is consumed in the power plant, it is first ground to the fineness as powder. Blown into the power plants boiler, the carbon is consumed, leaving molten particles rich in silica alumina and calcium. These particles solidify as microscopic, glassy spheres that are collected from the power plants exhaust before they can fly away- hence the products name fly ash [7]. There are two basic types of fly ash: Class F and Class C. According to ASTM C618, fly ash belongs to Class F if ($SiO_2$+$Al_2O_3$+$Fe_2O_3$) > 70% and belongs to Class C if 70% > ($SiO_2$+$Al_2O_3$+$Fe_2O_3$) > 50%. Both of these fly ashes undergo pozzolanic reaction with lime (Calcium hydroxide) created by hydration of cement and water to form calcium silicate hydrate like cement. In addition, some Class C fly ashes may possess enough lime to be self cementing material in addition to the pozzolanic reaction with lime from cement hydration.

The major aim of this investigation is to evaluate and explore the compatibility of the use of fly ash in structural concrete and its efficiency in enhancing concrete durability performance as well as strength characteristics through improvement of the concrete microstructure.

## 2. RESEARCH SIGNIFICANCE

Portland cement is the most important constituent of concrete. Unfortunately, cement manufacturing consumes large amount energy about $7.36*10^6$ kJ per tone of cement. The net cement production in the world is increased from about 1.4 billion tones in 1995 to almost 2 billion tones in the year 2010. Also, approximately 1 tone of $CO_2$ is released into the atmosphere during the production of 1 tone of cement [8]. This would lead to the emission of about 2 billion tones to $CO_2$ in the atmosphere every year. In order to reduce the harmful green house effect, use of cement must be replaced with other environmentally friendly and efficient cementitious material such as fly ash [9]. It also ensures the proper utilization of fly ash, by-product of coal combustion in power plants, in an effective way which otherwise been dumped making environmental hazard.

The durability of concrete depends a lot upon its resistance to ingress of aggressive species. The aggressive species specially chloride that enters into the concrete can lead to corrosion of steel reinforcement and reduce the life of the structures drastically. So, the durability characteristic of concrete depends largely upon the permeability of concrete that is defined as its ability which allows the fluids to pass through it. Even though durability is a key factor affecting longevity of concrete structures, limited studies are reported to be carried out to investigate the permeability/transport properties of fly ash concrete as obtained by partial replacement of cement. In this study, an attempt has been made to observe the effect of fly ash with different levels on the chloride permeability of concrete.

## 3. EXPERIMENTAL PROGRAM

The experimental program was planed to study the effect of cement composition and replacement of cement with supplementary cementing materials on the electrical conductivity or RCPT results and strength of hardened cement concrete. Cement replacement at various percentage levels were used in this investigation to observe the effects of different fly ash levels in concrete in contributing chloride ion penetration resistance and strength at different curing ages.

### 3.1. Materials

Concrete samples were cast using ordinary Portland cement (OPC), Fly ash, crushed gravel as coarse aggregate and natural river sand as fine aggregate. **Table 1** provides the physical properties and chemical composition of the OPC and fly ash. 12.5 mm downgraded crushed stone, with fineness modulus 6.58 and specific gravity 2.70, was used as coarse aggregate. The fine aggregate was river sand with fineness modulus 2.58 and specific gravity 2.61.The gradation of coarse and fine aggregates are presented in **Table 2.** In order to improve workability of concrete, super plasticizer was used in all concrete mixtures.

**Table 1 : Physical properties and chemical analysis of ordinary Portland cement and fly ash**

| Types | ASTM Type-I Cement | ASTM Class F Fly ash |
|---|---|---|
| **Physical properties** | | |
| **Fineness** | | |
| Passing #200 Sieve | 95% | 99% |
| Blains, $m^2$/kg | 340 | 400 |
| **Compressive Strength, MPa** | | |
| 3 days | 15.4 | -- |
| 7 days | 19.9 | -- |
| 28 days | 30.2 | -- |
| **Specific gravity** | 3.15 | -- |
| **Chemical analysis, %** | | |
| Calcium oxide, CaO | 65.18 | 8.6 |
| Silicon dioxide, $SiO_2$ | 20.80 | 59.3 |
| Aluminum oxide, $Al_2O_3$ | 5.22 | 23.4 |
| Ferric oxide, $Fe_2O_3$ | 3.15 | 4.8 |
| Magnesium oxide, MgO | 1.16 | 0.6 |
| Sulfur trioxide, $SO_3$ | 2.19 | 0.1 |
| Sodium Oxide, $Na_2O$ | -- | 3.2 |
| Loss on ignition | 1.70 | -- |
| Insoluble residue | 0.6 | -- |

**Table 2 : Grading of aggregates**

| Coarse aggregate | | Fine aggregate | |
|---|---|---|---|
| Sieve size mm | Cumulative percentage retained | Sieve size mm | Cumulative percentage retained |
| 19 | 0 | 4.75 | 0 |
| 12.5 | 0 | 2.36 | 4 |
| 9.5 | 58 | 1.18 | 21.5 |
| 4.75 | 100 | 0.6 | 46.5 |
| – | – | 0.3 | 88 |
| – | – | 0.15 | 98 |
| – | – | Pan | 100 |

### 3.2. Mix design and sample preparation

Around 50 cylindrical specimen of size 100 mm diameter and 50 mm height and other 300 cubical specimens of 100 mm size from eight different types of fly ash concretes were prepared according to the mix proportion as described in **Table 3**. The small size of specimen i.e. 100 mm was taken in order to accommodate large number of specimens in the limited sized curing tanks. The specimens were demoulded after 24 hours of casting and cured in PW at 27±2°C.

**Table 3 : Mix proportions and properties of fresh concrete**

| Mixture constituent & properties (kg/m$^3$) | Mix Type* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **C100 FA0** | **C90FA 10** | **C80FA 20** | **C70FA 30** | **C60FA 40** | **C50FA 50** | **C40FA 60** | **C30FA 70** |
| Cement | 350 | 315 | 280 | 245 | 210 | 175 | 140 | 105 |
| Fly Ash | -- | 35 | 70 | 105 | 140 | 175 | 210 | 245 |
| Water | 155 | 155 | 155 | 155 | 155 | 155 | 155 | 155 |
| Sand | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 |
| Stone Chips | 1060 | 1060 | 1060 | 1060 | 1060 | 1060 | 1060 | 1060 |
| Slump (mm) | 63 | 66 | 67 | 69 | 72 | 73 | 78 | 79 |
| Air content % | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.7 |

* C – Cement; FA – Fly Ash; C90FA10 means Cement : Fly Ash = 90:10

### 3.3. Experimental procedures

#### 3.3.1 *Strength*

The compressive strength and tensile strength of various water cured concrete specimens were tested at the ages of 3, 7, 14, 28, 90 and 180 days in accordance with the BS EN 12390-3:2009 for compressive strength and BS EN 12390-6:2000 for tensile strength. Again at each case, the reported strength is taken as the average of three tests results.

#### 3.3.2 *Rapid chloride penetration tests*

Cylinder sample of 100 mm diameter and 200 mm height were prepared in accordance with ASTM C39. They were demoulded after 24 hrs and cured in water until the age of 26 and 178 days. Then they were cut into 50 mm thick slices. The cut cylinders were left to dry in laboratory condition for 24 hrs before application of epoxy coatings. All specimens were epoxy coated around the cylindrical surface. At the age of 28 and 180 days, the prepared cut cylinders were tested using the procedures described in the ASTM C1202. The average of three test results was taken at each test point. The test setup for determination of chloride ion penetration resistance is shown in **Fig. 1 to 8**. The ASTM guidelines concerning the chloride ion penetrability are given in **Table 4**.

**Table 4: Guidelines for Chloride-ion penetrability based on charge passed (ASTM C 1202)**

| Charge passed, Coulombs | Chloride ion penetrability |
|---|---|
| >4000 | High |
| 2000-4000 | Moderate |
| 1000-2000 | Low |
| 100-1000 | Very Low |
| <100 | Negligible |

**Fig 1: Sealing of the Cell with Grease**

**Fig 2: Sealing of the Sample with the cell**

**Fig 3: Pouring 3% NaCl Solution in One Cell**

**Fig 4: Pouring 0.3% NaOH Solution in Other Cell**

**Fig 5: Attaching Connector with Cell Containing 3% NaCl Solution**

**Fig 6: Attach Connector with Cell Containing 0.3% NaOH**

**Fig 7: Test Arrangement for RCPT**

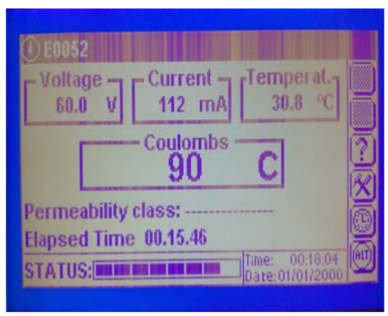


**Fig 8: Display Unit of RCPT Equipment**

## 4. RESULTS AND DISCUSSION

### 4.1 Compressive strength

The compressive strength of OPC and fly ash concrete has been graphically represented in **Fig.9**. Also for the ease of comparison, the relative compressive strengths are plotted in **Fig.10**. Among all the mixes and for 3, 7 and 14 days compressive strength, OPC concretes achieve relatively higher strength as compared to fly ash concrete. Test result shows that the 7 days compressive strength for OPC concrete is 6%, 9%, 15%, 22%, 33%, 59% and 67% higher than C90FA10, C80FA20, C70FA30, C60FA40, C50FA50, C40FA60 and C30FA70 concrete respectively. Up to curing period of 14 days, compressive strength is seen to decrease with the increase in fly ash content when compared with no fly ash concrete. 28 days compressive strength test result of the specimens up to 50% replacement level are very similar to OPC concrete, within the range of ±8% variation. Compressive strength is slightly higher by 3%, 5%, 8% and 3% for C80FA20, C70FA30, C60FA40 and C50FA50 concrete respectively; whereas the 28 days strength for C90FA10, C40FA60 and C30FA70 concrete is reported to be lower by 2%, 11% and 14% respectively when compared with no fly ash concrete. 90 days compressive strength data obtained for C80FA20, C70FA30, C60FA40 and C50FA50 concrete are respectively 5%, 7%, 11% and 4% higher than no fly ash concrete. C90FA10, C40FA60 and C30FA70 concrete strength are lower than C100FA0 concrete by 2%, 12% and 16%. After 180 days, maximum compressive strength is achieved for C70FA30 and C60FA40 concrete specimens with an increase in strength of 10% and 17% respectively as compared to OPC concrete. Also C80FA20 and C50FA50 concrete shows an increase in strength of 8% and 7% respectively when compared C100FA0 concrete.

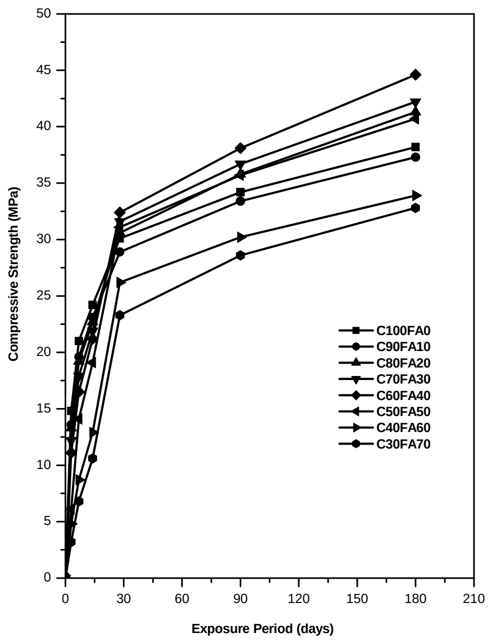


Fig 9: Compressive strength- exposure time relation for fly ash concretes

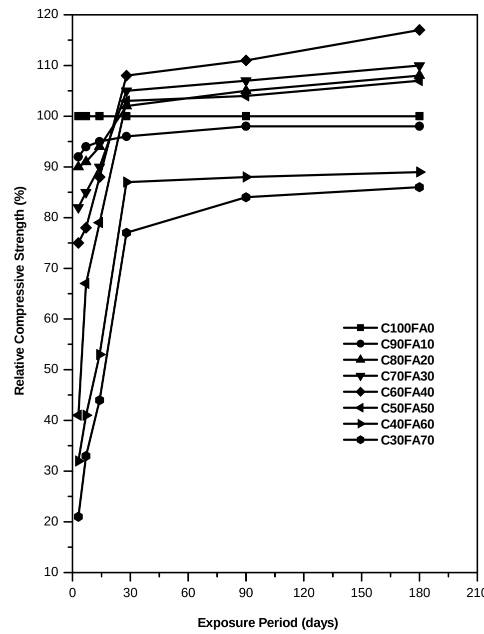


Fig 10: Relative compressive strength-exposure time relation for fly ash concretes

Cement normally gains its maximum strength within 28 days. During that period, lime produced form cement hydration remains within the hydration product. Generally, this lime reacts with fly ash and imparts more strength. For this reason, concrete made with fly ash will have slightly lower strength than cement concrete up to 28 days and substantially higher strength at the later ages of curing. Fly ash retards the hydration of $C_3S$ in the early stages but accelerates it at later stages. Conversely in cement concrete, this lime would remain intact and with time it would be susceptible to the effects of weathering, loss of strength and durability. Yamato and Sugita [10] found that the later age strength of fly ash concrete was higher than that of the control and that the modulus of elasticity was comparable to that of concrete made with moderate heat Portland cement.

### 4.2 Tensile strength

The tensile strength of concrete mixes made with and with out fly ash was determined at the ages of 3, 7, 14, 28, 90 and 180 days. **Fig.11** shows the variation of tensile strength with age for different fly ash concretes**.** Also for the ease of comparison, the relative tensile strength is plotted in **Fig.12**. The tensile strength of the specimens is seen to increase with age. At early ages of curing (3 days and 7 days) the tensile strength decreases with increase in fly ash content in concrete. However the rate of decrease diminishes with increasing age of curing. As compared to control specimens tensile strength values are 96%, 97%, 104%, 109% and 101% for C90FA10, C80FA20, C70FA30, C60FA40 and C50FA50 concrete at the curing age of 28 days. C40FA60 and C30FA70 concrete achieved 82% and 62% strength of OPC concrete.

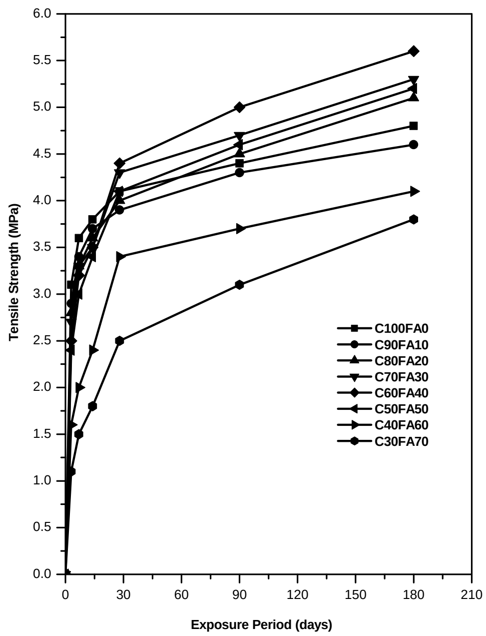

Fig 11: Tensile strength- exposure time relation for fly ash concretes

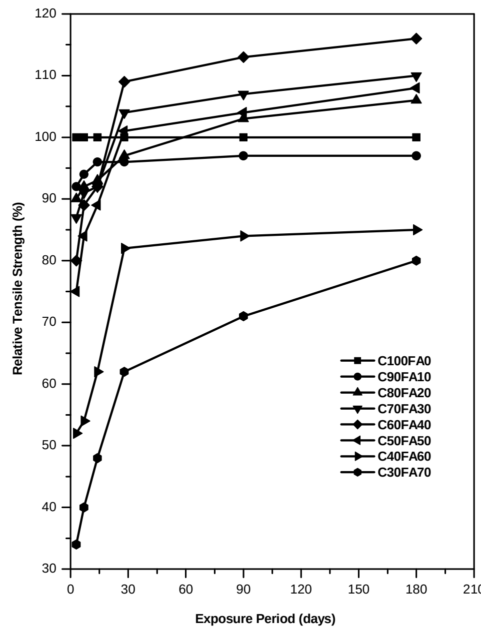

Fig 12: Relative tensile strength-exposure time relation for fly ash concretes

After 90 days, maximum tensile strength of 5.0 MPa was achieved for C60FA40 concrete, with an increase of 13% higher strength than C100FA0 concrete. At similar age of curing, even the concrete C80FA20, C70FA30 and C60FA40 showed higher tensile strength of 3%, 7% and 3% respectively than OPC concrete. At an age of 180 days curing, a maximum tensile strength of 5.6 MPa was achieved for C60FA40 concrete which is 16% higher than the reference concrete. Even 20%, 30% and 50% fly ash replaced concrete showed higher strength. However, C40FA60 and C30FA70 concrete provided a decrease in strength of around 15% and 20%. It may be due to the fact that fly ash being a pozzolanic material, the reactive silica of pozzolan and calcium hydroxide producing form the hydration of cement react together and produce calcium silicate hydrate which imparts strength for concrete. As it takes time to produce $Ca(OH)_2$ by hydration of cement, strength gaining rate slows down at initial ages of curing but increases at the later ages. Korac and Ukraincik [11] found that the early-age strengths upto 50% fly ash concretes were lower than that for the controls and after long curing period, the strengths were found comparable.

### 4.3 Rapid chloride penetration

Rapid chloride penetration value for OPC and fly ash concrete cured for 28 days and 180 days curing period are shown in **Table 5**. In case of OPC concrete, amount of passing charge is observed as 3190 coulombs whereas the similar value for fly ash concretes are 2918, 2647, 2314, 2182, 2303, 2106 and 2987 coulombs for C90FA10, C80FA20, C70FA30, C60FA40, C50FA50, C40FA60 and C30FA70 concretes respectively at the curing age of 28 days. The incorporation of pozzolanic materials improved the resistance to chloride penetration of concrete as confirmed by other researchers [12]. A close observation of the data shows that fly ash concrete has relatively better resistance against chloride ion penetration.

**Table 5 : Chloride Permeability (Coulombs) for Fly Ash Concretes of Various Replacement Level**

| Curing Period (days) | Mix Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **C100 FA0** | **C90FA 10** | **C80FA 20** | **C70FA 30** | **C60FA 40** | **C50FA 50** | **C40FA 60** | **C30FA 70** |
| 28 | 3190 | 2918 | 2647 | 2314 | 2182 | 2303 | 2706 | 2987 |
| 180 | 2242 | 1945 | 1745 | 1532 | 1388 | 1495 | 1803 | 1965 |

Also after 180 days curing, rapid chloride penetration values are 13%, 22%, 32%, 38%, 33%, 20% and 12% lower for C90FA10, C80FA20, C70FA30, C60FA40, C50FA50, C40FA60 and C30FA70 concretes respectively as compared to OPC concrete. Overall observation shows that at relatively longer curing period, rapid chloride penetration resistance increased for fly ash concrete as compared to OPC concrete. This value lies in the range of 4 to 6%. Fly ash has high fineness and can react with the products liberated during hydration. It forms secondary C-S-H gel that fills all the pores inside concrete and makes it more impermeable [10]. So it reduces the amount of charge passed thorough the concrete. The study result also shows that as the amount of fly ash used in concrete is increased, charge flow through the concrete sample is decreased. This is due to the reduction of the pore spaces inside the concrete specimen that makes the concrete dense and compact and as a result the amount of charge flow is decreased.

After 180 days of curing, compressive strengths are reported as 10%, 17%, 7% higher for C70FA30, C60FA40, C50FA50 concrete than OPC concrete respectively whereas the corresponding tensile strength are 10%, 16%, 8% higher for the similar concrete. Rapid chloride penetration value is 32%, 38%, 33% lower for C70FA30, C60FA40, C50FA50 concrete as compared to OPC concrete. From both strength and rapid chloride penetration test point of view, these three types of concrete are comparable and C70FA30 and C60FA40 concrete are better from strength consideration. Again from these two mixes, C60FA40 concrete shows better resistance against chloride ion penetration. After analyzing all the experimental result, it may be concluded that C60FA40 concrete is best among the concretes studied from durability as well as strength point of view.

## 5. CONCLUSION

Based on the results of the investigation conducted on different fly ash concretes made with various level of cement replacement and cured for varying curing period up to 180 days, the following conclusions are drawn:

(1) At early ages of curing, the rate of gain in compressive as well as tensile strength of fly ash concrete specimens is lower as compared to the corresponding OPC concrete.

(2) The resistance to chloride penetration of concrete is significantly increased with the incorporation of fly ash.

(3) Fly ash concrete mix having various cement replacement level up to 50% exhibited satisfactory results for both compressive strength and tensile strength.

(4) From both strength and chloride resistance consideration, the optimum fly ash content is observed to be 40% of cement. After 180 days curing, fly ash concretes with 40% cement replacement shows around 17% higher compressive strength and 16% higher tensile strength as compared to OPC concrete. Also, it shows around 38% lower rapid chloride penetration value.

(5) Chloride penetration resistance for fly ash concrete is observed to be rapidly improved with curing ages as compared to OPC concrete.

(6) Fly ash concrete is reported as environmentally friendly. Use of fly ash as partial replacement of cement in any construction work markedly reduces the cost of cement which otherwise been dumped making environmental hazard and also provides lower impact on environment by reducing $CO_2$ emission, judicious use of resources etc.

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# DIVERSITY AND ABUNDANCE OF PHYTOPLANKTON IN THE HAZARIBAGH TANNERY EFFLUENT SEWAGE WATER OF THE RIVER BURIGANGA IN RELATION TO POLLUTION LEVELS

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## ABSTRACT

Hazaribagh is densely populated area of Dhaka city where about 185 leather processing industries have been operating and discharging solid and liquid wastes directly to the downstream areas of the river Buriganga and to the canals around without proper treatment. This has lead towards a high pollution level in the river extinguishing the aquatic life.
Physico-chemical including the conventional water parameters and a biological examination of tannery effluents and sewage water was carried out in relation to phytoplankton abundance, at four selected points (viz. Kamrangirchar: K1, K2 and K3; Hazaribagh Tempo Stand: H) of Buriganga river during October 2009 to September 2010. Altogether 27 genera of Phytoplankton belonging to the families Cyanophyceae, Bacillariophyceae, Chlorophyceae, Euglenophyceae and Cryptophyceae were identified from the above points. Among these, *Merismopedia* of Cyanophyceae was considered to be the most significant genus based on their abundance and frequency of occurrence when compared to other observed genera of phytoplankton viz., *Anabaena*, *Oscillatoria*, *Raphideonema*, *Arthrospira*, *Microcystis*, *Anabaenopsis* of Cyanophyceae, *Nitzschia*, *Synedra*, *Navicula*, *Pleurosigma*, *Cymbella*, *Cycotella* of Bacillariophyceae, *Crucigenia*, *Ankistrodesmus*, *Tetradesmus*, *Clostridium*, *Coelostrum*, *Strusastrum*, *Ourococcus*, *Chlamydomonas*, *Senedesmus* of Chlorophyceae, *Euglena* ,*Phacus*, *Trachaelomonas* of Euglenophyceae, *Rhodomonas*, *Cryptomonas* of Cryptophyceae were also found in three other points . *Merismopedia* was the most abundant form ($3.6x10^4 – 2.4x10^6$ cell/L) comparison to the presence and loads ($72 – 1.4x10^3$ cell/L) of other phytoplankton (*Nitzschia*, *Synedra*, *Pleurosigma* of Bacillariophyceaea, *Euglena* of Euglenophyceae and *Strusastrum*, *Crucigenia*, *Ourococcus* of Cholorophyceae) at K1the station closest to the tannery effluent outfall. The abundance of *Merismopedia* increased gradually (K2- $6.45x10^4 – 3.68x\ 10^6$, K3- $6.95x10^4$ -$1.68\ x10^7$ and H- $1.0x10^5 – 2.06x10^{7)}$ along with decreasing pollutants concentration of the water. Above mentioned genera of Cyanophyceae, Bacillariophyceae, Chlorophyceae and Euglenophyceae were found ($70 – 6.5x10^2 – 1.4x10^4$cell/L) in K2. All genera of five groups of phytoplankton were found in both K3 and H point (K3: $70 – 7.0X10^5$ and H: $70 – 7.0X10^6$).

**Key words:** Phytoplankton, Tannery effluent, Buriganga river, Pollution, *Merismopedia*, Cyanophyceae, Bacillariophyceae.

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## 1. INTRODUCTION

Hazaribagh is a densely populated area of Dhaka city where about 185 leather processing industries have been operating and discharging solid and liquid wastes directly or indirectly to the low-lying areas, river and natural canals through two open drains without proper treatment. The water in the lowlying areas near Hazaribagh, with a direct link to the Buriganga river, is polluted in such a degree that it has become unsuitable for public uses. The river is seriously polluted by discharge of industrial effluents (toxic Chemicals: hydrogen sulphide, ammonia, poisonous chlorine, heavy metals) into river water, indiscriminate throwing of household, clinical, pathological & commercial wastes, and discharge of fuel and human excreta. The water of the river has become so polluted that its aquatic life has almost been extinguished. A survey in 1999 revealed that the up to 40,000 tones of tannery waste flows into the river Buriganga, Turag, Dhaleshwari, Balu, and Narai daily along with sewage water. Phytoplankton occupies the functional and basic significance in the overall food web [1]. Due to the pollution, phytoplankton population is affected and leading to drustic change in the food chain of the fresh water environment [2]. Some phytoplankton species are often used a good indicator of water quality and pollution. Reports of previous studies revealed that outburst of *Skeletonema costatum* as a result of pollution in Visakhaplanam harbor [3]. The phytoplankton community was stressed by huge flow from El- Umoum effluents [4]. There is no study was conducted in Buriganga river near Hazaribagh area regarding the relationship between phytoplankton and pollutants. The aim of this work was to study the diversity and abundance of phytoplankton in relation to the level of pollution.

## 1. MATERIAL METHODS

Samples for physical, chemical and biological variables were performed from four different sites in Hazaribagh (Kamrangirchor), located in Dhaka, Bangladesh ($23^{o}$43’N, $90^{o}$21’E), VIZ. (K1) main tannery effluent discharging point (Companyghat), (K2) 100 meters north from K1 downstream location from the sluice gate, (K3) 150 meters from K2 & (H) Hazaribagh tempo stand during October 2009 to September, 2010. The water samples were collected in morning between 7.00 am to 9.00 am. Water temperature (by using precise mercury thermometer), hydrogen ion concentration (by using pH-meter), electrical conductivity (conductivity meter), turbidity level (by using turbidi-meter) were recorded at the spot [5] and rest of the parameters were determined in the laboratory. Water samples were collected for chemical and biological analysis using pre-washed polyethylene bottle by water sample twice before filling and stored at 4°C. Following physiochemical parameters were measured in the lab: Dissolved oxygen (by using DO meter), Biological oxygen demand, BOD (5 day BOD test [6], Chemical oxygen demand, COD (by sample digestion method), Phosphate (by using Standard Colorimetric method, ascorbic acid) [7], Nitrite- nitrogen, Nitrate-nitrogen and Ammonia (by using spectrophotometer methods [7,8]. Collected algal samples were preserved in 4% formalin and lugol’s iodine solution. Algal identification was done by using standard monographs [9, 10, 11, 12, 13, and 14].

## 2. RESULTS

### 3.1. Physicochemical parameters

In present study, difference in the water quality and phytoplankton composition was observed between the highly polluted sites (K1, K2 & K3) and the last point H, which was comparatively less polluted.

In points K1, K2 and K3, results showed that overall range of temperature was $18^{0}$ C – $26.5^{0}$ C, turbidity 6.69– 9.12 NTU, pH 6.0- 7.79, conductivity 789 – 912 µS/cm, dissolved oxygen

0.89-1.31 $mgL^{-1}$, inorganic nitrogen, Nitrite-Nitrogen ($NO_2$-N ) 0.23 - 0.72 $mgL^{-1}$, Nitrate-Nitrogen ($NO_3$-N ) 2.23 - 3.74 $mgL^{-1}$, ammonia ($NH_4$ ) 4.96 - 6.51 $mgL^{-1}$, total phosphorus 0.23 – 5.03 $mgL^{-1}$, Chemical Oxygen Demand (COD) 50.65 - 70.84 $mgL^{-1}$ and Biological Oxygen demand ( BOD) 9.0 - 13.65 $mgL^{-1}$ ( Tab 1).
On the other hand, in point H, temperature was $17.8^0$ C – $26.^0$ C, turbidity 6.85 – 7.52 NTU which was remarkably less than that of K1, pH 6.89- 7.74 and conductivity 856 – 899 µS/cm. Dissolve oxygen (1.35-1.89 $mgL^{-1}$), inorganic nitrogen ( $NO_2$-N 0.71 - 0.78 $mgL^{-1}$, $NO_3$-N 3.23 - 4.22 $mgL^{-1}$) were higher than the other three points. Though, Biological Oxygen demand (BOD, 8.5 - 10.05 $mgL^{-1}$) was less than rest of the points. Chemical Oxygen Demand (COD, 54.23 - 55.58 $mgL^{-1}$), ammonia ($NH_4$ 3.56 - 6.18 $mgL^{-1}$) & total phosphorus (0.16 – 0.97 $mgL^{-1)}$ were more or less similar to K1, K2 &K3 (Tab 1).

### 3.2. Biological characteristics

Altogether 27 genera of Phytoplankton belonging to the families Cyanophyceae, Bacillariophyceae, Chlorophyceae, Euglenophyceae and Cryptophyceae were identified from these four points.
*Merismopedia* of Cyanophyceae was evidently the most abundant and frequent genera. The green algae (Chlorophyceae) were the more diverse group and their diversity and abundance increased with the decrease of pollution. Notable of this group were *Crucigenia, Ankistrodesmus, Tetradesmus, Clostridium, Coelostrum, Strusastrum, Ourococcus, Chlamydomonas, Senedesmus*.
After Chlorophyceae, Diatom (Bacillariophyceae) and Blue green alga (Cyanophyceae) showed the remarkable diversity and abundance. *Oscillatoria, Raphideonema, Arthrospira, Microcystis, Anabaenopsis* of Cyanophyceae and *Nitzschia, Synedra, Navicula, Pleurosigma, Cymbella, Cycotella* of Bacillariophyceae were recorded during the study.

Point k1, located in the immediate of industrial discharge, 9 genera were recorded. The average abundance of phytoplankton number in this area was $7.7X10^5$ Cell. $mL^{-1}$( Table 1) . The genera dominance was shown by *Merismopedia* ($2.86x10^6$ Cell. $mL^{-1}$) from the total number of $1.75x10^7$ Cell. $mL^{-1}$. Other genera collected and identified form this area, are *Nitzschia* ($1.4X10^3$ Cell. $mL^{-1}$), *Synedra* ($1.4x10^3$ Cell. $mL^{-1}$), *Pleurosigma* ($9.5X10^2$ Cell. $mL^{-1}$), *Oscillatoria* ($8.6X10^2$ Cell. $mL^{-1}$), *Euglena* ($3.5X10^2$ Cell. $mL^{-1}$), *Ourococcus* ($9.5X10^2$ Cell. $mL^{-1}$), *Strusastrum* ($2.5X10^2$ Cell. $mL^{-1}$) & *Crucigenia* ($1.4X10^2$ Cell. $mL^{-1}$).

At point K2 totally 13 genera of phytoplankton were recorded and represented by average $1.13X10^6$ Cell. $mL^{-1}$. The genus dominance was shown by *Merismopedia* ($3.68x10^6$ Cell. $mL^{-1}$) from the total number of $3.25x\ 10^7$ Cell. $mL^{-1}$ followed by *Ankistrodesmus* ($6.5x10^4$ Cell. $mL^{-1}$) , *Oscillatoria* ($2.94x10^4$ Cell. $mL^{-1}$) & *Crucigenia* ($1.75x10^4$ Cell. $mL^{-1}$). Other genera which were collected and identified form this area are *Nitzschia* ($8.4x10^3$ Cell. $mL^{-1}$), *Clostridium* ($8.4x10^2$ Cell. $mL^{-1}$), *Microcystis* ($7.0x10^3$ Cell. $mL^{-1}$), *Synedra* ($1.4x10^3$ Cell. $mL^{-1}$), *Anabaenopsis* ($7.0x10^2$ Cell. $mL^{-1}$), *Navicula* ($3.5x10^2$ Cell. $mL^{-1}$), *Cymbella* ($3.5x10^2$ Cell. $mL^{-1}$), *Euglena* ($3.5x10^2$ Cell. $mL^{-1}$ ) & *Cycotella* ($1.4x10^2$ Cell. $mL^{-1}$ ).

Total 21 genera of phytoplankton were recorded from the point K3 and the average phytoplankton of this point was $3.14x10^6$ Cell. $mL^{-1}$. Like other points, here also *Merismopedia* ($1.68x10^7$ Cell. $mL^{-1}$) showed the prime dominance from the total number of phytoplanton of this area ($7.85x\ 10^7$ Cell. $mL^{-1}$) followed by *Nitzschia* ($7.0x10^5$ Cell. $mL^{-1}$), *Coelostrum* ($4.65x10^5$ Cell. $mL^{-1}$), *Trachaelomonas* ($3.15x10^5$ Cell. $mL^{-1}$) *&*

*Ankistrodesmus* ($1.4x10^5$ Cell. $mL^{-1}$). Other genera which were collected and identified form this area are *Crucigenia* ($8.8x10^4$ Cell. $mL^{-1}$), *Oscillatoria* ($3.6x10^4$ Cell. $mL^{-1}$), *Cryptomonas* ($2.1x10^4$ Cell. $mL^{-1}$), *Euglena* ($3.5x10^2$ Cell. $mL^{-1}$), *Rhodomonas* ($1.4x10^4$ Cell.$mL^{-1}$), *Synedra* ($1.4x10^3$ Cell.$mL^{-1}$), *Senedesmus* ($1.05x10^4$ Cell.$mL^{-1}$), *Clostridium* ($9.6x10^3$ Cell. $mL^{-1}$), *Microcystis* ($8.5x10^3$ Cell. $mL^{-1}$), *Phacus* ($7.0x10^3$ Cell. $mL^{-1}$), *Raphideonema* ($7.0x10^3$ Cell. $mL^{-1}$), *Navicula* ($2.8x10^3$ Cell. $mL^{-1}$), *Cymbella* ($1.4x10^3$ Cell. $mL^{-1}$), *Chlamydomonas* ($1.4x10^3$ Cell. $mL^{-1}$), *Anabaenopsis* ($1.4x10^3$ Cell. $mL^{-1}$) , *Arthrospira* ( $3.5x10^2$ Cell. $mL^{-1}$ ).

Table 1: Physico-chemical properties and Phytoplankton diversity of Buriganga River from September 2009 to August 2010

| **Studied parameters** | **Point 01(K1)** | **Point 02(K2)** | **Point 03(K3)** | **Point 04(H)** |
|---|---|---|---|---|
| Water Temperature ($^0C$) | 19-26 | 18-26.5 | 18.5-26 | 17.8-26 |
| pH | 6.00-7.54 | 6.69-7.58 | 6.80-7.79 | 6.89-7.74 |
| Dissolved Oxygen (mg $L^{-1}$) | 0.9-1.23 | 1.0-1.19 | 0.89-1.31 | 1.35-1.89 |
| Chemical Oxygen Demand (COD) (mg $L^{-1}$) | 59.56-66.48 | 69.0-70.84 | 50.65-54.49 | 54.23-55.58 |
| Biochemical Oxygen Demand (BOD) (mg $L^{-1}$) | 10.23-12.55 | 11.65-13.65 | 9.0-11.75 | 8.5-10.05 |
| Turbidity (NTU) | 8.69-9.12 | 7.65-8.78 | 6.69-7.85 | 6.52-7.65 |
| Nitrate-Nitrogen ($NO_3$-N) (mg $L^{-1}$) | 2.23-2.61 | 2.85-3.45 | 3.0-3.74 | 3.23-4.22 |

Continue….

| | | | | |
|---|---|---|---|---|
| Nitrite-Nitrogen ($NO_2$-N) (mg $L^{-1}$) | 0.23-0.52 | 0.31-0.65 | 0.56-0.72 | 0.71-0.78 |
| Phosphate (mg $L^{-1}$) | 4.65-5.03 | 3.56-5.02 | 0.23-0.86 | 0.16-0.97 |
| Conductivity (µS/cm) | 865-912 | 866-902 | 789-862 | 856-899 |
| Ammonia as Nitrogen (mg $L^{-1}$) | 5.81-6.13 | 5.03-6.39 | 4.96-6.51 | 3.56-6.18 |
| Phytoplankton No of genera | 9 | 13 | 21 | 23 |
| Abundance of Phytoplankton | 7240-2681880 | 60540-3771600 | 110600-17606750 | 124670-27926730 |

| | | | | |
|---|---|---|---|---|
| (Cell.mL$^{-1}$) | (703786.4) | (1303318) | ( 3142771.6) | (5741871.6) |
| Dominant Genus | *Merismopedia* | *Merismopedia* | *Merismopedia* | *Merismopedia* |
| | | *Ankistrodesmus* | *Coelostrum* | *Crucigenia* |
| | | | *Ankistrodesmus* | *Ankistrodesmus* |
| | | | *Nitzschia* | *Coelostrum* |
| | | | *Trachaelomonas* | *Clostridium* |
| | | | | *Nitzschia* |
| | | | | *Tetradesmus* |

At the point H, totally 23 genera of phytoplankton were recorded and represented by average Cell. mL$^{-1}$. The genus dominance was shown by *Merismopedia* (2.06X10$^{7}$ Cell. mL$^{-1}$) from the total number of 1.43x 10$^{8}$ Cell. mL$^{-1}$ followed by *Nitzschia* (7.0x10$^{6}$ Cell. mL$^{-1}$ ), *Crucigenia* ( 4.9x10$^{5}$ Cell. mL$^{-1}$), *Ankistrodesmus* (4.2x10$^{5}$ Cell. mL$^{-1}$), *Senedesmus* ( 1.25x105 Cell. mL$^{-1}$ ) & *Clostridium*(1.05x10$^{5}$ Cell. mL$^{-1}$). Other genera which were collected and identified form this area are *Synedra* (8.7x10$^{4}$ Cell. mL$^{-1}$), *Chlamydomonas* (7.0x104 Cell. mL$^{-1}$), *Oscillatoria* (3.6x10$^{4}$ Cell. mL$^{-1}$), *Cryptomonas* (2.5x10$^{5}$Cell. mL$^{-1}$), *Tetradesmus* (2.4x10$^{4}$ Cell. mL$^{-1}$), *Navicula* (1.26x10$^{4}$ Cell. mL$^{-1}$), *Raphideonema* (1.4x10$^{4}$ Cell. mL$^{-1}$), *Microcystis* (1.0x10$^{4}$ Cell. mL$^{-1}$), *Pleurosigma* (8.4x10$^{3}$ Cell. mL$^{-1}$), *Phacus* (8.4x10$^{3}$ Cell. mL$^{-1}$), *Trachaelomonas* (8.4x10$^{3}$ Cell. mL$^{-1}$) , *Arthrospira* ( 8.4x103 Cell. mL$^{-1}$), *Anabaenopsis* (7.0x10$^{3}$ Cell. mL$^{-1}$) , *Coelostrum* ( 7.0x10$^{3}$ Cell. mL$^{-1}$), *Strusastrum* (7.0x10$^{3}$ Cell. mL$^{-1}$) , *Euglena* (1.4x10$^{3}$ Cell. mL$^{-1}$) & *Anabaena* (3.2x10$^{2}$ Cell. mL$^{-1}$).

## 3. DISCUSSION

Many human activities cause pollution of the aquatic environment, modification of the environmental conditions and thereby change in the aquatic communities [15]. High concentration of heavy metals VIZ. Cr, Zn, Pb, Ni, Cu, Cd, As and other ions like $Cl^{-}$, $Na^{+}$, $K^{+}$, $Ca^{+2}$, $SO4^{-2}$ were reported from the tannery effluents previously from the identical location in Hazaribagh area by Zahid [16] and Arias- Barreiro [17] which are considered as major pollutants of river Buriganga. BOD, COD were high in 1$^{st}$ point which gradually decrease in rest of the point .On the other hand dissolved oxygen increased from the 1$^{st}$ point to the remaining. This indicates that the pollution gradually increased from the K1 to H [18]. In this study, we significantly found fewer numbers of phytoplankton in comparison to the results of other studies [19, 20]. We found a least diversity and abundance of phytoplankton at the point K1 which is the closest to the opening mouth of tannery effluents. The abundance and diversity had increased along with the decrease of pollution at the rest of the points (Table 1). This result is comparable to other similar studies in South east coast in India [21], Estuarine Creek in Lagos, Nigeria [22] . *Merismopedia* of Cyanophyceae was found to be dominant. This genus seems to be resistant to polluted environment. Begum and Hossain [23] and Begum [24] also observed more or less comparable abundance of these species in a pond receiving effluents from two textile industries. Abundance of five genus of *Chlorophyces:*

*Crucigenia*, *Ankistrodesmus*, *Clostridium*, *Coelostrum*, and *Senedesmus* of Chlorophyceae *and* Bacilariophycae; *Nitzschia* were evident. Begum and Hossain [23] observed the similar pattern in the abundance of Bacilariophycaean & chlorophycean phytoplankton in their study points. Previously Islam and Begum [25] and Begum [24] reported the abundance of above genera in polluted water bodies and textile industrial effluents, respectively. Moreover all these genera accumulate heavy metals significantly [26]. With a few exceptions, among all the groups of phytoplankton recorded, *Trachaelomonas* of Euglenophyceae showed dominance in K2 station (Table 1). Similar observations were made earlier in two polluted ponds by Islam *et al.* [25] and in textile industrial effluents by Begum and Hossain [23].

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# CHARACTERISTIC ANALYSIS OF MATUAIL LANDFILL LEACHATE

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## ABSTRACT

This research was undertaken to investigate the characteristic analysis of Matuail landfill leachate in order to intend an appropriate treatment option. Samples were collected twice from two different pits of Matuail landfill site for both dry and wet weather conditions. Characteristics of the landfill leachate samples were determined through extensive laboratory analysis. The leachate samples were in intermediate semi-aerobic phase and characterized as medium aged. Low bio-degradability of Matuail leachate indicates that these samples may be efficiently treated with physico/chemical process or reverse osmosis rather than biological treatment. The concentrations of various contaminants reveal that the quality of leachate varied considerably with location and time but all the samples had the potential to contaminate soil, surface water and groundwater of the site.

**Key Words:** ammonia; bio-degradability; $BOD_5$; COD; landfill; leachate composition; rainfall.

## 1. INTRODUCTION

Leachate usually drains or 'leaches' from a landfill and varies widely in composition regarding the age of the landfill and the type of waste that it contains. It can contain both dissolved and suspended material. Landfill leachate may be characterized as a liquid having four groups of contaminants such as dissolved organic matter, inorganic macro components, heavy metals and xenobiotic organic compounds. The generation of leachate is caused principally by precipitation percolating through waste deposited in a landfill. In order to arrive at an appropriate treatment process, it is necessary to understand the leachate characteristic and the factors affecting it. Leachate is formed when water passes through the waste in the landfill cell. The precipitation can be from rain, melted snow or the waste itself. As the liquid moves through the landfill, many organic and inorganic compounds are transported in the leachate. The amount of leachate produced is directly linked to the amount of precipitation around the landfill. The amount of liquid waste in the landfill also affects the quantity of leachate produced. A large landfill site will produce greater amount of leachate than a smaller site. How the landfill has been constructed determines whether the leachate pollutes groundwater or not. In landfill sites which have been created recently, liners are present and so this greatly limits the leachate leaking and the only way it will leave the cell is if the liner tears.

## 2. GENERAL LEACHATE COMPOSITION

The physical appearance of leachate when it emerges from a typical landfill site is a strongly-

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odoured yellow or orange coloured cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen, nitrogen and sulfur rich organic species such as mercaptans. In a landfill that receives a mixture of municipal, commercial, and mixed industrial waste, but excludes significant amounts of concentrated specific chemical waste, landfill leachate may be characterized as a water-based solution of four groups of contaminants (Kjeldsen et al., 2002):

i) Dissolved organic matter, quantified as Chemical Oxygen Demand (COD) or Total Organic Carbon (TOC), volatile fatty acids (that accumulate during the acid phase of the waste stabilization, Christensen and Kjeldsen, 1989) and more refractory compounds such as fulvic-like and humic-like compounds.
ii) Inorganic macrocomponents: calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^{+}$), potassium ($K^{+}$), ammonium ($NH_4^{+}$), iron ($Fe^{2+}$), manganese ($Mn^{2+}$), chlorine ($Cl^{-}$), sulfate ($SO_4^{2-}$) and hydrogen carbonate ($HCO_3^{-}$).
iii) Heavy metals: cadmium ($Cd^{2+}$), chromium ($Cr^{3+}$), copper ($Cu^{2+}$), lead ($Pb^{2+}$), nickel ($Ni^{2+}$) and zinc ($Zn^{2+}$).
iv) Xenobiotic organic compounds (XOCs) originating from household or industrial chemicals and present in relatively low concentrations (usually less than 1 mg/l of individual compounds). These compounds include among others a variety of aromatic hydrocarbons, phenols, chlorinated aliphatics, pesticides, and plastizers.

Other compounds may be found in leachate from landfills: for example, borate, sulfide, arsenate, selenate, barium, lithium, mercury, and cobalt. However, in general, these compounds are found in very low concentrations and are only of secondary importance. Leachate composition may also be characterized by different toxicological tests, which provide indirect information on the content of pollutants that may be harmful to a class of organisms.

### 2.1. Leachate Characterization

Leachate characteristics produced in a landfill is governed by following factors (Sumanaweera, 2004).

1. Composition of the waste being landfilled.
2. Climatic and hydrogeological conditions prevailing within the landfill area.
3. Age of the waste.
4. Leachate collection and management system used.

Two main characteristics of leachate are the volumetric flow rate and the composition. The flow rate from sanitary landfill change from site to site and seasonally at each site. The design of the tip, the climate (rainfall and evaporation) and the nature of the waste (moisture content and liquid entering the landfill) are the factors determining the flow rate (Lema et al, 1988). Water percolating through landfill contains both organic and inorganic substances, released from the material deposited or as a result of biotic and abiotic reactions. These substances may be transported from the landfill through leachate, and could develop an environmental hazard. Different biological, chemical and physical processes taking place successively in a municipal landfill affect both the leachate and the gas production. In order to understand the fundamental microbiological and chemical processes which give rise to gas and leachate within a domestic waste landfill, during and beyond the active life of the site, it is necessary to understand the basic processes of waste decomposition. The major processes involved in the decomposition of landfilled household wastes, result in three phases in which decomposition takes place over time. These are broad and overlapping phases, and are summarized below:

Phase 1: Aerobic decomposition rapidly (typically in much less than a month, maybe in only a few days) uses up oxygen which is present within the wastes. This phase is relatively unimportant in terms of leachate quality at most landfill sites.

Phase 2: Anaerobic and facultative organisms (acidogenic and acetogenic bacteria) hydrolyse and ferment cellulose and other putrescible materials, producing simpler, soluble compounds such as volatile fatty acids and alcohols (with a high BOD value) and ammoniacal nitrogen.

Phase 3: More sensitive and slower growing methanogenic bacteria gradually become established and start to consume these simple organic compounds, producing the mixture of carbon dioxide and methane (plus various trace constituents) which is released as landfill gas.

Phase 1 is short, perhaps lasting only a few days or weeks. However, it may persist for longer periods, producing significant quantities of carbon dioxide, in shallow (<3m) deposits of waste where air can readily enter, or if air is drawn into wastes by excessive pumping of landfill gas. Significant quantities of hydrogen (up to about 20% by volume) can be produced during this period, particularly if the site is relatively dry. Although short-lived, Phase 1 is an exothermic stage, where high temperatures may be reached which may benefit later phases if landfill insulation is able to retain some of this heat.

Phase 2 can last for years, or even decades. Processes that take place within it can be deduced from extensive literature describing the theory and mechanisms of digestion of organic substrates by anaerobic micro-organisms (Gendebien et. al., 1992). Leachates produced during Phase 2 are characterised by high BOD values (commonly >10,000 mg/l) and high ratios of BOD: COD (commonly 0.7 or greater) indicating that a high proportion of soluble organic materials is readily degradable. Other typical characteristics are acidic pH values (typically 5 or 6), strong unpleasant smells and high concentrations of ammonia (often 500 - 1,000 mg/l). The aggressive chemical nature of such leachate assists in dissolution of other components of wastes, so leachates can contain high levels of iron, manganese, zinc, calcium and magnesium. Gas production consists mainly of carbon dioxide with lesser quantities of methane and hydrogen.

Leachates generated during Phase 3 are often referred to as "stabilized" but at this stage the landfill is biologically most active, with a dynamic equilibrium eventually established between acetogenic and methanogenic bacteria, with low steady-state concentrations of soluble intermediates such as fatty acids, relatively uniform rates of gas evolution, and wastes continuing active decomposition. This active production of landfill gas can last several years, at a relatively high rate. It may then continue at a gradually reducing rate over a period of many decades (or maybe even centuries) before the landfilled wastes are largely decomposed and atmospheric oxygen can once more diffuse into the fill. Leachates produced during Phase 3 are characterised by relatively low BOD values, and low ratios of BOD: COD. Odour is also reduced to being non-existent or merely "earthy" in its nature. However, ammoniacal nitrogen continues to be released by the continuing first stage acetogenic processes, and will remain present at high levels in leachate. Inorganic substances such as iron, sodium, potassium, sulphate and chloride may continue to dissolve and leach from the landfill for many years. Particularly important, therefore, is the change from early acidogenic/ acetogenic conditions, where high organic strength leachates are generated, to later methanogenic phases, where these organic compounds are actively converted to landfill gases, and are therefore not found in leachate to the same extent. Stage 1 and 2 leachates are often called "acetogenic" and Stage 3 described as "methanonogenic". The timescale of these changes has vital consequences for all aspects of environmental control, including leachate treatment, and landfill gas control and utilization schemes.

According to Heyer & Stegman (2003), acid, intermediate and methanogenic phases could be characterized by $BOD_5$/COD ratio. The typical ratios of the three stages are presented in Table 1.

In very old landfills where, more refractory organic carbons remain in the landfill wastes, a second aerobic phase may appear in the upper layer of the landfill. As methane production will be very low, air from the atmosphere starts diffusing into the landfill. This will give rise to development of aerobic zones in the landfill. Table 2 represents the constituents of municipal solid waste landfill leachate at different stages.

Young leachates are characterized by COD>10,000 mg/L, mainly due to volatile fatty acids, which are intermediate products of anaerobic degradation and by low nitrogen concentrations (<400 mg/L). Old leachates are characterized by high ammonia (>400 mg/L), high content of refractory compounds and low biodegradable organic fraction (Zamora et al, 2000). Leachate quantity depends on rainfall precipitation, evaporation, surface run-off, infiltration and storage capacity. Generally about 18% of precipitation turns in to leachate. Water is consumed in the anaerobic biological degradation and lost due to gas production. With aging, this component reduces, thus increasing the volume of leachate produced. Table 3 presents the general leachate characteristics with suitability of treatment options in terms of biodegradable, intermediate and stabilized landfill leachate.

As the young landfill is rich in organic, biological treatment is more appropriate than physico-chemical which is suitable for the old landfill. However, effectiveness of combined treatment process for the treatment of a leachate produced at specific landfill age has not been considered. Individual treatment options cannot be a long-term solution for leachate treatment as they are not effective in treating leachate generated at different period of time and do not adapt to changing leachate characteristics. Again stabilized leachate has the following properties according to Baig and Liechti (2001):

- COD < 2,000 mg/L
- Slightly alkaline pH
- Biodegradability (expressed as $BOD_5$ /COD) of 0.1

Table 1: Landfill leachate phase and biodegradability (Heyer and Stegman, 2003)

| Leachate Phase | $BOD_5$/COD |
|---|---|
| Acid | 0.4 |
| Intermediate | 0.2 to 0.4 |
| Methanogenic | 0.2 |

Table 2: Constituents in Municipal solid waste landfill leachates (Heyer and Stegman, 2003)

| Parameter (mg/L except pH) | Acid phase | Intermediate phase | Methenogenic phase |
|---|---|---|---|
| pH | 6.3-7.8 | 6.7-8.3 | 7-8.3 |
| COD | 950-40,000 | 700-28,000 | 460-8300 |
| $BOD_5$ | 600-27,000 | 200-10,000 | 20-700 |
| $NH_4$-N | 17-1,650 | 17-1,650 | 17-1,650 |

Table 3: Relation between Leachate Characteristics and Treatments (Amokrane, et al., 1997)

| **Leachate Type** | **I (biodegradable)** | **II (intermediate)** | **III (stabilized)** |
|---|---|---|---|
| pH | < 6.5 | 6.5 to 7.5 | > 7.5 |
| COD (mg/L) | > 10,000 | < 10,000 | < 5,000 |
| COD/TOC | < 2.7 | 2.0 to 2.7 | > 2.0 |
| $BOD_5$/COD | > 0.5 | 0.1 to 0.5 | < 0.1 |
| **Process** | **Treatment Efficiency** | | |
| Biological Treatment | Good | Fair | Poor |
| Chemical Oxidation | Fair-poor | Fair | Fair |
| Chemical Precipitation | Fair-poor | Fair | Poor |
| Activated Carbon | Fair-poor | Good-fair | Good |
| Coagulation-flocculation | Fair-poor | Good-fair | Good |
| Reverse Osmosis | Fair | Good | Good |

There are many factors affecting the quality of leachate, i.e., age, precipitation, seasonal weather variation, waste type and composition. In particular, the composition of landfill leachate varies greatly depending on the age of the landfill. There are three types of leachate have been defined by Alvarez-Vazquez et al. (2004) according to landfill age (Table 4). As landfill age increased, organics concentration (COD) in leachate decreased and increase of ammonia nitrogen concentration. Landfill leachate from old sites is usually highly contaminated with ammonia resulting from the hydrolysis and fermentation of nitrogen containing fractions of biodegradable refuse substrates. The existing relation between the age of the landfill and the organic matter composition may provide useful criteria to choose a suited treatment process. In general, leachate may contain large amounts of organic matter (biodegradable, but also refractory to biodegradation), where humic-type constituents consist an important group, as well as ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts.

The characteristics of the landfill leachate can usually be represented by the basic parameters COD, BOD, the ratio BOD/COD, pH, Suspended Solids (SS), Ammonium nitrogen etc. Recirculation of leachate will produce stabilized leachate containing relatively low concentrations of degradable carbon compounds but high concentrations of ammonia therefore, COD and BOD will be removed, but ammonia concentrations will climb.

**2.2. Biodegradability of Leachate**

Different levels of biodegradability of leachate and their ranges are presented in Table 5. Biodegradable leachate can contain low molecular organic acids and alcohols, humic substances with high molecular weight, fulvic acid like materials with high molecular weight. The first group is made out of easily bio-degradable compounds, mainly fatty acids. In acidic leachate, the amount may be more than 90% of TOC. The second group consists of rather stable organics derived from cellulose and lignin. This group is present from 0.5% to 5% in the leachate. The third group contains compounds relatively rich in carboxylic and hydroxylic groups, which are predominant in methenogenic leachate and are difficult to degrade. Other than these organics, benzene, aminoacids, phenols and halogenated compounds, i.e. absorbable organic halides (AOX) may be detected in methanogenic leachates. Moreover, extremely high levels of ammoniacal nitrogen (500 to 3000 mg/L) can be observed too (Cossu et al., 2003).

Table 4: Landfill leachate classification vs. age (Alvarez-Vazquez et al., 2004)

| | **Young** | **Medium** | **Old** |
|---|---|---|---|
| Age (year) | <1 | 1-5 | >5.0 |
| pH | <6.5 | 6.5-7.5 | >7.5 |
| COD (g $L^{-1}$) | >15 | 3.0-15 | <3.0 |
| $BOD_5$/COD | 0.5-1 | 0.1-0.5 | <0.1 |
| $NH_3$-N (mg $L^{-1}$) | <400 | 400 | >400 |

Table 5: Relative biodegradability of leachate (Heyer and Stegman, 2003)

| **Biodegradability** | **BOD/COD** |
|---|---|
| Low | <0.5 |
| Medium | 0.5-0.75 |
| High | >0.75 |

## 3. MATUAIL LANDFILL LEACHATE

### 3.1. General

Rapid urbanization of Dhaka city and its fast increasing population over the last few decades have created much pressure on its urban services. The existing services are far too inadequate to serve the inhabitants and solid waste management is one of the major problems faced by the authorities and the inhabitants alike. Dhaka City Corporation (DCC) is executing the solid waste disposal as its task. Present landfill at Matuail operated by DCC is properly designed to protect the environment and the neighbourhood from adverse impacts of landfill. But due to the current densely polluted leachate coming from the solid waste of municipal, industrial and clinical, the treatment option designed by DCC does not give satisfactory removal of organic matters and this issue becomes a growing concern for the surrounding environment and public health. The waste disposed off at the dumping site is usually highly polluted with toxic metals. Disposal of waste on land may lead to leaching (aggravated by rainfall) and subsequent contamination of soil and groundwater aquifers and hence may pose a potential threat to environment (BRTC, 2008).

Matuail, located approximately 5 km southwest from the city centre is one of the major landfill sites of DCC. A total of 3,656 tonnes of solid waste is generated every day of which 2,208 tonnes are collected and dumped into the two dumping grounds of DCC - one at Matuail and the other at Aminbazar, said Dr. Tariq Bin Yousuf, project director of DCC Landfill Improvement Project (BRTC, 2008). The remaining 1,448 tonnes are dumped into drains, rivers, canals, other water bodies, open spaces and low-lying areas. The Dhaka City Corporation is set to inaugurate its first-ever sanitary landfill site at Matuail with an aim to reduce the risks of health and environmental hazards, said an official of the corporation. The landfill site had been constructed as per the master plan on solid waste management, formulated in 2005 with the technical assistance from the Japan International Cooperation Agency aiming at making the city clean by 2015. The total area of the landfill is about 40 hectares and a 15 year old open dump is situated on 20 hectares of the land adding that 20 more hectares of land have been developed for landfill in future. Major sanitary landfill components introduced under the project were leachate collection and gas venting system, surface drainage improvement, systematic operation of waste by daily coverage, slope reformation, working roads, weighbridge operation and vehicle washing facilities.

### 3.2. Matuail Landfill Leachate Characteristics

Leachate samples were collected for analysis and leachate production was measured through measuring the leachate flow at different outlet points of the Matuail Landfill site. It was observed that there is a seasonal fluctuation of leachate flow which varies widely from $2m^3$/hour to $10m^3$/hour in dry season and from $50m^3$/hour to $60m^3$/hour in wet season (BRTC, 2008). It was also observed that leachate $BOD_5$ and COD varies widely, mainly due to fluctuation of flow with season and in the dry season the maximum $BOD_5$ was found to be around 1650 mg/L and the corresponding COD was around 2900 mg/L. The minimum $BOD_5$ as low as 240 mg/L was observed during the rainy season due to dilution of the raw leachate by the rain water. A maximum ammonia concentration of around 2130 mg/L was detected. It was also found that the leachate is highly alkaline. Although collected samples were highly colored, suspended solids concentration was less than 150 mg/L (BRTC, 2008).

The generation of leachate in a landfill can continue for many years. The pollution potential of a leachate depends on its composition and it usually contains high levels of contaminants. Leachate generated in landfill sites is a growing concern for surrounding environment. Uncontrolled and untreated leachate of a landfill site pollutes the surrounding soil, surface water and groundwater and hence may pose a potential threat to human and environment. Studies on leachate quality at Matuail disposal site were carried out by BRTC and Hasan (2005). Hasan collected samples from four different points of the peripheral drain of the disposal site. One leachate sample collected from the internal roadside drain was analyzed at BRTC to assess the quality of the leachate. The results have been presented in Table 6 along with the data of the past studies. The data presented in Table 6 reveal that the quality of leachate varied considerably with location and time but all the samples had the potential to contaminate soil, surface water and groundwater of the site.

Table 6: Leachate characteristics of Matuail landfill (BRTC, 2008)

| SI # | Water Quality Parameters | Lcachate Characteristics | | |
|---|---|---|---|---|
| | | BRTC, 2000 | Hasan, 2005 | BRTC, Aug. 2006 |
| 1 | pH | 7.96 | 7.0-8.5 | 8.23 |
| 2 | Turbidity (NTU) | — | — | 210 |
| 3 | Color (Pt-Co Unit) | 9130 | 4150-40,000 | 7250 |
| 4 | Alkalinity mg/L as $CaCO_3$ | — | — | 5500 |
| 5 | Total Iron (mg/L) | 10.5 | 4.13-208.6 | |
| 6 | Manganese (mg/L) | 0.5 | 1.28-12.02 | 1.12 |
| 7 | Lead (mg/L) | 0.67 | 1.58-13.51 | |
| 8 | Cadmium (mg/L) | 0.0 | 0.016-0.15 | |
| 9 | Chromium (mg/L) | — | 0.18-51.04 | |
| 10 | Zinc (mg/L) | 1.358 | 7.66-34.7 | |
| 11 | Copper (mg/L) | 0.27 | 0.70-18.5 | |
| 12 | Nickel (mg/L) | 0.2313 | 0.019-0.926 | |
| 13 | Chloride (mg/L) | — | 800-36,000 | 1750 |
| 14 | $NH_3$-N (mg/L) | — | 976-2245 | 588 |
| 15 | $NO_3$-N (mg/L) | — | — | 6.0 |
| 16 | $NO_2$-N (mg/L) | — | — | 0.058 |
| 17 | $P0_4$ (mg/L) | — | 27.5-86.0 | 17.04 |
| 18 | $S0_4$ (mg/L) | — | — | <0.1 |
| 19 | COD (mg/L) | — | 1300-12,200 | 2410 |
| 20 | BOD (mg/L) | — | 980-10,000 | |

| | | | | |
|---|---|---|---|---|
| 21 | Electric Conductivity (μS/cm) | — | — | 11780 |
| 22 | Total Dissolved Solids (mg/T) | 6133 | 500-10600 | |
| 23 | Suspended Solids (mg/L) | 3475 | — | |
| 24 | Total Solids (mg/L) | 9608 | — | |
| 25 | F. Coliform (CFU/100ml) | — | 200000-1500000 | |

## 4. EXPERIMENTAL METHOD

### 4.1. Selection of Sampling Points

The study included the visit to Matuail landfill site for proper selection of sampling stations. There are a lot of collection pits around the leachate dumping site where the leachate is first accumulated from the waste and then goes to the collection pond for biological treatment. The heavy portion of fresh leachate coming from the dumping site is collected in pit no. 30 and comparatively diluted leachate coming with the rainwater during rainfall from the dumping site is gathered in pit no. 34 through surface drain. Samples were collected twice from two different pits at 21 days time interval. Samples were then labeled as sample no. 1 from Pit #30 and sample no. 2 from Pit #34. For collection, plastic containers were cleaned with tap water and leachate was collected from beneath the top surface. Each of the sample containers was labeled with the necessary information.

### 4.2. Sampling Method

Collection of leachate samples by following the proper standard is of great importance. Representative samples were tested in the laboratory for the assessment of the existing pollutants. The collected samples were transported to the laboratory quickly and preserved in refrigerator for two days. Within two days the leachate characteristics were analyzed so that no significant change may occur in the quality of the samples. Prior to the experiments, large particles and debris were removed to minimize particulate effects.

## 5. QUALITY ASSESSMENT OF MATUAIL LANDFILL LEACHATE

Characteristics of the landfill leachate samples were determined through extensive laboratory analysis. The leachate parameters were determined including temperature, pH, colour, turbidity, TDS, TS, TSS, DO, alkalinity, COD, $BOD_5$, $NO_3$-N, $NO_2$-N and $NH_3$-N. Digital pH meter was used for the determination of pH and temperature of the samples. The turbidity was measured with an electronic turbidimeter. The concentrations of dissolved species were determined by DR-4000 spectrophotometer UV-visible at the following wavelengths: $NO_3$-N was determined at $\lambda$ = 400 nm (cadmium reduction method, using Nitra Ver 5 Nitrate reagent, Hach 8171), ammonia nitrogen at $\lambda$ = 425 nm (Nessler reagent, using Nessler reagent, Mineral stabilizer and Polyvinyl Alchohol Dispersing Agent 8038). DO was measured by Winklers method and total alkalinity was measured by titration with 0.02N $H_2SO_4$. $BOD_5$ was measured by incubation in the dark at $20^0$C for 5 days. Suspended and dissolved solids were dried to a constant weight at $105^0$C. The comparison of different parameters of Matuail Landfill leachate with Bangladesh standards are given in Table 7.

### 5.1. Characterization of Matuail Landfill Leachate

The ratio of $BOD_5$ to COD for both the samples were 0.2 to 0.35 which indicates that the leachate samples were in intermediate semi-aerobic phase according to Heyer and Stegman (2003). Also the pH, COD and $BOD_5$ values are in the range of intermediate phase according to Heyer and Stegman (2003) given in Table 2. According to Amokrane, et al. (1997) Matuail leachate type is II (intermediate) due to the ratio of $BOD_5$ to COD in between 0.1 to 0.5 having COD values of < 10,000 though the pH value is slightly greater than the range given in Table 3. For this type of leachate Biological Treatment, Chemical Oxidation, Chemical Precipitation have fair treatment efficiency rather Activated Carbon, Coagulation-flocculation would give more treatment efficacy. Reverse Osmosis process would be a good but costly treatment option for this leachate condition according to Amokrane, et al. (1997). As COD concentration is between 3-15 g/l and the ratio of $BOD_5$ to COD is in the range of 0.1 to 0.5, it is concluded that the Matuail landfill leachate was characterized as medium aged having 1-5 years of age according to Alvarez-Vazquez et al. (2004).

Table 7: Comparison of different parameters of Matuail landfill leachate with Bangladesh standards

| Parameter | Unit | **Sample # 01** (From Pit No. 30) | **Sample # 02** (From Pit No. 34) | Bangladesh standards for discharging treated leachate into Inland surface water |
|---|---|---|---|---|
| pH | - | 8.34 | 8.25 | 6 - 9 |
| Colour | Pt-Co unit | 14050 - 24650 | 4700 - 5675 | - |
| Turbidity | NTU | 454 | 194.5 | - |
| TDS | mg/l | 12754 | 5884 | 2100 |
| TS | mg/l | 14600 | 12704 | - |
| TSS | mg/l | 1846 | 6820 | 150 |
| DO | mg/l | 0.49 | 0.06 | 4.5 - 8.0 |
| Alkalinity | mg/l | 14100 | 4510 | - |
| $NO_3$-N | mg/l | 10 | 10 | - |
| $NO_2$-N | mg/l | 0.25 | 0.2 | - |
| $NH_3$-N(T) | mg/l | 3582.5 - 3760 | 430 - 662.5 | 50 |
| COD | mg/l | 6600 - 11520 | 2700 - 4100 | 200 |
| $BOD_5$ | mg/l | 1400 - 4000 | 800 - 880 | 50 |
| $BOD_5$/COD | - | 0.212 – 0.347 | 0.215 – 0.296 | - |

According to Heyer and Stegman (2003), the leachate samples were made out of low bio-degradable compounds as the ratio of $BOD_5$ to COD is less than 0.5. The leachate samples contain compounds relatively rich in carboxylic and hydroxylic groups, which are predominant in methenogenic leachate and are difficult to degrade. Other than these organics, benzene, aminoacids, phenols and halogenated compounds, i.e. absorbable organic halides (AOX) may be detected in methanogenic leachates. Moreover, extremely high levels of ammoniacal nitrogen (up to 3760 mg/L) are observed too. Low bio-degradability indicates that the removal efficiency of Matuail landfill leachate through biological process would be fair and these samples may be efficiently treated with chemical process like Fenton oxidation and coagulation process rather than biological treatment.

## 6. CONCLUSION

The physical appearance of Matuail leachate samples were reddish to blackish coloured and the smell were acidic and offensive. It was observed that leachate $BOD_5$ and COD varies widely, mainly due to fluctuation of flow with rainfall and in the dry weather the maximum $BOD_5$ was found to be around 4000 mg/L and the corresponding COD was around 11520 mg/L. It was also found that the leachate is highly alkaline having high pH values. Collected samples were highly colored as well as maximum suspended solids concentration was 6820 mg/L. The ratio of $BOD_5$ to COD for both the samples was 0.2 to 0.35 which indicates that the leachate samples were in intermediate semi-aerobic phase. Again from this ratio it is concluded that the Matuail landfill leachate was characterized as medium aged and the removal efficiency of Matuail landfill leachate through biological process would be fair. Biodegradability signifies that the leachate samples were made out of low bio-degradable compounds and were not stabilized. Low bio-degradability indicates that these samples may be efficiently treated with physico/chemical process or reverse osmosis rather than biological treatment. The concentrations of various contaminants reveal that the quality of leachate varied considerably with location and time but all the samples had the potential to contaminate soil, surface water and groundwater of the site.

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# QUALITATIVE CHANGES OF RICE HUSK FOR ENERGY AND MATERIAL

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## ABSTRACT

Rice husk is a by-product of rice milling industries. Husk is mainly used as fuel for producing steam for rice parboiling. However, the use of rice husk as feed stock for gasification is not suitable due to the very high content of ash in husk. The ash of rice husk contains more than 90% of silica. After burning of huks in boiler furnace the silical is transformed in crystalline, so the ash looses the quality. The rice husk char contains more than 50% ash and this char is not suitable as precursor of activated carbon. With some treatment the quality of rice husk easily can be improved. The ash content of rice husk can be reduced drastically to 2.5%. Such as the calorific value of rice husk can be improved by 25% higher than the raw husk. Ash content of rice husk char can be reduced to 4% from 50%. Ash can be used for preparation of adhesive material. Finally the rice husk char containing low ash content can be used as very high grade of precursor for preparation of activated carbon.

**Key Words:** Rice husk, volatile material, Fixed carbon, calorific value, ash, activated carbon, sodium silicate.

## 1. INTRODUCTION

Rice husk is a byproduct of rice milling industries. The quantity of rice husk is fairly 20% of whole grain of raw rice by weight. A huge quantity of rice is produced arround the world every year amounting 132 million tonne globally  and 8 million tonne in Bangladesh [1]. Rice husk has good merit as biomass fuel no dought. However high quantity of ash content in rice husk draw some disadvantages of biomass fuel lide wood fuel. The ash content of rice husk is to be 20% of husk by weight, whereas ash content in wood fuel is arround 1% by weight. Rice husk fuel would show better performance as fuel if the ash content could be reduced from rice husk. Rice husk ash cntains more than 90% silica by weight. This silica is a valuable material suitable producing silicate adhesive, insulating material in steel industries and raw material for producing cement as pozzolan, ditergent and for so many other uses. Rice husk can be used as precursor for producing activated carbon instead of fossil coal as a source of carbon. When rice husk heated to produce char for activated carbon, it contains more than 50% ash by weight. Again this high ash content degrades the quality of ash for activated carbon. Hence removal of ash from rice husk char is important to produce superior

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grade of carbon for precursor of activated carbon. This study is focused on the changes of properties of rice husk and rice husk char when ash is removed from it.

## 2. METHODOLOGY

Six number of rice husk samples from different variety of rice husk are analysed to determine the proximate quantity. Out of six samples one sample is selected for detail analysis. The samples are washed with tap water to remove dust and soil particle and then the husk is dried at 104°C to gain constant weight and the samples are cooled in desiccator and stored in polybag. Before conducting proximate analysis samples are dried in oven at 120°C for 2 hours followed by the cooling of samples in desicator. After cooling of samples 1 gram (approx.) of each sample is taken in a closed crusible silicon crucible. The crusible is specified desinged having ground silicon cover (Tatlock brand). To determine the volatile matter the samples are placed in a muffle furnace at 900°C for 7 minutes. Then the samples are removed from the furnace and cool in desicator. After cooling the loss of weight of the samples were measured and termed as volatile matter. To determined the fixed carbon and ash content the samples were put in the muffle furnace at 815°C for 2 hours [2] to completely burn the rest of sample. At this time the cover of the crucible is removed to allow oxygen to burn the rest of carbon completely. The remaining weight of the sample in crucible is termed as ash content and the loss of mass is termed as fixed carbon.

Rice husk ash (RHA) is extracted from rice husk by sovent extraction method (digesting the husk in sodium hydroxide solution). Opaline silica in rice husk reacts with sodium hydroxide and makes sodium silicate compound. The chemical reaction between sodium hydroxide and opaline silica is shown in Equation 1.

$$2NaOH + SiO_2 = Na_2SiO_3 + H_2O \text{ ------ Eq. (1)}$$

Sodium silicate solution is filtered and concentrated by heating. After filtration rice husk is washed with tap water and dried. Treated rice husk characterised by determining the proximate quantities, calorific value mass yield and energy yield. Extraction of silica from rice husk is done by digestion in sodium hydroxide solution at boiling and ambient temperature condition. Then the optimum time of extraction of ash from rice husk is optimized. The rice husk char contains higher degree of ash than raw husk. The ash is needed to remove from rice husk char to get higher grade of char. The char is also passed through the same procedure for removing ash as for ash removal from husk. The proximate content of treated husk and char are determined. The calorific value of different type of rice husk are determined using bomb calorimeter both for raw and treated husk. To conduct the reserch an experiment is setup in laboratory of Mechanical and Chemical Engineering Department of Islamic University of Technology, Board Bazar, Gazipur.

## 3. RESULTS AND DISCUSSION

### 3.1. Proximate Analysis of Rice Husk

Proximate analysis shows the percentage values of volatile matter, fixed carbon and ash cotent of six different varieties of rice husk (Fig. 1).The volatile content of different varieties of rice husk varies from 62% to 66% of total mass in dry basis. Volatile matter in the biomass fuel is driven up in pyrolyis zone at the temperatures of 200-500°C forming a vopour consisting of water, tar, oils and gases. Fuel with high volatile matter content produces more tar, causing problems to internal combustion engine. Volatile matters in the fuel determine the design of gasifier for removal of tar [3]. As a general rule if the fuel contains more than 10 percent volatile matter it should be used in downdraught gasifier [4]. The volatile matter makes a good gaseous fuel for e.g. a gas engine or a turbine, the latter being very efficient [5].

Fixed carbon content of rice husk varies from 15.75% to 17.5% of total mass in dry basis. The ash content of rice husk varies from 16% to 22% of total mass in dry basis. The results of proximate analysis there is a variation of different constituent of rice husk irrespective of variety. Especially comparatively more variation is observed in ash content. Mineral contents of fuel which remains in oxidized form after combustion of fuel is called ash. In practice, ash also contains some unburned fuel. Ash content and ash composition have impact on smooth running of gasifier. Melting and agglomeration of ashes in reactor causes slagging and clinker formation. If no measures are taken, slagging or clinker formation leads to excessive tar formation or complete blocking of reactor. In general, no slagging occurs with fuel having ash content below 5% [3]. However, ash contains some important mineral that could be valuable product if the ash is collected properly. There are two way of benefit of ash removal from rice husk. Firstly rice husk with reduced ash improves the calorific value of rice husk and second is collection of important minerals. Rice husk ash contains more that 90% opaline silica by weight. This silica content causes some problem during the use of husk as fuel. High content of ash directs the special design of furnace with high volume for ash deposition and disposal causing extra money for ash removal mechanism. Therefore, ash removal from rice husk is important for improvement of rice husk as fuel and extraction valuable product from ash.

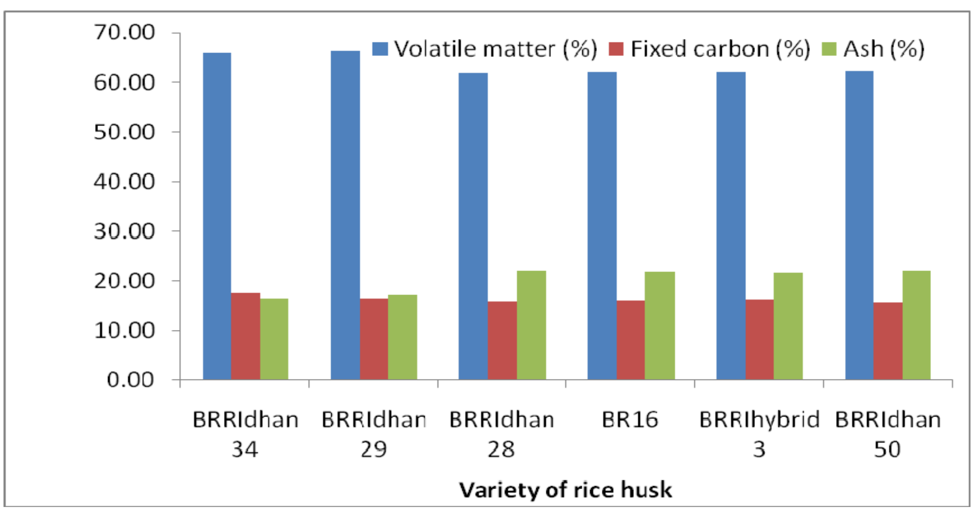


Fig. 1: Proximate analysis of rice husk from different popular varieties in Bangladesh

### 3.2 Removal of Ash from Rice Husk

Since the silica remains in amorphous from in husk it can be easily removed by solvent extraction method. Ash from rice husk is removed by digesting the husk in sodium hydroxide solution. The ratio of sodium hydroxide and husk depends on the content of silica mass in husk. Since there is a variation of ash content for different variety of husk sodium hydroxide and husk ratio of will vary. BRRIdhan 50 (Banglamoti) variety is selected to conduct the ash removal experiment. Five different mass ratios of sodium hydroxide and rice husk are used in the experiment. The mixture of rice husk and sodium hydroxide solution is boiled in reflux apparatus to maintain constant volume of solution. The mixture is boiled for 2 hour. After boiling the sodium silicate solution is filtered and the rice husk is washed with tap water to reach neutral pH. The treated rice husk is then dried and cooled in desiccators for further analysis. The proximate analysis results of treated rice husk are shown in Fig. 2. Proximate content shows that the ash content decreased with increase of sodium hydroxide ratio. The ash content decreased from 22% to 2.8% after heating the sample. The ash content of treated husk is not varied significantly beyond the ratio 0.2 (sodium hydroxide: husk). The volatile matter increased from 62% to 81% and the fixed carbon percentage is almost similar as before treatment. Hence the optimum ratio of sodium hydroxide and rice husk is found to 0.2.

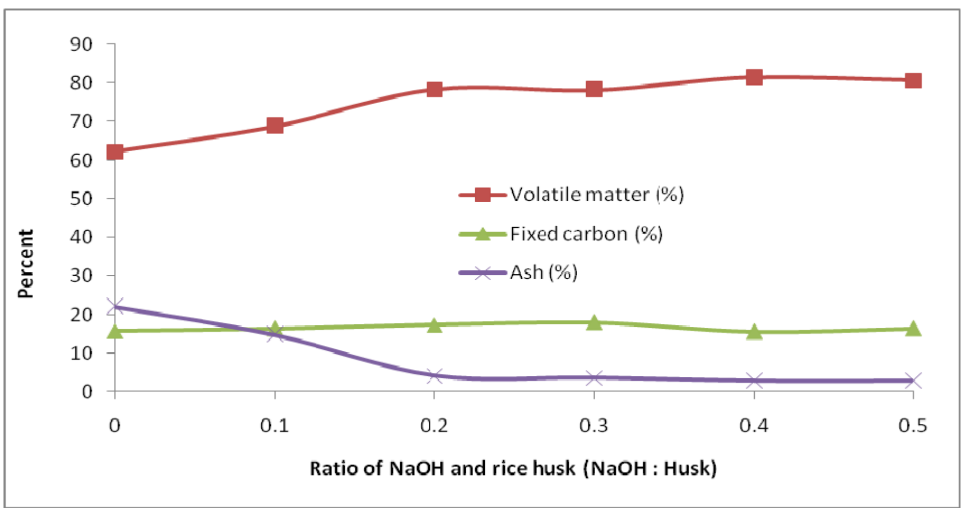


Fig. 2: Removal of ash from rice husk boiling in sodium hydroxide solution for 2 hours

### 3.2.1. Effect of Heating Time on Removal of Ash from Rice Husk

An experiment was conducted to find out the optimum duration of the heating for removing ash from rice husk. The ratio of sodium hydroxide was taken as 20% of weight of husk as shown in Fig. 2. Seven different steps of heating duration were taken to boil the husk in alkali solution starting from 5 minute to 110 minute. The proximate content of rice husk sample boiling for different duration in alkali solution is shown in Fig. 3. The results show that after 30 min of boiling the ash content of rice husk becomes almost constant. The ash content decreased from 22% to 2.9% after 30 minute of boiling. Again the volatile matter increased to 80% and the fixed carbon is slightly increased from 15.75% to 19%. Therefore, it is decided that 30 minute of boiling is enough to remove ash from rice husk.

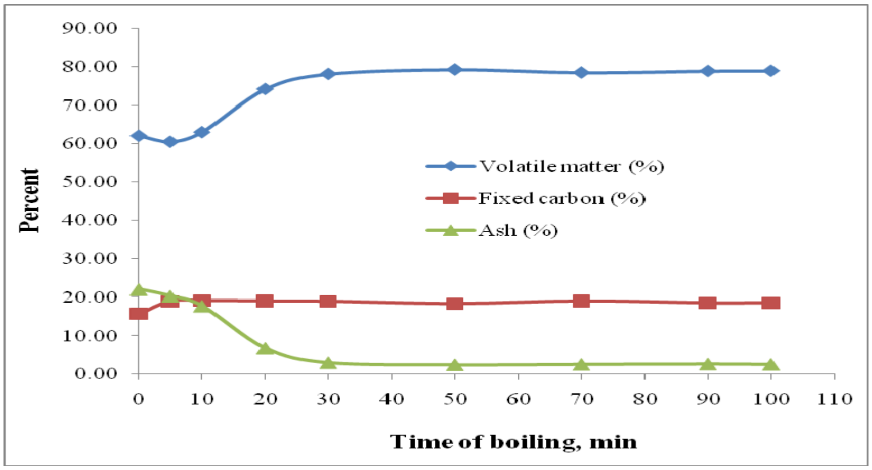


Fig. 3: Effect of boiling time on removal of ash from rice husk

### 3.2.2. Effect of Soaking Time on Removal of Ash from Rice Husk

Ash removal by boiling is concerned of energy expenditure during the process. Therefore, another experiment was conducted to examine the impact of ash removal from rice husk by soaking in alkali solution at 20% ratio with husk for different duration. The soaking duration started from 16 hour to 65 hours. The proximate analysis of different rice husk sample from different soaking duration is shown in Fig. 4. The results show that the ash content decreased from 22% to 5.53% after 65 hours of soaking. It reveals that the ash content can be reduced at expected level by soaking. However, it is more time consuming compared to boiling process of ash removal.

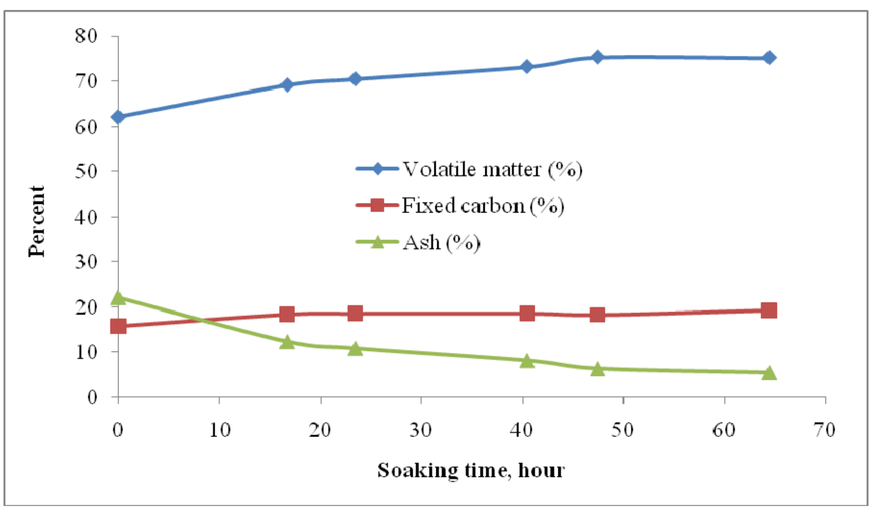


Fig. 4: Effect of soaking time on removal of ash from rice husk (20% ratio of NaOH by weight) at ambient temperature

### 3.3 Ash Removal from Rice Husk Char

Rice husk char is prepared during the process of activated carbon preparation. Since rice husk contains more than 60% volatile matter, it is liberated during the char production. The rice husk is heated at different temperature starting from 250°C to 850°C for 2 hours. The char yield percentage of original mass decreases with the increase of temperature. Char yield from rice husk did not decreased significantly after 750°C. Higher yield of char at lower temperature of heating reveals that volatiles matter still remains in the char (Fig. 5). Proximate analysis results of rice husk char at different temperature is shown in Fig. 6. The share of ash in the remaining char increased to more than 50% at 750°C heating. This ash reduces the mass of share of carbon in the activated carbon from rice husk that causes the low performance of activated carbon from rice husk. Then ash removal from rice husk char is important to get higher grade of carbon containing low ash.

Rice husk char (RHC) is heated in a reflux apparatus under different ratio of sodium hydroxide and rice husk char. The results show that the ash content decreases with the increase in ratio of sodium hydroxide and RHC. Ash content of RHC is not decreased significantly after the increase of ratio beyond the ratio of 0.5 (Fig. 7). Hence the optimum ratio of sodium hydroxide and RHC is found to be 0.5 to reduce the ash content of RHC at a reasonable level.

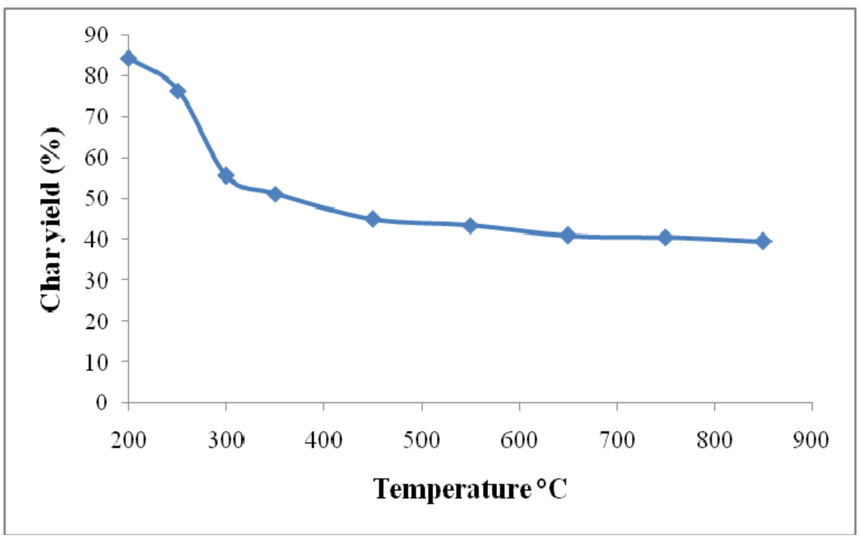


Fig. 5: Effect of temperature on the char yield from rice husk

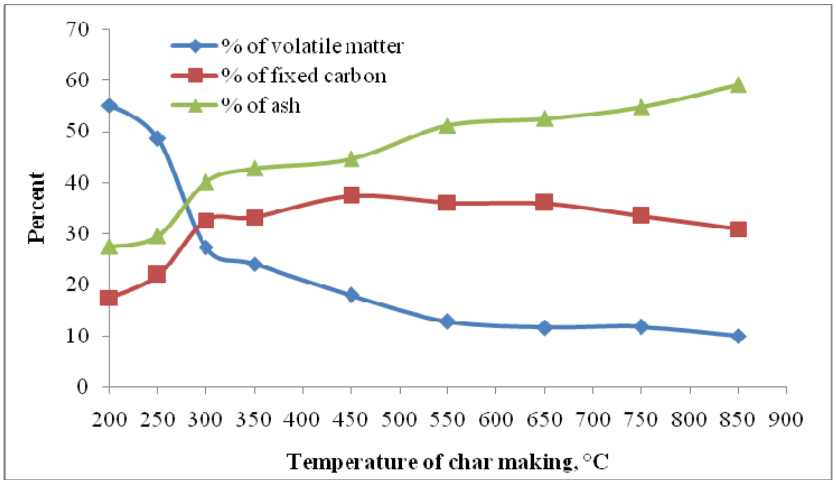


Fig. 6: Proximate analysis of rice husk char produced at different temperature

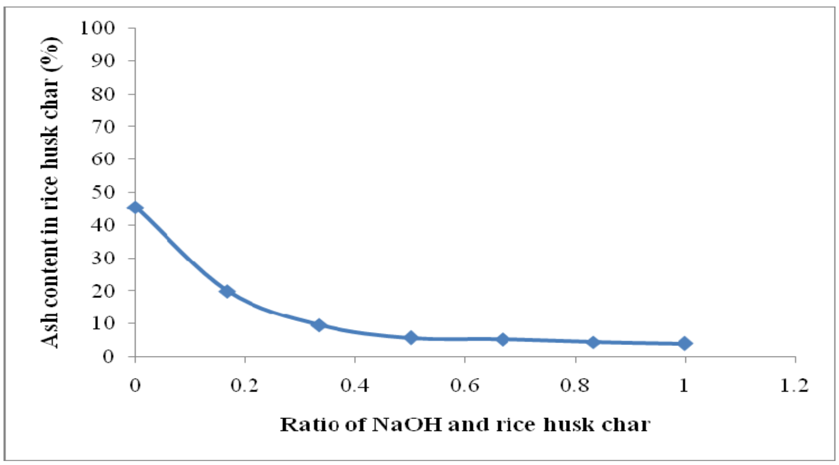


Fig. 7: Removal of ash from rice husk char boiling in NaOH solution at different ratio of NaOH and rice husk char

### 3.3.2 Effect of Heating Duration on Removal of Ash from Rice Husk Char

In previous section it is observed that duration soaking and heating have a positive impact on the removal of ash from rice husk. Therefore, an experiemntal study was conducted to determine the optimum duration of heating for removal of ash from rice husk char. Rice husk char is mixed with sodium hydoroxide solution with ratio of 0.5 of sodium hydroxide to RHC by weight. Seven number of different samples were taken and boiled for different steps of duration starting from 5 minutes to 90 minutes. Ash content of RHC decreases with the increase of boiling time. After 50 minutes of boiling duration the ash content did not decreased significantly (Fig 8). Hence 50 minutes of boiling is enough for removing silica from rice husk char.

Again ash removal by thermal treatment is concern of energy consumption, therefore an experimental study is conducted to find out the impact of soaking duration on removal of ash from rice husk char. RHC is soaked in sodium hydroxide solution for different duration upto 75 hours. The results show that rate of reaction between silica and sodium hydroxide is low compared to thermal application process. Ash content reduced at 28% from 47% after 75 hours of soaking (Fig. 9). Therefore, soaking at ambient temperature is not suitable for removing from rice husk char.

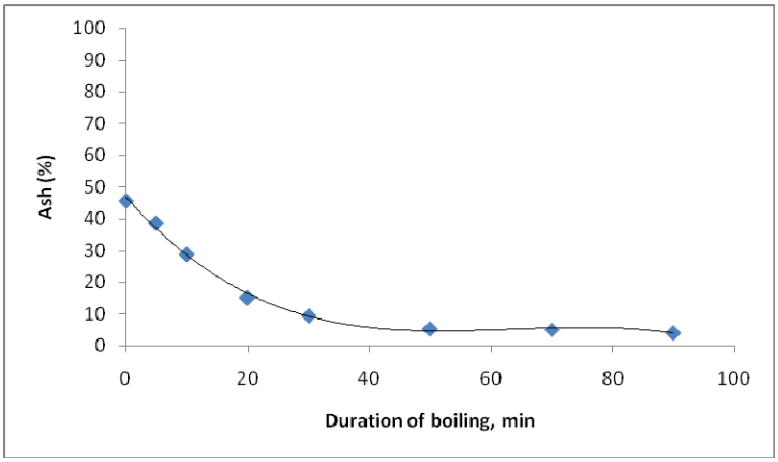


Fig. 8: Removal of ash from rice husk char boiling in NaOH solution at 50% ratio of NaoH and rice husk char by weight

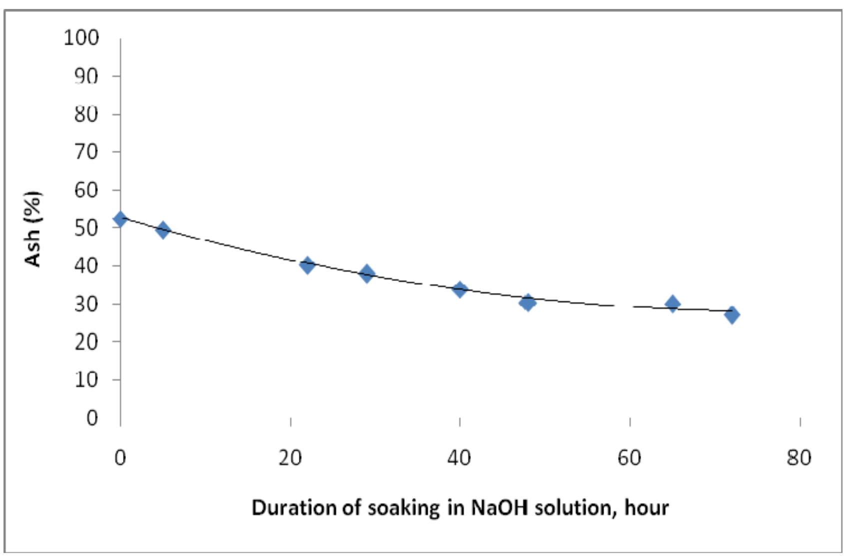


Fig. 9: Removal of ash from rice husk char soaked in NaOH solution at 50% ratio of NaoH and rice husk char by weight

### 3.4. Impact of ash removal on calorific value of rice husk

Calorific value of different varieties of rice husk are determined and presented in Fig. 10. The results shows that there is a variation of calorific values ranges from 11.72 to 13.75 MJ/kg. It is observed that the rice husk containing lower ash gives higher value of calorie. Husk from BRRIdhan 34 and BRRIdhan 29 gives higher calorific value and lower ash content (Fig. 10 and Fig. 1). Calorific value of treated rice husk are determined and presented in Fig. 11. The results show that the calorific value of rice husk increases with decreasing of ash. The calorific value of husk from BRRIdhan 50 is increased from 12.30 to 16.07 for ash content of 22.07% and 2.61%, respectively.

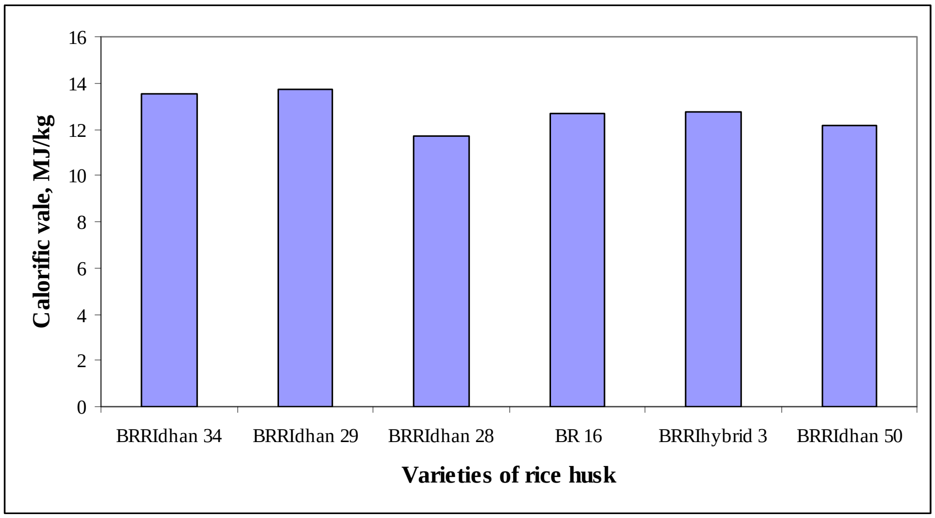


Fig. 10: Calorific of different types of rice husk

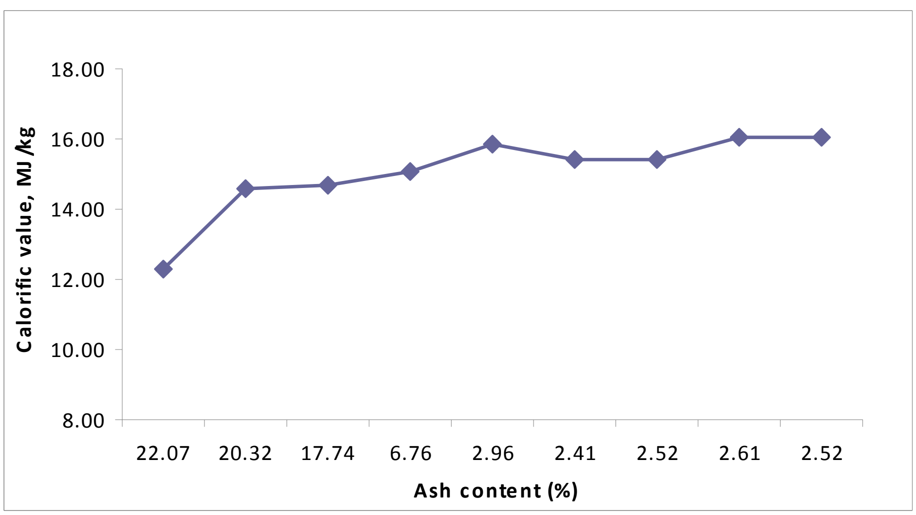


Fig.11: Improvement of calorific value of rice husk by reducing ash content

## 4. CONCLUSION

Rice husk is a waste biomass of rice milling industry and it contail high quantity of silica. Quality of rice husk can be improved by extracting silica in the form of sodium silicate. Sodium silicate is a valuable material as industrial chemical. Rice husk char can be substitute of precursor of activated carbon instead of fossil coal. In that silica from rice husk char is to be removed for obtaining high grade of precursor for activated carbon.

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# SPATIAL DISTRIBUTION OF FIRE VULNERABILITY IN CHITTAGONG CITY

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## ABSTRACT

Fire safety parameters can vary widely from building to building even from floor to floor but some common patterns of public consciousness can be identified within a study area. A study was conducted to identify such pattern and fire vulnerability according to building location which in turn can be a representative of regulatory efforts, planning efforts and overall socioeconomic condition and educational level of the inhabitants. Fire vulnerability map is prepared for the high-rise apartments of selected study area (ward no 8 and ward no 15) of Chittagong City Corporation. To prepare the map six attributes are selected. These are accessibility, fire station, transformer and power line, open space in between two apartments, emergency exit and fire alarm. The first three factors represent efforts from authorities to reduce fire hazard whereas the last three factors represent building owners consciousness towards fire safety and regulations. Each attribute is expressed as a map and then all the attribute maps are integrated to make fire vulnerability map. Significant zone separation can be observed from these maps. This study can help to sort out more vulnerable population within the study area.

**Key Words:** fire safety, hazard map, Chittagong city, accessibility, emergency exit, zonal separation

## 1. INTRODUCTION

A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire. As with most problems in this country, lack of awareness is one of the major impediments in making our buildings safe from fire related accidents. The difference here is that instead of going by the cliché of developing consciousness among the public, it is the professionals who have to first understand the emerging and growing need to be knowledgeable about fire, its dangers, causes and consequences, and then evolve design solutions that make a safe living environment. In case of high-rise buildings (above 6 story) some of these parameters are more significant; like accessibility to fire trucks with high-reach ladders and active fire suppressing system.

However, recent trends show that the use of combustible materials for interior decoration is increasing along with houses and offices are becoming air-conditioned. Windows, which were once open for ventilation, are now closed; thus increasing not only the possibility of a

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fire developing and smoke clogged zone, but the enclosed situation also contributes to jeopardizing escape of affected persons. The possibility of a fire breaking, the potential fire area, the likelihood of a fire starting, the possible risks to life, and the extent of damage increase with the size of a building; the increase in height can only make the situation worse. Needless to argue that the potential risk of fire is higher in garment factories, industries, cinema halls, offices in tall buildings, and shopping centers, but there is no cause for complacency with regard to the implied dangers at home; particularly now because apartments are being housed in large and tall buildings (Ahmed, 2007).

Chittagong City has been experiencing high rate of urbanization since the last few decades. Presently, more than 4 million people are living in Chittagong City. The development trend of Chittagong City is deliberately shifting vertical direction to cope with the extensive population pressure.

High-rise buildings are being constructed in every parts of the city but in most cases dwellings are being constructed without maintaining the planning rules and regulations. Fire hazard vulnerability of Chittagong City dwellers has been increased due to reckless building construction and non conformation of Fire Protection Act, 2003.

## 2. BACKGROUND OF THE STUDY

Fire hazards occur frequently in our country because of different reasons such as unplanned urbanization and lack of public awareness of fire, according to the statistics available with the Fire Service and Civil Defense. The statistics showed the number of fire incidents was 6,289 in 2003, 7,140 in 2004, 7,475 in 2005, 9,542 in 2006, 9,196 in 2007 and 9,310 in 2008. Fire causes huge loss of lives and properties every year. Although termed as ‘fire accident’, most fires are preventable.

From the Table 1 it is apparent that the fire incident and the economic loss are increasing gradually. In the port City Chittagong, every year devastating fire causes huge loss of property and human lives. The number of fire incidents is higher than another region of the country. This is due to total environment and circumstances are not in favor to prevent fire.

From the Table 2 it evident that fire hazards and economic loss is increasing gradually. Records showed that electric short-circuits have topped the list of reasons of fire incidents. Burner posses second position to generate fire hazard. Table 2 also reveals that number of fire incidents in dwelling-house is increasing in Chittagong day by day. Lack of residents’ awareness of electric wiring and burner fire are also the reasons for fire, especially in dwelling-house.

The fire incidents are on an increase due to lack of awareness and practicing fire fighting drills, violation of building codes and non-compliance with the Fire Checking and Extinguishing Law, 2003.

Table 1: Total number of fire hazards and extent of losses due to fire hazards in Bangladesh

| Year | Number of Fire Hazards | Extent of Loss in Tk (crore) |
|---|---|---|
| 2002 | 5404 | 112.21 |
| 2003 | 6289 | 110.59 |
| 2004 | 7140 | 213.78 |
| 2005 | 7475 | 272.64 |
| 2006 | 9542 | 238.76 |
| 2007 | 9196 | 309.00 |
| 2008 | 9310 | 231.00 |

Table 2: Total number of fire hazards, death toll and extent of losses due to fire in Chittagong

| Time Period | No. of Fire Hazard | Extent of Loss (Tk.) | Total No. of Fire in Dwelling House | Economic Loss (Taka) | Death Toll (Human) |
|---|---|---|---|---|---|
| 2007 | 778 | 14,13,83,600 | 347 | 6,70,03,200 | 29 |
| 2008 | 836 | 39,33,60,066 | 419 | 7,76,15,400 | 33 |
| 2009 | 1053 | 34,16,71,500 | 496 | 8,47,30,400 | 11 |

From the table it evident that fire hazards and economic loss is increasing gradually. Record showed that electric short-circuits has topped the list of reasons of fire incidents. Burner posses second position to generate fire hazard.

- **Fire in Bowbazar** At least eight shops and nine dwelling houses were gutted in separate fire incidents at Kazi Nazrul Islam Road under Kotwali thana and Bowbazar area under Bakalia thana in the port city on March, 2010. Valuables of eight shops and two dwelling houses would be worth about Taka eight lakh that burnt to ashes in the fire (The New Age, 2010).
- **Chemical godown** Fire gutted a chemical goodown in city’s Nalapara Ice factory road on June 28, 2010. Sources said Lucky Emporium rented the gowdown from Karnaphuli Paper Mills long ago and stored various types of chemicals including calcium carbonate. Fire service sources said the fire broke out as the chemicals came in contact with rainwater and soon engulfed the entire godown. The affected godown owner claimed that the extent of loss from the fire could go up to Tk five crore.
- **Fire in KTS** At least 54 workers were killed and over 100 seriously injured when a textile KTS factory burned down in the Bangladeshi port city of Chittagong on February 23, 2006. Many of those killed or badly injured were prevented from escaping because factory guards had locked the main entrance and other gates to prevent theft and monitor the 600, mainly young women, working the night shift.
- **28 shanties** A fire burned down at least 28 shanties at a slum in Bakolia thana area of the port city on November 03, 2009. Fire Brigade sources said the fire

originated at a shanty on Rajakhali embankment at about 1am and soon engulfed the adjacent ones. The fire gutted valuables worth about Tk. 10 lakh, creating immense suffering to the distressed people.

According to a CDA (Chittagong Development Authority) official, there are just over 400 high-rise apartment, office and shopping complexes in the city. The majority of the high-rise apartments are at Mehdibagh, Khulshi, Nasirabad, OR Nizam Road and Lalkhan Bazar, while the commercial complexes can be mostly found around Agrabad, Khatunganj, Jamal Khan Road, Chawkbazar and GEC circle. Nearly a dozen of private hospitals and diagnostic centers are allegedly housed at the high-rise complexes without adequate fire protection and other safety precautions.

## 3. METHODOLOGY AND STUDY AREA

To carry out the study resourcefully, four sets of questionnaire have been developed. Each questionnaire has several variables and several natures. These questionnaires have been developed on the basis of objectives to assessing the fire hazard prevention system in high-rise apartments of residential areas in Chittagong City. Questionnaire on expert group mainly higher officials on FSCD, Chittagong Development Authority (CDA), are emphasis on suggestions and recommendations for the best approaches of fire hazards prevention in high-rise apartments. A total of 104 samples were collected.

O.R. Nizam Road, Mehedibag, Nasirabad Housing Society, Suganda, and Khulshy Hill's high-rise residential areas of Chittagong City were selected for the study.

Table 3: Descriptions of five High-rise Residential Area (study area)

| Indicators | Nasirabad, Suganda and Khulshi Residential Area | O.R. Nizam Road and Mehedibug Residential Area |
|---|---|---|
| Location | 8 no ward (Sulakbahar) in Chittagong City These areas are on the middle portions of the city and is largely hilly in character. | 15 no ward (Bagmoniram) in Chittagong City. This ward is situated to the middle north side of the city. |
| Area | This ward has an area of about 3 sq. mile. | This ward has an area of about 4 sq. mile. |
| Population | The population of the Area (8 no ward) was about 250000 (CCC, 2010). | The population of the Area (15 no ward) was about 100000 (CCC, 2010). |

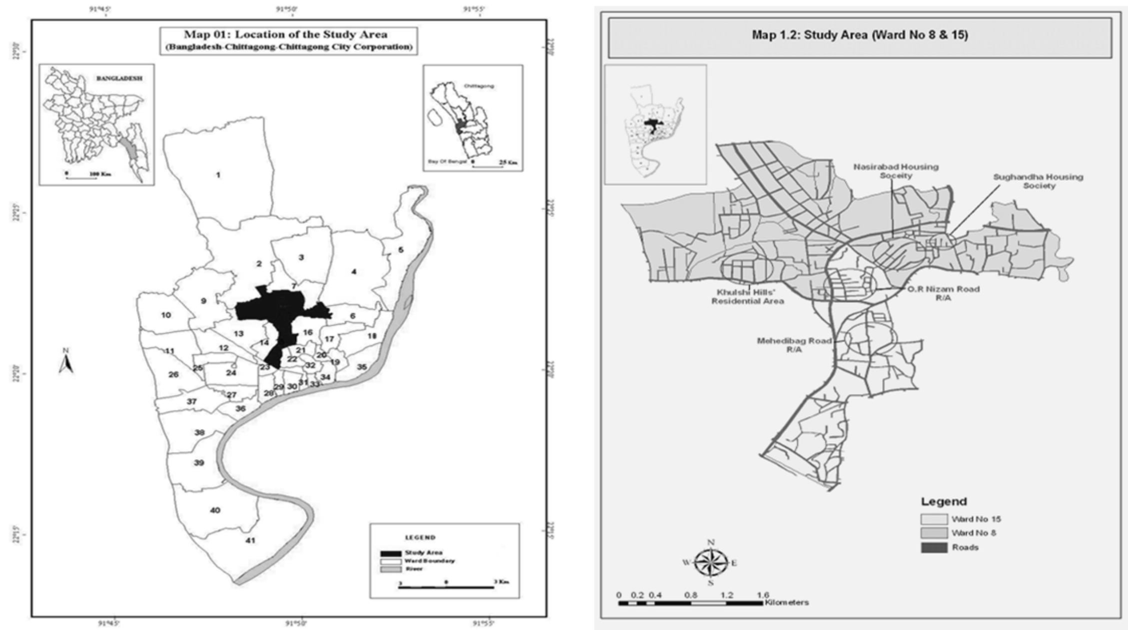


Figure 1: Map of the Study Area

Table 4: Apartment sampling

| Sl. No | Study Area | No. of Apartment |
|---|---|---|
| 01 | Nasirabad Hosing Society | 32 |
| 02 | Suganda Housing Society | 08 |
| 03 | Khulshi Residential Area | 31 |
| 04 | O.R Nizam Road Residential Area | 18 |
| 05 | Mehidibug Residential Area | 15 |
| | Total | 104 |

## 4. RESULTS

Fire vulnerability map is prepared for the high-rise apartments of selected study area (ward no 8 and ward no 15). To prepare the map six attributes are selected. These are accessibility, fire station, transformer and power line, open space in between two apartments, emergency exit and fire alarm. Each attribute is expressed as a map and then all the attribute maps are integrated to make fire vulnerability map.

### 4.1 Accessibility

Accessibility is one of the important attribute for making vulnerability map of high-rise apartments considering fire hazard. Fire affected apartments are supposed to be served by fire engines coming from fire stations which carry water, ladder and various fire fighting equipments. If the roads leading to the affected apartment are not accessible to fire engines, the apartment cannot be served effectively by fire fighters and it become vulnerable to fire. In our country, fire fighting engines which required for high-rise apartments can go through roads at minimum 30 feet width. The road pattern of the study area was analyzed with Geographical Information System (GIS) map which was collected from the Chittagong City Corporation (CCC). The width is not same along the whole length of the road. For example at some point the road may be 30 feet wide but this same road may become 20 feet wide at another point. As a result fire engines cannot go through the road. That is why accessibility is an important factor for vulnerability assessment.

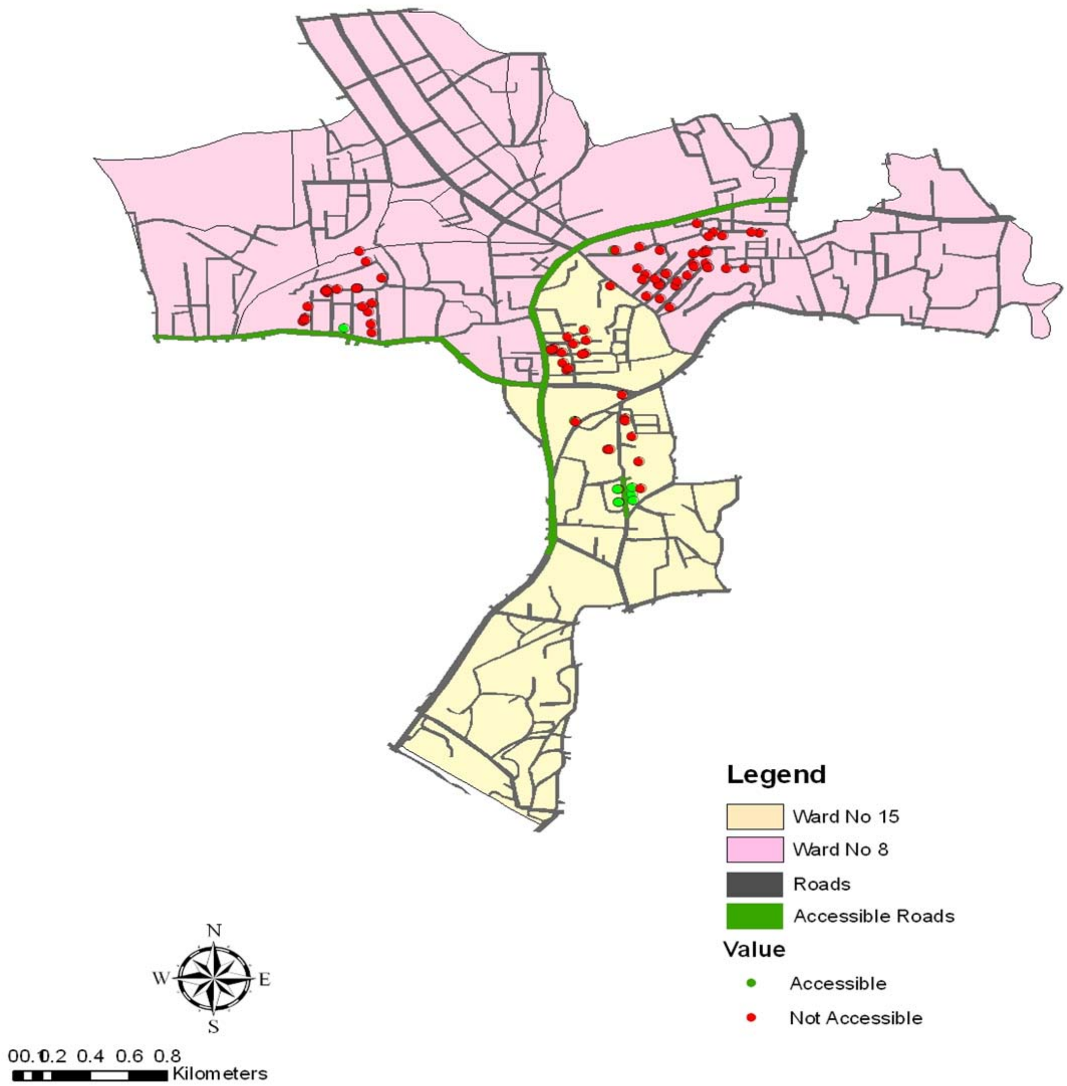


Figure 2: Accessibility Map

### 4.2. Open Space in between Multi-level Building

This is another important attribute for vulnerability map preparation of high-rise apartments considering fire hazard. If an apartment is affected by fire it can spread its neighboring apartment. But if the apartments are built in safer distance its possibility is low.

From the field survey it is found that in many cases there was little space between apartments. So fire can easily spread up quickly in such densely built apartments. Vulnerability distance is taken as neighboring distance less than 15 feet.

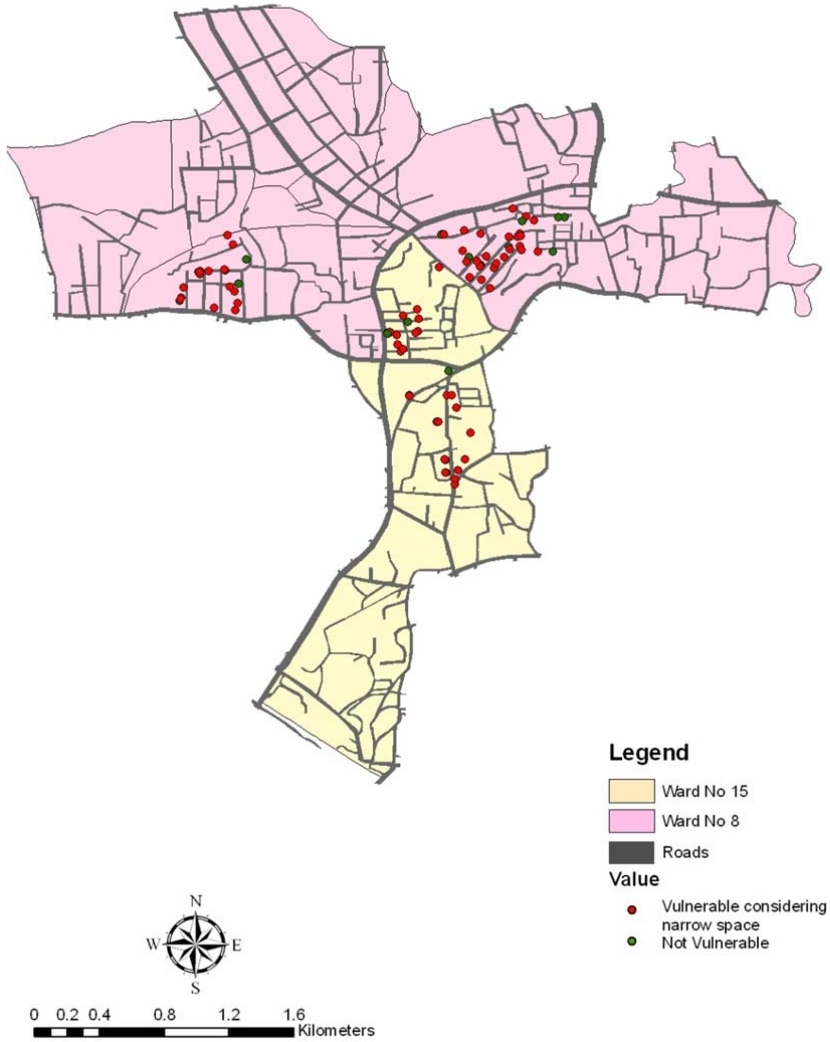

Figure 3: Vulnerability Considering Clear Space Between Buildings

### 4.3. Location of the Transformer and Power Cables

Snorkel and Turntable Ladder appliances needs over headed open space. Besides these appliances mainly use to fight against fire in high-rise buildings but if over headed space in front of buildings is blocked by electricity line it's impossible to rescue and fire fighting.

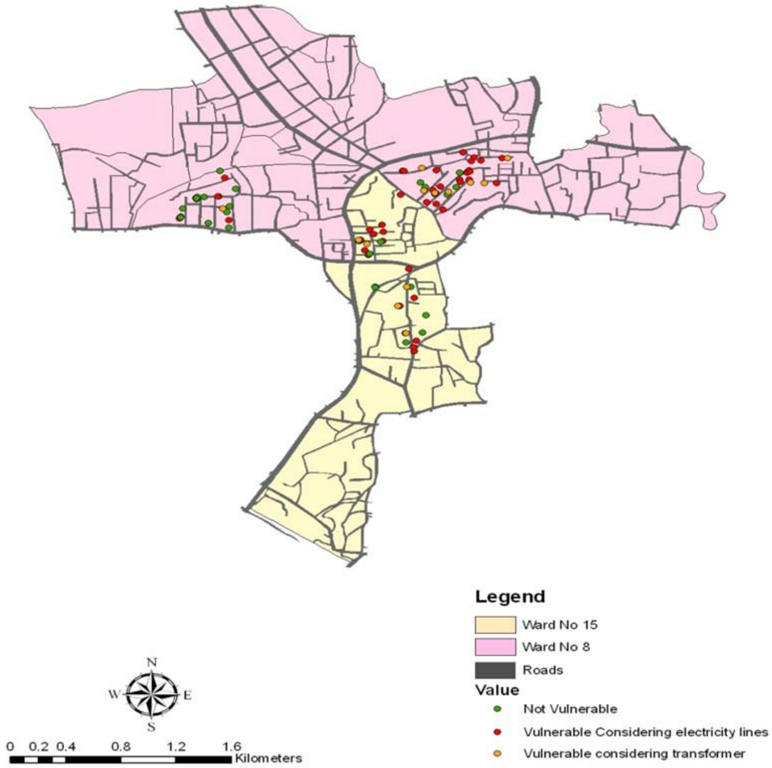


Figure 4: Vulnerability Map Considering Transformer and Power Cables

### 4.4. Location of Fire Fighting Station

This is another important attribute for vulnerability map preparation of high-rise apartments.

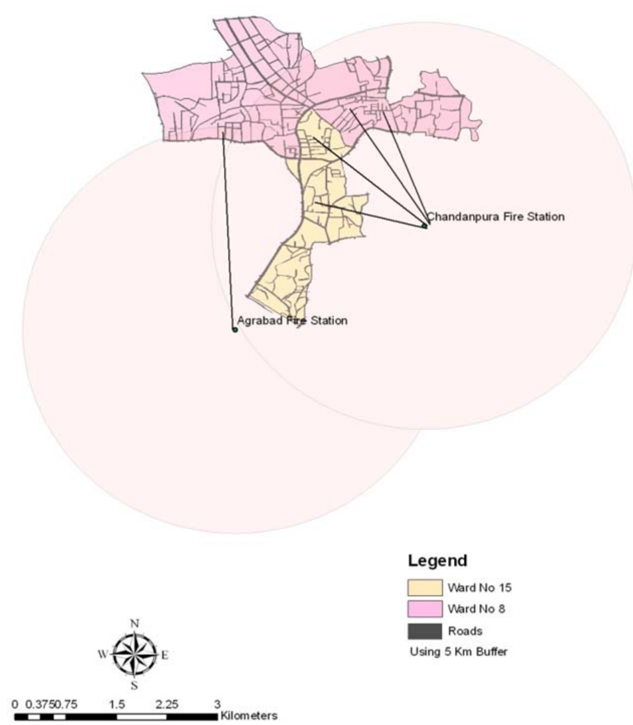


Figure 5: Vulnerability Due to location of Fire Stations

### 4.5. Emergency Exit

This is another important attribute to prepare vulnerability map of high-rise apartment considering fire hazard. An emergency exit in high-rise apartment is a special exit for emergencies such as a fire; the combined use of regular and special exits allows for faster evacuation, while it also provides an alternatives if the rout to the regular exit is blocked.

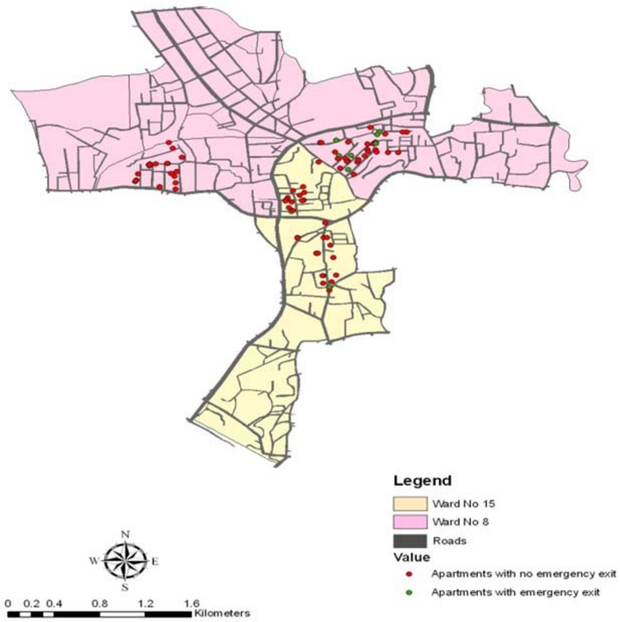


Figure 6: Vulnerability Map Considering Emergency Exit

### 4.6. Fire Alarm

Fire alarm system is an important part of a security to fire protection. That is why this attribute is taken to prepare vulnerability of apartment.

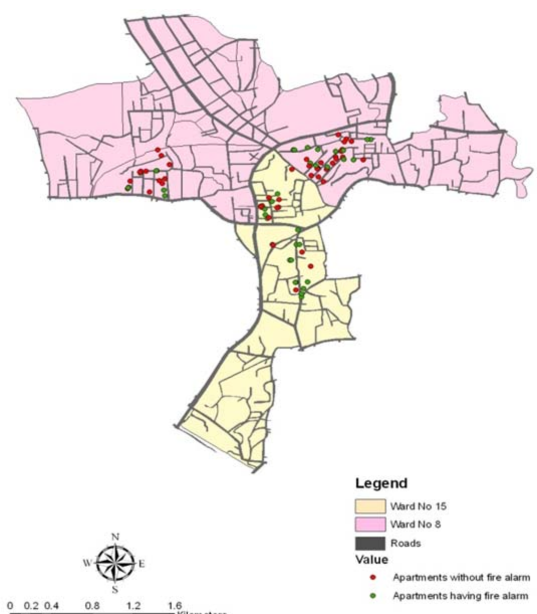


Figure 7: Vulnerability Map for Fire Alarm

## 5. CONCLUSION

To improve the fire fighting aspect, indiscriminate filling up of water bodies must be prevented and adequate right- of- ways should be ensured. It is particularly important in the new development areas. Public awareness campaigns, including fire drills, may be conducted. These results and maps show some spatial variations in the fire vulnerability data. For example, accessibility is better in the central and by main roads which is expected. But, other data shows that most of the building fails to get up to the required mark and thereby fire vulnerable. These data shows a grave picture of our fire safety consciousness level as well as necessity of immediate steps.

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# FIRE SPREAD PARAMETERS REGARDING KNITWEAR: GENERATED HEAT FLUX AND THERMAL INSULATION BY COTTON AROUND COLUMNS

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## ABSTRACT

Bangladesh is positively known for its export of knitwear and is also becoming negatively identified for the recurrent occurrences of fire event in knitwear garments' factories and subsequent huge loss of property and life. This study deals with the characteristics of cotton burning, i.e. its spreading technique and fume development along with the generated heat flux. It can be seen from the study that though cotton produces high heat and smoke during burning but due to its low thermal conductivity, also works as heat barrier. In this industry, it's a common practice to stack up goods around columns and wall. But, due to this phenomena stated above, cotton goods works as an insulator around the column. But if the fire prevails for longer period, then fire reaches to the column and results a closer and more dangerous exposure of column to fire. Thus it can also introduce structural collapse of that column. This study tries to find the balancing effect of these two contradictory phenomenons. Heat release rate of the cotton is also expressed cumulatively and thus enables to calculate the fire load acting on a given column.

**Key Words:** fire, knitwear, column, heat flux, cotton, fire load

## 1. INTRODUCTION

Bangladesh is famous for its wide-spread range of exports in Knitwear and related products. The garments industry has been one of the top earners of foreign remittance. While the production technology is one of the top-notch, the management and safety concerns has been not-so-looked after which is evident from the recurrence of fire events and mass loss of lives in each event.

Flammability of cotton and semi-synthetic material has been a major concern in the garments industry. All fabrics will burn but some are more combustible than others. Untreated natural fibers such as cotton, linen and silk burn more readily than wool, which is more difficult to ignite and burns with a low flame velocity.

The weight and weave of the fabric will affect how easily the material will ignite and burn. Heavy, tight weave fabrics will burn more slowly than loose weave, light fabrics of the same

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material. The surface texture of the fabric also affects flammability. Fabrics with long, loose, fluffy pile or "brushed" nap will ignite more readily than fabrics with a hard, tight surface and in some cases will result in flames flashing across the fabric surface. [1]

In terms of flammability, silk may be the worst with a high burning rate, which may be increased by the dyes and other additives to provide color. Cotton and linen also have a high burning rate but this can be alleviated by the application of flame-retardant chemical additives. Acetate and triacetate are as flammable as or slightly less flammable than cotton. However, they can be made flame-retardant with chemical treatment. Nylon, polyester and acrylic tend to be slow to ignite but once ignited, severe melting and dripping occurs. Wool is comparatively flame-retardant. If ignited, it usually has a low burning rate and may self-extinguish. Glass fibers and mono acrylic are almost flame-resistant. These synthetic fibers are designed and manufactured to possess flame-retardant properties.

This paper focuses on the stacking of cotton in mills around the structural elements, i.e. columns. In case of a fire event, having a flammable material close to a load-bearing element may be a recipe for disaster. Again, as locations of columns are usually in the peripheral zone and at mid-span where passages are located, they provide automatic choices for stacking of goods. This also adds up to the potential of fire-load around the column.

## 2. ESTIMATION OF FIRE SCENARIO

Fire load can be termed as total combustible material per square foot of floor space. At first, one has to determine the weight of combustible materials in the compartment for which he wish to calculate fire load. This value is represented by "W" and is measured in kilograms. After that, determine the value of these materials in joules using their respective calorific value. This value is represented by "C" and is measured in kilojoules/kilogram. Then area of the compartment is to be measured in square meters (A).

$$\text{Fire Load} = (M \times C) / A \;\ldots\ldots\ldots\ldots\; (1)$$

For usual cases, Rate of heat released is release of KCAL heat from combustion of material divided by time in hours or second. Total Fire load means summation of weight of combustible material multiplied by their respective calorific value.

### 2.1. Calculation of Fire Load for Cotton Factory

Table 1 shows some parameters regarding cotton bale size. These dimensions will be used to calculate fire load contributed from a single bale of cotton. Hence the net contributing area to the total fire load is calculated and charring depth is also being observed.

Table 2 represent calorific rate for some common materials. These data can be used for calculation of any type of fire load. Using table 2 and table 1, fire load for a cotton bale can be estimated.

Some other material data has been provided with the table along with cotton properties as they can be used to visualize the significance of these parameters and overall scenario of the cotton property.

Table 1: Properties of Cotton Bale

| | English | SI |
|---|---|---|
| Net Weight | 500 pound | 226.8 Kg |
| Length | 54-55 inch | 1.37-1.40m |
| Width | 20-21 inch | 0.51-0.53m |
| Average Bulge Thickness | 33 inches (or less) | 0.84m (or less) |
| Volume | 17 $ft^3$ | 0.48$m^3$ |
| Density | 28 lbs./$ft^3$ | 472 km/$m^3$ |
| Surface Area | 49.9 sq.ft. (apprx.) | 4.654 sq.m. (apprx.) |

Table 2: Net Calorific Values of Fuels

| **Commercial fuels** | Kcal/kg |
|---|---|
| **Coal(gross calorific value)** | |
| Hard coal | 5000 |
| Lignite beown coal | 2310 |
| Charcoal | 6900 |
| **Petroleum products (net calorific value)** | |
| LPG | 10800 |
| Gasoline/naptha | 10500 |
| Kerosene | 10300 |
| Jet fuel | 10400 |
| Fuel oil | 9600 |
| Natural gas | 8000 - 9480 |
| Electricity | 860 |
| **Biomass** | |
| **Agricultural residues** | |
| Paddy straw | 3000 |
| Rice husk | 3040 |
| Mango leaves | 3390 |
| Groundnut | 4200 |
| Sugarcane | 3800 |
| Wheaat straw | 3800 |
| Cotton stalks | 4700 |
| Maize stalks | 3500 |
| Maize cobs | 3850 |
| Bajra stalks | 3950 |
| Gram straw | 3810 |
| Masoor straw | 3980 |
| **Forestry residues** | |
| Wood wastes | 2500 - 3850 |
| Bark | 2500 - 2850 |
| **Animal wastes** | |
| Cowdung | 3290 |
| Cowdung cake | 3140 |

Table 3: Fire Load for Single Column Stack

| Stack Height (Unit) | Stack Height (meter) | Volume ($m^3$) | Weight (kg) | Fire Load (mega joule) |
|---|---|---|---|---|
| 1 | 0.52 | 0.607152 | 226.8 | 1708.07616 |
| 2 | 1.04 | 1.214304 | 453.6 | 3416.15232 |
| 3 | 1.56 | 1.821456 | 680.4 | 5124.22848 |
| 4 | 2.08 | 2.428608 | 907.2 | 6832.30464 |
| 5 | 2.6 | 3.03576 | 1134 | 8540.3808 |
| 6 | 3.12 | 3.642912 | 1360.8 | 10248.45696 |

Table 4: Surface Exposure for Single Column Stack

| Stack Height (Unit) | Stack Height (meter) | Surface area | | | |
|---|---|---|---|---|---|
| | | Four Face Exposed ($m^2$) | One Long Face Exposed ($m^2$) | One Short Face Exposed($m^2$) | Corner Stack ($m^2$) |
| 1 | 0.52 | 4.6544 | 1.8904 | 1.6044 | 2.3272 |
| 2 | 1.04 | 6.9736 | 2.6132 | 2.0412 | 3.4868 |
| 3 | 1.56 | 9.2928 | 3.336 | 2.478 | 4.6464 |
| 4 | 2.08 | 11.612 | 4.0588 | 2.9148 | 5.806 |
| 5 | 2.6 | 13.9312 | 4.7816 | 3.3516 | 6.9656 |
| 6 | 3.12 | 16.2504 | 5.5044 | 3.7884 | 8.1252 |

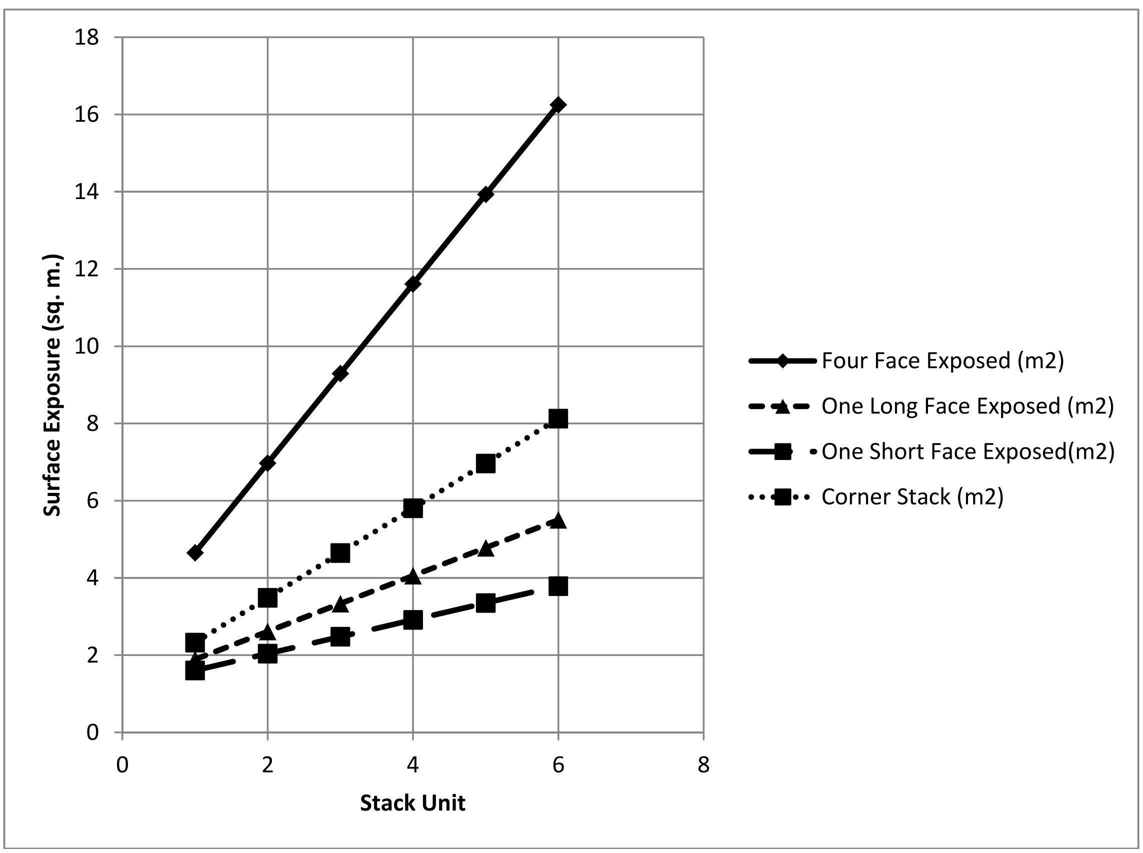


Figure 1: Surface Exposure vs. Stack Height

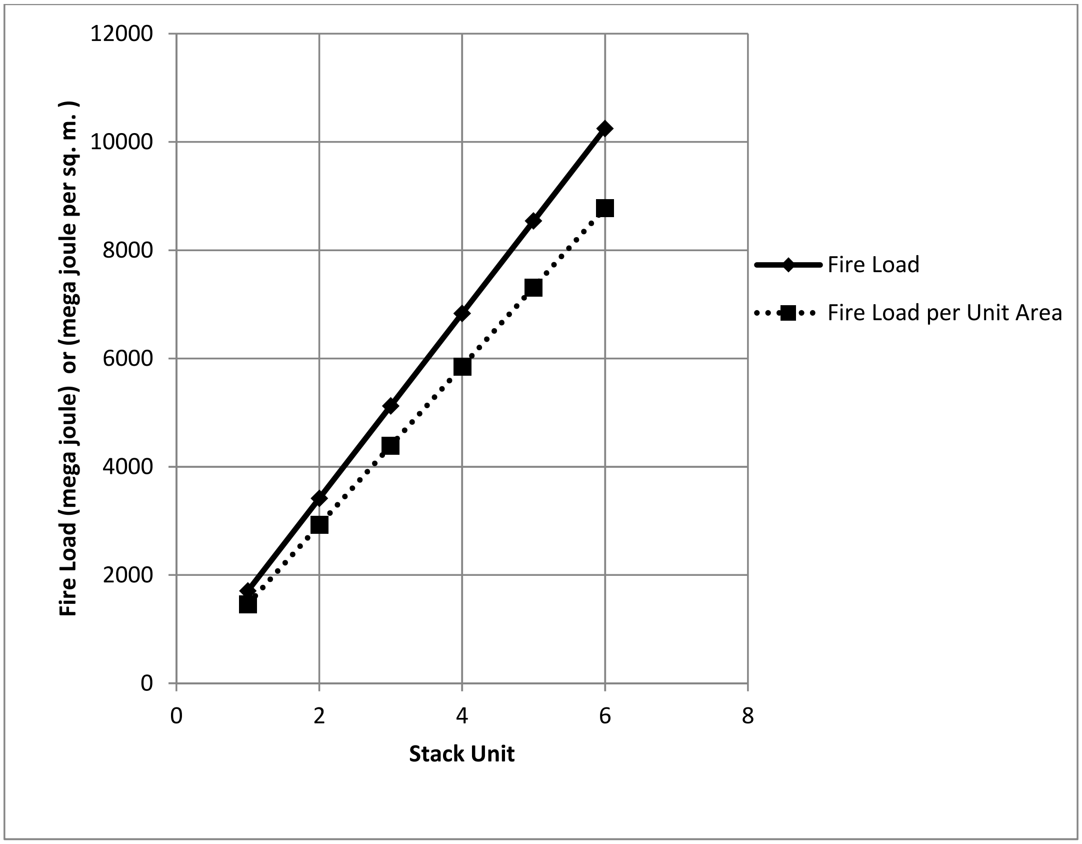


Figure 2: Fire load vs. Stack Height

Table 5: Comparison of Heat Conductivity of Some Common Building Material

| Material/Substance | Conductivity (k - (W/mK)) |
|---|---|
| Air (gas) | 0.024 |
| Bitumen | 0.17 |
| Brick dense | 1.31 |
| Brick work | 0.69 |
| Cement, portland | 0.29 |
| Cement, mortar | 1.73 |
| Concrete, light | 0.42 |
| Concrete, stone | 1.7 |
| **Cotton/ Wool** | **0.03** |
| Glass | 1.05 |
| Iron | 80 |

The R-value is a measure of thermal resistance used in the building and construction industry. Under uniform conditions it is the ratio of the temperature difference across an insulator and the heat flux (heat transfer per unit area, $\dot{Q}_A$) through it or $R = \Delta T / \dot{Q}_A$.The R-value being discussed is the unit thermal resistance. This is used for a unit value of any particular material. It is expressed as the thickness of the material divided by the thermal conductivity. For the thermal resistance of an entire section of material, instead of the unit resistance, divide the unit thermal resistance by the area of the material. For example, if one has the unit thermal resistance of a wall, divide by the cross-sectional area of the depth of the wall to compute the thermal resistance. The unit thermal conductance of a material is denoted as C and is the reciprocal of the unit thermal resistance. This can also be called the unit surface conductance and denoted by h. The bigger the number, the better the building insulation's effectiveness. R-value is the reciprocal of U-value. Around most of the world, R-values are given in SI units, typically square-metre Kelvin per watt or $m^2 \cdot K/W$ (or equivalently to $m^2 \cdot °C/W$).

If the interior of  home is at 20 °C, and the roof cavity is at 10 °C, the temperature difference is 10 °C (= 10 K). Assuming a ceiling insulated to R–2 (R = 2.0 $m^2K/W$), energy will be lost at a rate of 10 K / 2 $K \cdot m^2/W$ = 5 watts for every square metre of ceiling. Similar procedure can be followed to estimate heat transfer for cotton bale. In calculating the R-value of a multi-layered installation, the R-values of the individual layers are added:

R-value(outside air film) + R-value(brick) + R-value(sheathing) + R-value(insulation) + R-value(plasterboard) + R-value(inside air film) = R-value(total)………. (2)

To account for other components in a wall such as framing, an area-weighted average R-value of the whole wall may be calculated. Cotton usually have an R-value of 0.65 $K \cdot m^2/W$. Now, as burning of cotton requires 200 degree Celsius (approximately), and taking ambient temperature as 25 degree Celsius, Temperature difference is 180 Kelvin. So 180K/0.65 $K \cdot m^2/W$=276 watt per meter square for a one meter thick layer. For, 1.39m thick layer, it should be 198.56 watt per square meter. [2][3]

## 3. CONCLUSION

It can be concluded that having a higher calorific value, cotton posses burning risk like any other flammable fuel. In fact cotton can be ignited at temperature close to 150 degree Celsius which makes it very prone to fire hazard. But as this study shows, lower conductivity rate and low surface exposure makes cotton a good thermal resistant. But stacking cotton bells up to 1tonne per column near structural element can posses' serious load bearing damage to that element though it is beyond the scope of this study.

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# FORECASTING GROUNDWATER LEVEL WITH TIME SERIES ANALYSIS

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## ABSTRACT

Groundwater level models can be appropriate tools to solve the ubiquitous groundwater related problems in an effective and satisfactory manner providing the useful information. This study investigates the application of time series analysis approach for predicting groundwater levels. The study site is located in the Kushtia district of Bangladesh, where the groundwater withdrawal rate is comparatively higher due to irrigation and municipal uses. A series of groundwater level observations collected on a weekly basis by the Bangladesh Water Development Board (BWDB) during the period 1999 to 2006 has been used for the experiments. Univariate time series models such as SARIMA models and the time series decomposition models are applied and the resulting accuracy of both models is compared. Empirical results reveal that groundwater level data series in this study shows cyclic patterns. SARIMA models generate more accurate forecasts than the decomposition model. The forecasting of SARIMA models presents the characteristics of trend and seasonal variations.

**Key Words:** Autocorrelation Function, SARIMA Model, Decomposition Model, Groundwater level, Seasonality, Time Series

## 1. INTRODUCTION

Water resources systems are generally complex in nature which often requires the quantitative understanding of its dynamic behaviour to manage it properly. In order to formulate or design an appropriate groundwater development and management strategy, groundwater level fluctuations over time in an aquifer system need to be evaluated as an initial and indispensable task. The conceptual and physically based models are the main tools for depicting hydrological variables and understanding the physical processes that are taking place within a system [1]. However, it is very common that sufficient hydrogeological parameters and domain boundary or initial conditions are often unavailable for physical modeling. Most often these parameters are very difficult to obtain as well because of the several natural and anthropogenic factors [6]. Therefore, time series modeling can be the better option for the area where nothing but the hydrological time series data is in hand.

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A time series model is an empirical model for stochastically simulating and forecasting the behavior of uncertain hydrologic systems [6]. Thus, time series models are the popular and useful tools for long-term forecasting and generating the synthetic data. A number of models such as the Markov models, Box–Jenkins (BJ) Seasonal Autoregressive Integrated Moving Average (SARIMA) models, deseasonalized Autoregressive Moving Average (ARMA) models, Periodic Autoregressive (PAR) models, Transfer Function Noise (TFN) and Periodic Transfer Function Noise (PTFN) models, are in use for these purposes [2,3,4]. The first three of these are univariate models and the last two are multivariate models. In addition, the PAR and PTFN models are periodic in nature [12]. The selection of an appropriate method for modeling a particular problem depends on many factors, such as the number of series to be modeled, required accuracy, modeling costs, ease of use of the models, ease of interpretation of the results, etc. [10]. Several applications of all these models have been proved to be useful for analyzing groundwater level fluctuations over time in several groundwater hydrology applications [5,7,9,13,14] and also for other relevant engineering applications [8]. However, it is also reported in the literatures that when the number of series to be modeled is relatively small and a large expenditure of time and effort can be justified, BJ method (SARIMA) is generally preferable. The choice is due to its inclusion of a family of models, which can be fitted to a wide variety of time series processes. An inherent advantage of the SARIMA family of models is that few model parameters are required for describing time series, which exhibit nonstationarity both within and across seasons [4,10]. The objective of this study to develop the SARIMA time series model and Decomposition model to evaluate the groundwater level fluctuations for the available water level observations in a highly groundwater developed zone (Kushtia District) of Bangladesh. The developed models are then subsequently applied for forecasting purposes. Also, comparative study has been made among the SARIMA model and decomposition model to find out the appropriate models for further application. The results are expected to provide useful information regarding the groundwater level fluctuations in the study area for developing the appropriate groundwater development and management strategy.

## 2. STUDY AREA DESCRIPTION AND DATA COLLECTION

Kushtia district has been selected as a case study area for this study (Fig. 1) based on the availability of data. The groundwater extraction rate is higher in this area because of the growing demand for water due to irrigation activities, municipal and commercial uses of water, and other purposes. The time series data of the observed groundwater level is also available from the Groundwater Circle (GWC) of Bangladesh Water Development Board (BWDB). The fluctuations of the groundwater flow can be understood and visualized from the observed groundwater levels. Observed groundwater level data of five monitoring wells for a period spanning over 1999 to 2006 is collected for this study. It can be mentioned that at least one representative monitoring well has been selected from each upazilla (sub-district) based on data availability. The BWDB data is available on weekly basis with a unit of m.PWD. The m.PWD is the public works datum (PWD) used by BWDB which is located at 0.46 m below mean sea level (MSL) near Bangladesh coast. For ease in identification, each monitoring well is given a unique name (e.g. KUS/BM) using the first three characters from its location district (Kushtia) with additional two characters from its located upazilla (Bheramara) name. All the monitoring stations are positioned on the study area map in the GIS framework using their location (latitude and longitude) coordinates (Fig 1).

## 3. MATERIALS AND METHODS

### 3.1 SARIMA Model

The multiplicative seasonal autoregressive integrated moving average model [2] of Box and Jenkins (BJ) which is denoted as SARIMA ($p, d, q$) X ($P, D, Q$)$_S$ is given by

$$\varphi(B)\Phi(B^S)(1-B)^d(1-B^S)^D Z_t = \alpha + \theta(B)\Theta(B^S)a_t \text{ ……………………. (1)}$$

where $p$, $d$, $q$, $P$, $D$, $Q$ are integers; $s$ is periodicity; $\varphi(B), \Phi(B^S), \theta(B), \Theta(B^S)$ are polynomials in B. The ordinary autoregressive and moving average components are represented by the operators $\varphi(B)$ and $\theta(B)$ of orders *p and q* respectively. The seasonal autoregressive and moving average components are represented by $\Phi(B^S)$ and $\Theta(B^S)$ of degree *P and Q;* the ordinary and seasonal difference components by $(1-B)^d$ and $(1-B^S)^D$ of orders $d$ and $D$; $B$ is the backward shift operator; $d$ is the number of regular differences; $D$ is the number of seasonal differences; $Z_t$ denotes observed value at time $t$, $t$ = 1, 2,………$k$; and $a_t$ is the Gaussian white noise or estimated residual at time $t$ (Eq. 1).

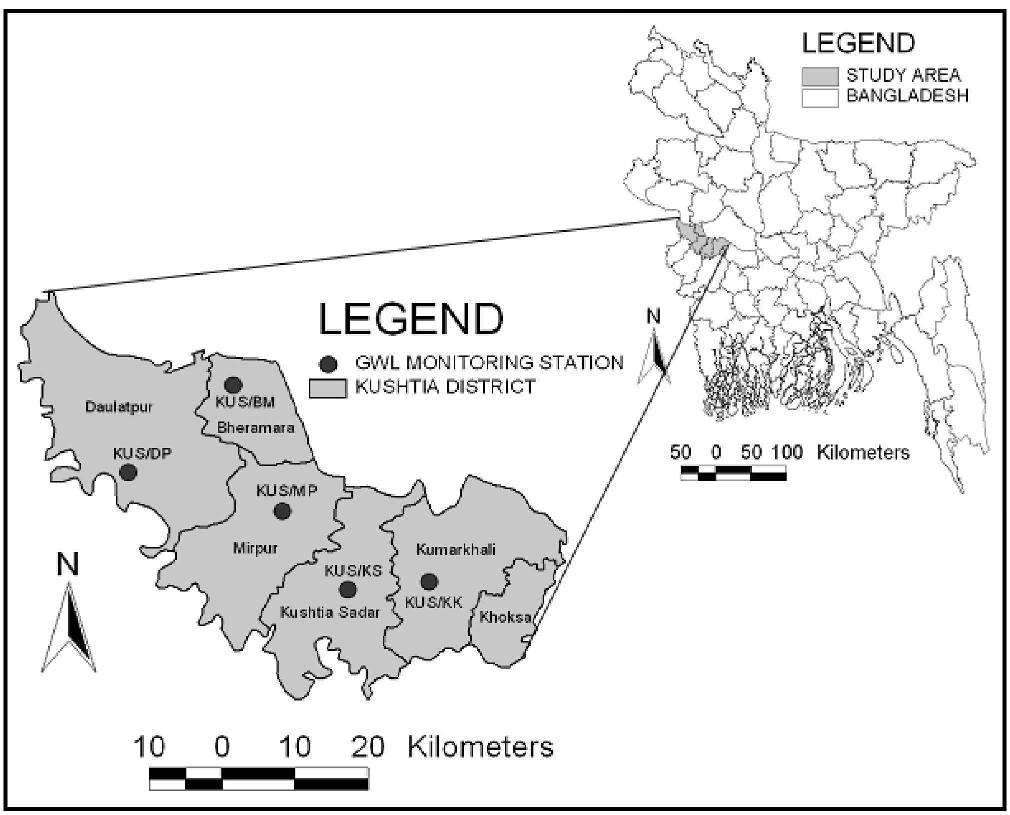


Fig 1: Location of the groundwater level monitoring stations within the study area.

### 3.2 Modeling Techniques

There are mainly four sequential but iterative steps in SARIMA modeling such as (a) identification of the SARIMA $(p, d, q) \times (P, D, Q)_S$ structure, (b) parameter estimation, (c) diagnostic checking of model residuals, and (d) generation of forecasts based on the known data [2, 3, 4]. However, the first to third steps are basically model calibration functions, and the last step is checking for the adequacy of the fitted model. At first, observed time series must be made stationary by applying the appropriate differencing of data. This stationary time series is referred to as being prewhitened. In the identification stage, graphical methods such as periodogram, autocorrelation function (ACF), and partial autocorrelation function (PACF) are useful to determine the periodicity and order as preliminary identification. The procedure for SARIMA model identification uses these functions to tentatively identify the model form for prewhitened time series of the observed data. After model identification, the parameters of the model are estimated by the method of maximum likelihood method [2]. All the developed models are then compared with respect to their error parameters. Appropriate model is selected and forecasting is generated for the groundwater level for each monitoring well within the study area. The present study investigates the pattern of groundwater table fluctuations for five monitoring wells in the Kushtia district of Bangladesh. For simplicity, the water level data of only one monitoring well is explored in details, while that of the remaining wells are used to support the results.

## 4. RESULTS

The statistical software MINITABv14 and SPSSv16 for Windows was employed to develop SARIMA and decomposition models for evaluating the groundwater level fluctuations in Kushtia district of Bangladesh within its software framework using Box-Jenkins ARIMA analysis.

### 4.1 Model Identification

The first step in developing a BJ model is to investigate if the time series data is stationary and if there is any significant seasonality present that needs to be modeled. For model identification, regression and periodic analyses were carried out to find the stationary time series and periodicity or seasonal components of the observed data.

Table 1: Results from linear regression analysis for KUS/BM

| Intercept (m.PWD) | Slope | Mean Absolute Deviation (m.PWD) | Mean Squared Deviation (m.PWD) |
|---|---|---|---|
| 8.34232 | - 0.0002471 | 1.642 | 3.566 |

Table 2: Statistics of raw data and data from the first differencing for KUS/BM

| Data | Maximum (m.PWD) | Minimum (m.PWD) | Mean (m.PWD) | Variance |
|---|---|---|---|---|
| Raw | 12.61 | 5.77 | 8.304 | 3.578 |
| 1$^{st}$ Difference | 1.390 | -0.81 | -0.002 | 0.095 |

### 4.1.1 Regression Analysis

A simple linear regression model is developed to characterize the trend component. The results of regression analysis are shown in Table 1. The trend of the overall groundwater level develops through time which shows a downward trend. This is because; the water suction rate gets high during the dry season due to irrigation purpose and other water evolved activities. The first insight into the statistical properties of the time series is shown in Table 2. Performing the first differencing on the groundwater level series reduces the series mean from 8.304 to -0.002. The first differencing often results in a stationary mean value of approximately zero.

### 4.1.2 Detecting Periodicity

Periodogram is been used to characterize the periodic behavior of the time series. Time series representing groundwater level typically have an underlying annual periodicity. Building a model of time series, detecting periodicity is a must. A plot of the time series may not always uncover the annual periodicity because time series contain random fluctuations that often mask the underlying structure. The plot of the periodogram shows a sequence of peaks with the lowest frequency peak at a frequency less than 0.02. Each of the data points in the time series represents a week, so an annual periodicity corresponds to a period of 52 in the current data set. As period and frequency are reciprocals of each other, a period of 52 corresponds to a frequency of 1/52 (or 0.0192). Fig 2 shows the periodogram for the given data set. Periodicity 52 has been determined from the periodogram as it is showing the frequency about 0.01915.

### 4.1.3 Autocorrelation Function and Partial Autocorrelation Function

Further illustration of the time series is obtained from the estimated Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). As shown in Fig. 3, lags up to 160 weeks long are taken. The ACF in Fig. 3 dies down slowly in a damped sine-wave pattern, indicating that the raw data is non-stationary. Significant correlations (|t-value|>1.6) exist at the lag 1 and lag 2 phases in Fig. 3(a). The ACF exhibits a strong 52 weeks seasonal component. To remove seasonal nonstationarity of the series, the first seasonal differencing of lag 52 is applied (Fig 4), although some significant correlation exists and its magnitude appears to be small as compared the seasonal differencing.

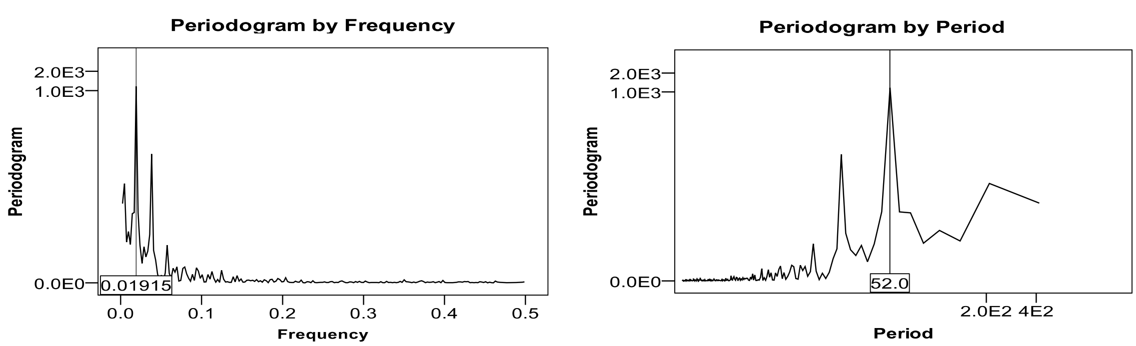


Fig 2: Periodogram of observed groundwater level for KUS/BM well.

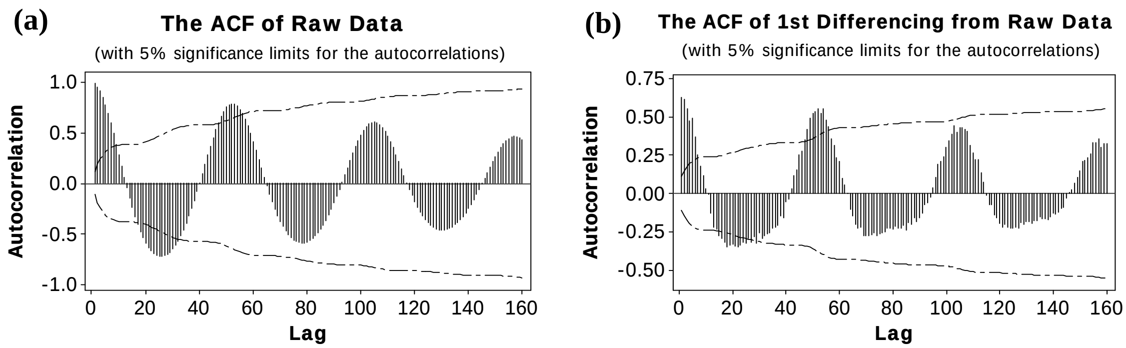


Fig 3: The ACF of KUS/BM well for (a) observed time series and (b) time series from the first differencing of observed data.

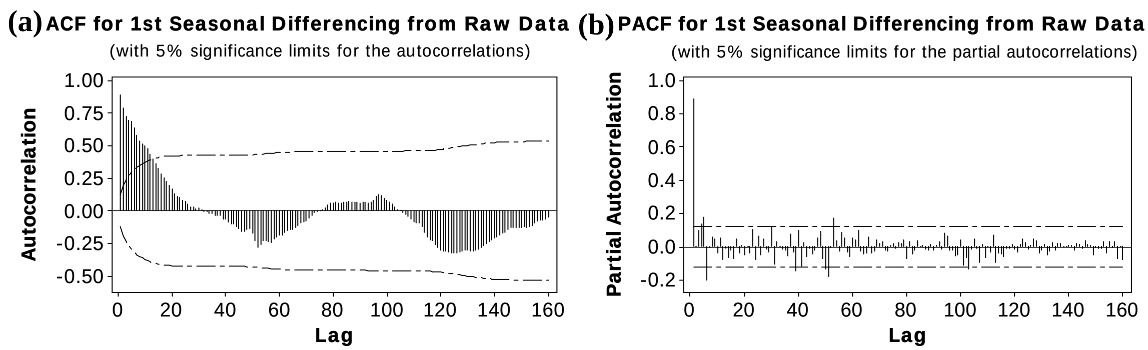


Fig 4: Plot of (a) ACF and (b) PACF for the time series of KUS/BM well obtained from the first seasonal differencing.

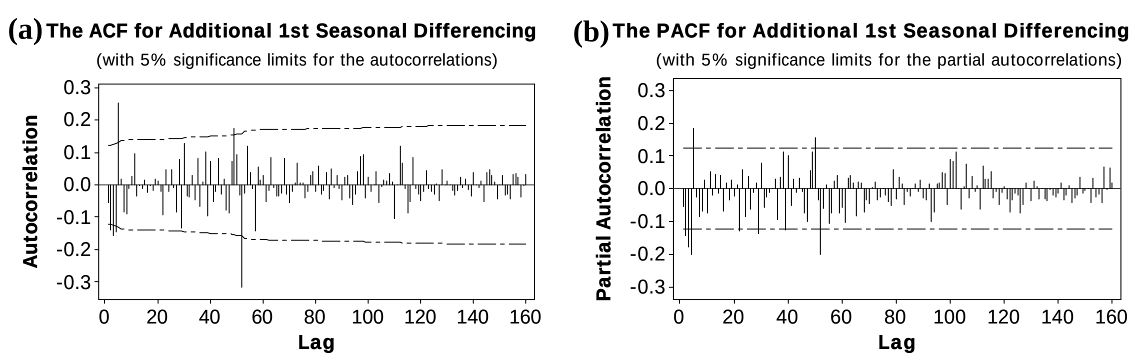


Fig 5: Plot of (a) ACF and (b) PACF for the time series of KUS/BM well obtained from the additional first seasonal differencing.

As the trend shows long term effect, another difference of lag 1 has induced to obtain stationarity and ensured not to be over differenced. A spike at the first seasonal lag 52 (|t-value|>1.6) appear on both ACF and PACF (Fig 5) indicating that the period of differencing is 52 weeks. The ACF and the PACF both exhibiting large spikes that gradually die out indicates that both autoregressive and moving averages processes are present.

### 4.2 Parameter Estimation

The parameters for each model are estimated with the ARIMA module of MINITAB software. The results are summarized in Table 3. The constant terms of all cases are negligibly small since the modeled differencing series has a nearly zero mean. The good quality of the coefficients are significantly greater than zero (|t-value|>2.0) and satisfy the stationarity conditions. Absolute values for all coefficients are also significantly different from 1.0.

### 4.3 Diagnostic Checking

The statistical adequacy of the estimated models is then verified. The ACF function for the residuals resulting from a good ARIMA model will have statistically zero autocorrelation coefficients. Fig 6 shows a plot of the residuals for ARIMA $(1,1,1)(1,1,0)_{52}$ model. The residual plot shows small variations around the zero mean. The plot of the estimated residual ACF in Fig 6 indicates that there is no significant autocorrelation, and the model adopted will be acceptable.

Table 3: Estimated parameters of SARIMA model for KUS/BM well.

| Model | Parameter | Coefficient | SE Coefficient | t-value |
|---|---|---|---|---|
| SARIMA $(0,1,1)(1,1,0)_{52}$ | SAR52 | -0.3716 | 0.0622 | -5.9700 |
| | MA1 | 0.1192 | 0.0620 | 1.9200 |
| | CONSTANT | 0.0008 | 0.0123 | 0.0700 |
| SARIMA $(1,1,0)(1,1,0)_{52}$ | AR1 | -0.0910 | 0.0622 | -1.4600 |
| | SAR52 | -0.3710 | 0.0623 | -5.9500 |
| | CONSTANT | 0.0009 | 0.0140 | 0.0700 |
| SARIMA $(1,1,1)(1,1,1)_{52}$ | AR1 | 0.6057 | 0.2434 | 2.4900 |
| | SAR52 | -0.0029 | 0.0792 | -0.0400 |
| | MA1 | 0.7124 | 0.2154 | 3.3100 |
| | SMA52 | 0.8419 | 0.0686 | 12.2700 |
| | CONSTANT | 0.0009 | 0.0010 | 0.8800 |
| SARIMA $(1,1,1)(1,1,0)_{52}$ | AR1 | 0.8180 | 0.0485 | 16.8800 |
| | SAR52 | -0.4241 | 0.0597 | -7.1100 |
| | MA1 | 0.9470 | 0.0276 | 34.3000 |
| | CONSTANT | 0.0002 | 0.0008 | 0.2500 |
| SARIMA $(1,1,0)(0,1,1)_{52}$ | AR1 | -0.0950 | 0.0623 | -1.5200 |
| | SMA52 | 0.7142 | 0.0655 | 10.9100 |
| | CONSTANT | 0.0004 | 0.0047 | 0.0900 |
| SARIMA $(0,1,1)(0,1,1)_{52}$ | MA1 | 0.1099 | 0.0621 | 1.7700 |
| | SMA52 | 0.8458 | 0.0535 | 15.8100 |
| | CONSTANT | 0.0028 | 0.0032 | 0.8700 |
| SARIMA $(1,1,1)(0,1,1)_{52}$ | AR1 | 0.8386 | 0.0600 | 13.9800 |
| | MA1 | 0.9313 | 0.0415 | 22.4300 |
| | SMA52 | 0.6609 | 0.0666 | 9.9300 |
| | CONSTANT | 0.0004 | 0.0004 | 0.9700 |
| SARIMA $(0,1,1)(1,1,1)_{52}$ | SAR52 | -0.0181 | 0.0777 | -0.2300 |
| | MA1 | 0.1100 | 0.0623 | 1.7700 |
| | SMA52 | 0.8415 | 0.0677 | 12.4300 |
| | CONSTANT | 0.0028 | 0.0032 | 0.8800 |
| SARIMA $(1,1,0)(1,1,1)_{52}$ | AR1 | -0.1014 | 0.0626 | -1.6200 |
| | SAR52 | -0.0199 | 0.0776 | -0.2600 |
| | SMA52 | 0.8412 | 0.0677 | 12.4300 |
| | CONSTANT | 0.0031 | 0.0036 | 0.8800 |

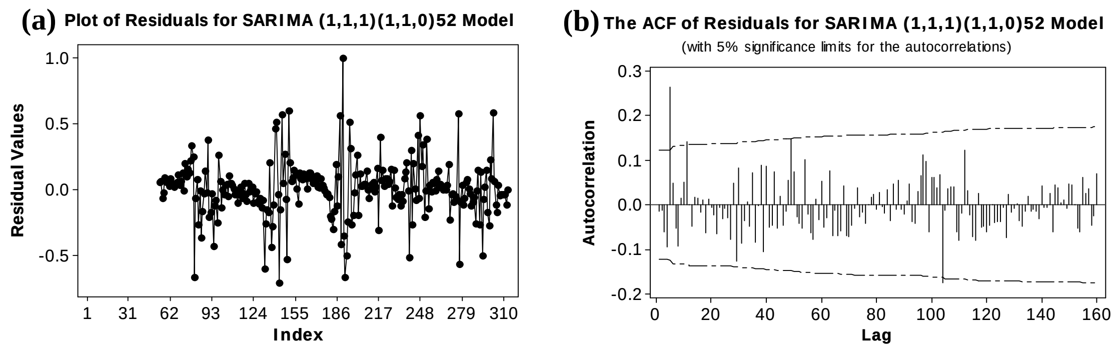


Fig 6: Plot of (a) the residuals and (b) ACF of the residuals of SARIMA $(1,1,1)(1,1,0)_{52}$ model for KUS/BM well.

### 4.4 Generation of Forecasting

SARIMA $(1,1,1)(1,1,0)_{52}$ model was applied to forecast the water level values from January 2005 to December 2006. The forecasts are then compared with the measured data. The forecasted time series and its 95% confidence level error bound are plotted in Fig 7 for both models. It is observed that all measured values fall within the error bound, and the forecasts track the seasonal pattern reasonably well.

### 4.5 Decomposition Model

Decomposition model is then induced to forecast the groundwater level data using multiplicative type model with seasonality 52. A total 104 number of forecasts have been generated in this case using the data from 1999 to 2004 and validated the forecast values with the actual data. Fig 8 shows the sequential plot of groundwater level and forecast values using decomposition model.

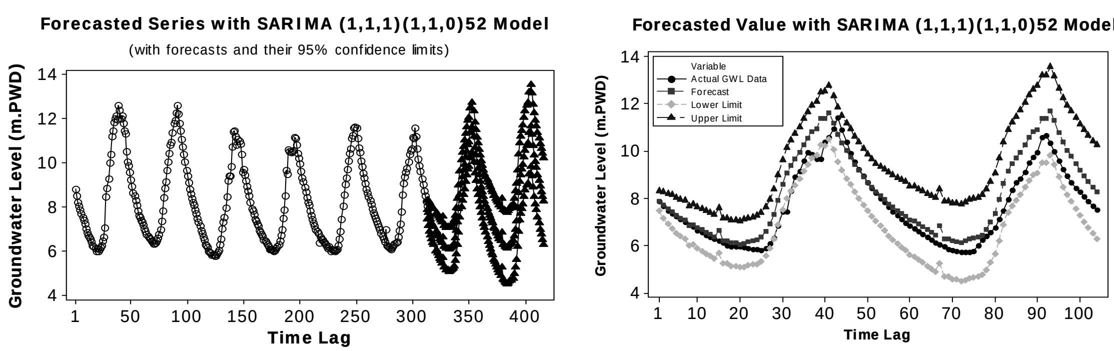


Fig 7: Plot of observed and forecasted values of SARIMA $(1,1,1)(1,1,0)_{52}$ model for KUS/BM well.

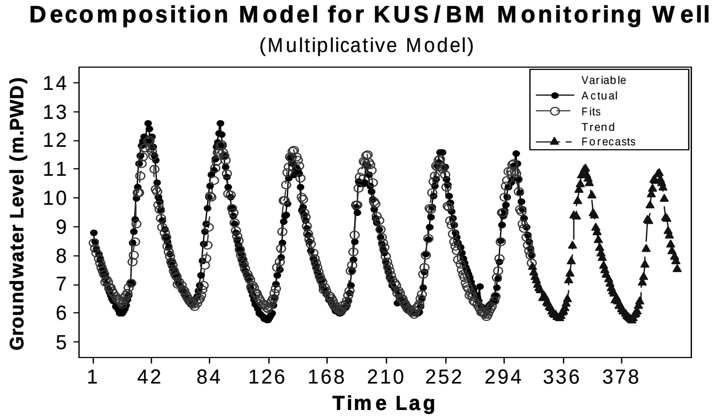


Fig 8: Plot of actual and forecasted value for KUS/BM well by decomposition model

Table 4: Forecasting performance of SARIMA and decomposition models

| Well ID | Model | MAE (m) | MSE ($m^2$) | MaxAE (m) |
|---|---|---|---|---|
| KUS/BM | SARIMA $(1,1,1)(1,1,0)_{52}$ | 0.54 | 0.48 | 1.71 |
| | Decomposition Model | 0.46 | 0.43 | 1.91 |
| KUS/DP | SARIMA $(1,1,1)(1,1,1)_{52}$ | 0.98 | 1.88 | 2.87 |
| | Decomposition Model | 1.10 | 1.92 | 2.94 |
| KUS/MP | SARIMA $(1,1,1)(0,1,1)_{52}$ | 0.46 | 0.37 | 1.79 |
| | Decomposition Model | 0.48 | 0.39 | 1.92 |
| KUS/KS | SARIMA $(1,1,1)(0,1,1)_{52}$ | 0.76 | 0.92 | 1.99 |
| | Decomposition Model | 0.85 | 0.99 | 2.05 |
| KUS/KK | SARIMA $(1,1,0)(0,1,1)_{52}$ | 0.67 | 0.59 | 1.53 |
| | Decomposition Model | 2.57 | 7.17 | 4.56 |

### 4.6 Comparison of SARIMA and Decomposition Model

Three accuracy indices such as mean absolute error (MAE), mean square error (MSE), and maximum absolute error (MaxAE) for nine possible combinations (Table 3) of SARIMA models and a decomposition model for each observation well are computed and the best combination of SARIMA model and the corresponding decomposition model results are presented in Table 4. It is observed that SARIMA model of almost all observation well shows better forecasting performance than their corresponding decomposition model.

## 5. CONCLUSION

This paper presents a data conservative approach of modeling the groundwater level time series to evaluate the groundwater fluctuations in Kushtia district, Bangladesh. The multiplicative combinations of nonseasonal and seasonal ARIMA models have been developed and applied to forecast groundwater fluctuations. The forecasting performance of the SARIMA model shows a seasonal trend. The various SARIMA models forecast weekly data for the evaluation with a MAE of about 0.46m to 0.98m, while the decomposition model gives a MAE of about 0.46m to 2.57m. According to the numerical accuracy measures, it can be concluded that the SARIMA model generates better forecasts than the decomposition model. However, it should be emphasized that the intention of this study is not to determine the best forecasting method rather to introduce the various techniques available for forecasting purpose.

## 6. ACKNOWLEDGEMENT

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# TREATMENT OF TEXTILE WASTEWATER USING LABORATORY PRODUCED ACTIVATED CARBON

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## ABSTRACT

Textile wastewater contains substances of different colors which are harmful to the environment. Activated carbon is used for the decolorization of textile wastewater. Most of the textile plants in Bangladesh do not use the activated carbon due to its expensive cost and still it is classified as imported item. For this, low-cost activated carbon production from locally available materials is necessary. This paper describes the color removal of textile wastewater by adsorption process using activated carbon derived from rice husk in a low-cost method. Adsorption studies with activated carbon derived from rice husk gave 75~90% color reduction from textile wastewater whereas the industrial grade activated carbon gave only 12~35% color reduction. The BOD, COD values, Cl-, Mn, $PO_4^-$ also reduce at about 90~93%, 67~80 %, 50~60 %, 63~87% and 63~87%, respectively from textile wastewater.

**Key Words**: Activated carbon, rice husk, textile wastewater.

## 1. INTRODUCTION

Textile industry plays an important role in the economy of our country. Uncontrolled and untreated disposal from this industries create severe water pollution in the urban and industrial areas. Out of various activities in textile industry, chemical processing contributes about 70% of pollution. It is well known that cotton mills consume large volume of water for various processes such as sizing, desizing, scouring, bleaching, mercerization, dyeing, printing, finishing and ultimately washing. Due to the nature of various chemical processing of textiles, large volumes of wastewater with numerous pollutants are discharged. Since these streams of water affect the aquatic eco-system in number of ways such as depleting the dissolved oxygen content or settlement of suspended substances in anaerobic condition, a special attention needs to be paid. Cotton provides an ecologically friendly textile, but more than 50% of its production volume is colored with reactive dyes. The effluents generated from textile industry are heavily colored, contain high concentrations of salts, and exhibit high biological oxygen demand (BOD) values. These dyes are unfavorable from an ecological point of view if discharged without treatment [1].

There are almost 400 textile industries in and around the Dhaka city and their number is increasing day by day. In the dyeing industries, above 30-60 Liters of water are consumed per

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kg of cloth dyed and large quantities of the effluents are released during processing. It amounts to about 16% of the total water consumed in each factory [2].

Color is one of the characteristics of an effluent which is easily detected and readily traced back to source. Most of the dyes are produced from different chemicals and not suitable for biological degradation. Color affects the nature of the water and inhibits sunlight penetration into the stream and reduces photosynthetic action. Because of hot and strongly colored textile effluents, it is difficult to treat. Some of the dyes are carcinogenic and mutagenic. Various chemicals are present in the effluent, such as phenols, benzene, toluene and other hydrocarbons, many of which are potential carcinogens. Toxicity of various azo dyes especially benzidine based dyes are well known because of their mutagenicity and carcinogenicity. The textile dyeing wastewater contains a large amount of suspended solids, high COD concentration and with a highly fluctuating pH. The presence of chemicals like hydrogen sulphide, sulphide and sulphur dyes causes rapid depletion of dissolved oxygen, affecting aquatic life adversely. Hence, there is a need to remove dyes from textile wastewater before it disposes to municipal sewer or to receiving water bodies [2]. Adsorption is a popular method for treating aqueous effluents, which are important for by-product water re-use and conservation [3].

The conventional methods for removal of dyes may not be efficient and economical for the Bangladesh context. Pollard et al [4] and Namasivayam [5] have reviewed low cost conventional and non-conventional adsorbents or activated carbon for the treatment of industrial wastewaters. Low cost non-conventional adsorbents used include agricultural solid wastes such as coir pith [6], banana pith [7], coconut husk [8], sawdust [9], biogas residual slurry [10], peat moss and rice hulls [11] and industrial solid wastes such as fly ash and red mud [12] and Fe/Cr (III) hydroxide [13].

The adsorbents are not easily and economically available. They are expensive in cost compare with its adsorption capacity. Hence much research interests have been on the investigation of the adsorption characteristics of locally available and economical materials [14].

## 2. MATERIALS AND METHODS

Based on the main objective of this study, rice husk, as raw material, was collected from the local market to produce activated carbon. Firstly, the rice husk was dried in open air. Then, a low-cost furnace was developed to produce activated carbon in the laboratory. Three types of furnaces with different conditions were made to produce the activated carbon. The furnaces were varied in their container dimensions. The container diameters were 4”, 10” and 16” with heights of 5”, 10” and 16”, respectively. The detailed fabrications of the furnaces were presented in another study [15].

### 2.1. Production of activated carbon

Firstly, the container bottom was filled up by raw material and then a separator tray was placed on it. A second layer of raw material was placed on the tray and another tray was placed on it. There was one inch gap between bottom layer of the material and the tray.

The raw materials in the bottom layer were compacted to a dense condition while the second layer of raw material on the tray was placed in a loose condition. After filling the container with raw material, the top of the container was closed and sealed with clay. The container was then placed in a furnace. Then the cover of the furnace was closed and also sealed with clay. The fuel was placed on the grit and started burning. The smoke, produced in the furnace, entered the pot through the bottom opening and passed through the top opening connected with furnace vent line. The heated air and high rise in ambient temperature was effective for the preparation of activated carbon. The smoke came out from the furnace was also observed and initially it was black. The furnace was fueled until the color of the smoke was changed to white. When the color of the smoke was turned into white, all the openings were sealed with clay. The outlet temperature was found to be 86$^{o}$C. Then the sealed furnace was kept unopened for 24 hours and after this time interval the prepared activated carbon was brought out from the container.

### 2.2 Textile wastewater treatment

In conical flask, 100 mL of each textile wastewater sample was taken and 1.0 g, 3.0 g, 5.0 g and 8.0 g of laboratory grade activated carbon and 1.0 g, 3.0 g, 5.0 g, 8.0 g, 11.0 g and 14.0 g of prepared crushed activated carbon, prepared activated carbon and two types of commercial grade activated carbon were added to conical flasks. Conical flasks were than subjected to mixing in a horizontal shaker at 200 rpm for predefined maximum adsorption time, 60 minutes and at 40oC temperature. Adsorbents were removed by filtration in order to get the clear samples. Percent transmittances of the filtered samples were measured. Experiments were repeated trice All other physico-chemical parameters were measured as per Standard Methods (AWWA, 2005). The results are expressed as average values with standard deviation. Spectrophotometer (DR/2500, HACH, USA) was used for measuring percent transmittance for measuring the color. Percent transmittances of all experimental samples were measured at 369 nm.

### 2.3 Results and Discussion

#### 2.3.1 Characteristics of textile wastewater after treatment with prepared activated carbon

From Table 1 and 2 it is seen that PRHAC adsorb 99% color, 90~93% BOD, 67~80% COD, 20~70% acidity, 50~56% Manganese, 63~87% Phosphate and 50~60 % Chloride from enzyme wash and desizing wash wastewater.

#### 2.3.2 Comparison between different activated carbon with prepared activated carbon

Figure 1 illustrates the color adsorption of the different types of activated carbon. Sample in beaker at the right of the top of the figure is the untreated textile wastewater. From the top of the Figure 1, 1st row represent wastewater treated by laboratory grade activated carbon, 2nd row represent wastewater treated by PRHAC (crushed), 3rd row represent PRHAC (uncrushed), 4th row represent commercial grade activated carbon 1 and 5th row represent commercial grade activated carbon 2. From this it was seen that PRHAC give better adsorption performance than both commercial grade activated carbon.

Table 1: Characteristics of Enzyme wash wastewater

| Parameter | Unit | After collection | After treated with PRHAC | |
|---|---|---|---|---|
| | | | Measured value | % |
| pH | - | 6.17 | 6.5 | |
| Color | Pt-Co | Very deep (7,53,00,000~9,15,00,000) | 8~16 | 99.9 |
| BOD | mg/L | 56 | 4 | 92.9 |
| COD | mg O2/L | 1263 | 421 | 66.7 |
| Acidity | mg/L | 100 | 80 | 20.0 |
| Mn | mg/L | 40 | 20 | 50.0 |
| PO4- | mg/L | 8 | 3 | 62.5 |
| Cl- | mg Cl-/L | 300 | 150 | 50.0 |

Table 2: Characteristics of Desizing wash wastewater

| Parameter | Unit | After collection | After treated with PRHAC | |
|---|---|---|---|---|
| | | | Measured value | % |
| pH | - | 6.23 | 7.18 | |
| Color | Pt-Co | Very deep (20,10,00,000~24,40,00,00,000) | 220~328 | 99.9 |
| BOD | mg/L | 116 | 12 | 89.7 |
| COD | mg O2/L | 4211 | 842 | 80.0 |
| Acidity | mg/L | 200 | 60 | 70.0 |
| Mn | mg/L | 180 | 80 | 55.6 |
| PO4- | mg/L | 38 | 5 | 86.8 |
| Cl- | mg Cl-/L | 250 | 100 | 60.0 |

The percentage removals of color with varying doses of different activated carbon at optimal temperature and time are shown in Figure 2. At dose 5 g, it can be seen that the color reduction for Laboratory grade, Produced activated carbon (crushed), Produced activated carbon (uncrushed), Commercial grade 1 and commercial grade 2 are 98%, 90%, 75%, 35% and 12%, respectively. Therefore, the PRHAC gives better performance than commercial grade activated carbon. The PRHAC was tested for two conditions. They were tested under crushed and uncrushed state. The activated carbon which was crushed to powder gives better performance than uncrushed prepared activated carbon.

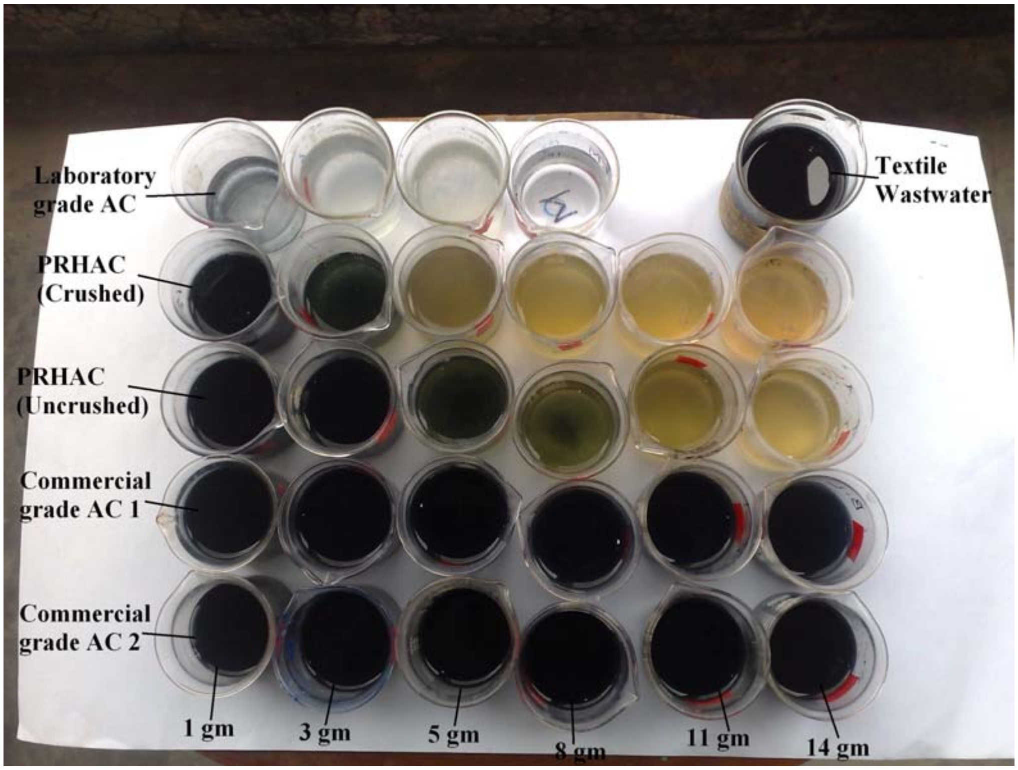


Figure 1: Change in color after various treatment of Textile wastewater is clearly shown in different samples

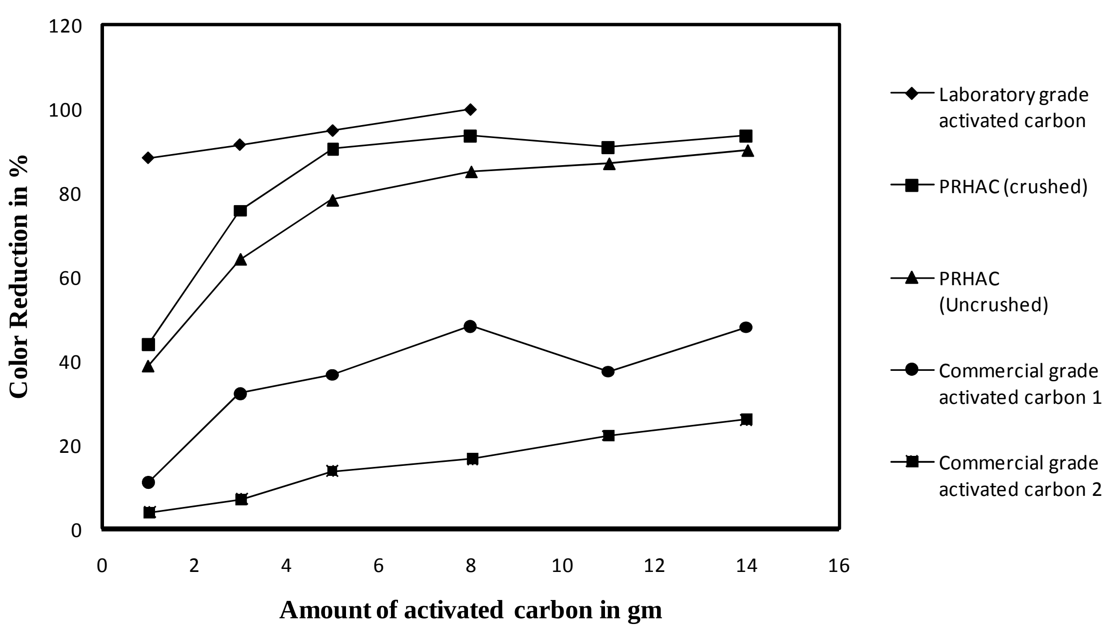


Figure 2: Percentage removal of different type's activated carbon

## 6. CONCLUSION

Adsorption studies with activated carbon derived from rice husk gave comparable and better performance than that of industrial grade activated carbon for decolorization of textile wastewater. Textile wastewater treated with activated carbon reduces BOD, COD, Manganese, Phosphate, and Chloride.

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# CONSTRUCTION MANAGEMENT PRACTICES FOR DEMOLITION AND RENOVATION OF STRUCTURE IN SOUTH-WEST REGION OF BANGLADESH: A CASE STUDY

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## ABSTRACT

Demolition is the tearing down of buildings and other structures for the beneficial purposes. Management refers to the co-ordination of demolition works with respect to time frame, objectives of demolition works and cost effectiveness in conjunction with safety measures that has been taken. A significant number of building structures in the south-west region of Bangladesh are damaged due to environmental effect, such as - salinity, corrosion of reinforcement and soil characteristic. Therefore an attempt has been under taken in demolition works in context to proper management such as investigation of affected structures, estimation, decision making, and preparation of work schedule with time frame. In this study, mainly roof slab and some other parts of a students' hall of residence (Fazlul Haque Hall) in Khulna University of Engineering and Technology (KUET) campus which was damaged due to salinity and corrosion of reinforcement was analyzed. This analysis dealt with demolition of those affected structures with reference to proper management, for instance: safety management, time management and cost management.

**Keywords:** Demolition works, damaged structures, construction management, environmental effects on structures, safety management, time management and cost effectiveness.

## 1. INTRODUCTION

Demolition is the opposite of construction, the tearing down of buildings and other component of structures [1]. A structure is demolished when the structure is required to repair or renovate, when its design life has been exceeded, when it become unfit to live or work in the building, when the existing building is to be used for multipurpose work, when it is required to increase the area of the building or change the internal arrangement. The word management is concern in any construction work to complete the work effectively with proper safety measure that has taken. Demolition and renovation management means the proper management to complete the demolition and renovation works effectively and safely. In this study, the demolition and renovation work of Fazlul Haque Hall is studied. This hall was built since 1974 in KUET campus with a seat capacity of 170.

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At present, it becomes unfit to live due to the severe damage in roof top and required to demolish and renovate. To complete the demolition and renovation work effectively and safely, an attempt has been under taken in context with proper management such as investigation of affected structures, decision making, estimation, preparation of work schedule with time frame. Therefore the most important part of the demolition work is how to manage the work such as how long does the work should run, is all the work run properly according to the plan, what safety measures should be taken, how to reduce the waste of the site, how to reuse the waste which have some salvage value, how to dispose the construction and demolition (C&D) waste etc.

## 2. METHODOLOGY

This study depends on the demolition and renovation work of the "Fazlul Haque Hall" so the study was performed corresponding to the demolition and renovation work of that Hall. First of all, the previous research work related to the demolition and renovation work has been studied. The construction site (Fazlul Haque Hall) has been observed and the initial condition for instance – there area required are to be protected for the pedestrian behind and in front of the hall, what safety measures have been taken, what preparatory work have been done, which method they are going to be demolished the roof top, where the students' dinning, kitchen, paper room were shifted. The necessary data in conjunction with the design of the renovation work, estimation of the work as per PWD rate schedule-2008/current market price, tender schedule, work order/notification of award, contract paper/agreement, works programme, date of completion of project were collected. This study was carried out with these information and regular observation was done with questionnaire survey about the progress of work, risk of their work, the plan of action has been followed, problems has been arisen while works in progress such as - labor crisis, communication gap between the authority and construction farm, sudden increase of construction material cost and transportation cost, delay of shifting the students. Finally these official information and questionnaire information were adjusted. The information's from two sources were analyzed by critical path method (CPM) method.

## 3. CAUSES OF DEMOLITION

Khulna University of Engineering and Technology (KUET) is a renowned university which is situated in Khulna district, the south-west region of Bangladesh. It was established since 1974 as an Engineering College. Fazlul Haque Hall was the first students' hall of residence that was constructed at the beginning of this institution. Therefore significant parts of this structure such as roof slab, outside and inside plaster, brick masonry were damaged partially after its life of 30-40 years. Moreover, due to environmental effect of the south-west coastal belt, these structures were affected by salinity, corrosion of reinforcement etc. Consequently some parts of the R.C.C roof slab were cracked severely. Some portion of concrete was separated and falling down from reinforcement (Fig 1) and the diameter of the reinforcement were reduced significantly. Therefore it has become a severe problem in the rainy season as rainfall water was leaked along these sections (Fig 2) and seemed to be risky structure according to the physical inspection report of the authority. So the authority of KUET had taken an initiative to demolish and renovate the roof top and other affected parts of this structure.

Fig 1: Falling down of plaster from a beam section

Fig 2: Leakage of slab cause rainfall intrusion

## 4. FUNDING OF THE WORK

The cost of the demolition and renovation work of “Fazlul Haque Hall” was sanctioned from the annual budget of the “Repair and Renovation Work” of Hall’s fund. The work was supervised by the “Engineering Section” of KUET. The estimated budget was 71, 24,425 Tk. According to the bidding of the construction farm they got the permission of the work with 62, 33,872 Tk at a discount of 12.7% of total estimated amount. The amount of VAT and source of tax were compensated from the running amount bill (R/A bill). The source of tax and VAT was followed by the rules of the National Board of Revenue of Bangladesh for the specific financial year (began from the 1$^{st}$ July of a year and end at 30$^{th}$ June of the next year). The rate for the VAT and source of tax are given in the table 1. Table 1 reveals that the amount of source of tax for two consecutive years were different. However the amount of VAT for any construction work that involves labor was 4.5% were identical.

**Table 1:** Rate of source of tax and VAT of two consecutive fiscal years [2], [3]

| Fiscal Year | Amount of money (TK) | Amount of source of tax (%) | VAT of the work |
|---|---|---|---|
| 2009-2010 | (0-1) lakh | 0% | 4.5% |
| | (1< to 5) lakh | 1% | |
| | (5< to15) lakh | 2.5% | |
| | (15< to 25) lakh | 3.5% | |
| | >25 lakh | 4% | |
| 2010-2011 | (0-2) lakh | 0% | 4.5% |
| | (2< to 5) lakh | 1% | |
| | (5< to 15) lakh | 2.5% | |
| | (15< to 25) lakh | 3.5% | |
| | 25 lakh< to 3 crore | 4.5% | |
| | >3 crore | 5% | |

*(source: www.nbr.gov.bd)

## 5. PLAN AREA OF THE DEMOLITION AND RENOVATION SITE

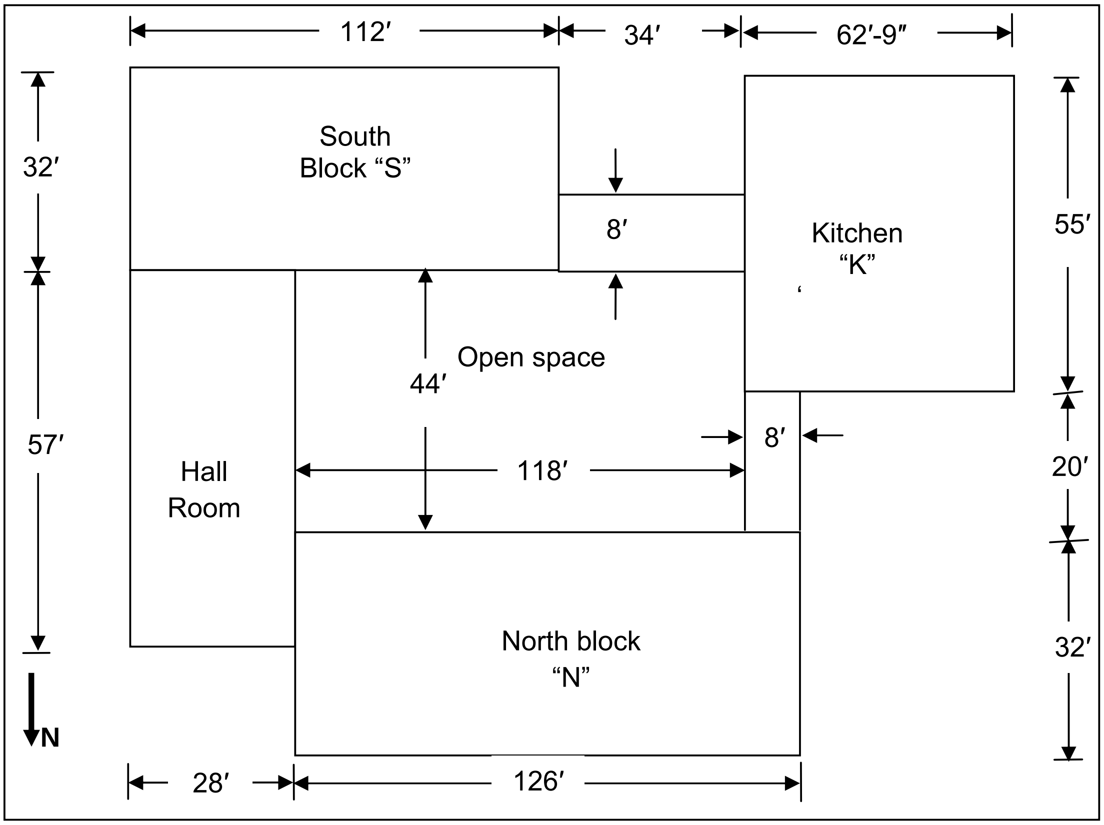


Fig 3: Typical plan view of the Fazlul Haque Hall

Three roof tops of this hall were demolished and renovated. In the fig 1.3, those were shown as north block “N” south block “S” and the kitchen block “K”. The slab thickness was 5″ with a 5″ thick lime terracing layer above it. Therefore total surface area of the demolished slab was 11,408 sq ft.

## 6. MANAGEMENT OF THE DEMOLITION AND RENOVATION WORK

The demolition and renovation work management can be divided into two parts (i) management prior to the demolition work and (ii) management during the demolition and renovation work.

### 6.1. Management Prior to the Demolition Work

Management prior to the demolition work involves the physical investigation, identification of the affected structures, estimation, decision making and pre-planning part of the work. This was done by the Engineering Section of KUET on behalf of KUET authority under the guidance of “Planning and Development” (P&D) section of KUET according to the “Public Procurement Act-2008”. First of all, a team of specialist from engineering section has investigated the Hall. According to their report, in presence of director of P&D, it was decided to demolish the roof top of the Hall and renovated the Hall. To implement this decision, the total cost of the demolition and renovation work was estimated and a call for tender was published. Different construction farms dropped their tender with three percent earnest money. Flowchart of plan of actions has shown in fig 4.

Affected site investigation by KUET authority

↓

Decided to demolish the affected parts and renovate

↓

Estimation of the total cost and advertising for a call of tender

↓

Tender dropped by the contractors

↓

Checking of comparative statement; evaluate the pre-requisite qualification of contractors

↓

Signing of agreement paper and handover the site to the qualified contractor

Fig 4: Pre-demolition management diagram[4]

### 6.1.1. Qualification of the Construction Farm to Bid the Tender

Prerequisite competencies of the construction farms for bidding are provided by the engineering section on behalf of KUET authority. These prerequisite are:

1. The farm has to show the attested copy of the enlistment license, A.I. license for the year of 2009-2010 including the VAT certificate for the year of 2008-2009 and these documents should be submitted with the submission of tender paper (schedule paper).
2. The farm has to show the original copy of the work order and the experience certificate from the executive engineer of any construction or repair work that was cost an amount of fifty lakh Tk and was performed by the farm itself.
3. At last the farm should has an average amount of Tk one crore as a constructional turnover for the previous five years.

By fulfilling those requirements a farm becomes qualified for the bidding. Comparative statement was calculated to found the lowest bidder. Lowest and qualified construction farm was selected by the evaluation committee. Then the farm signed an agreement paper with some terms and conditions.

### 6.1.2. Terms and Condition of the Agreement Paper

There were some terms and condition provided by the KUET authority according to the Public Procurement Act 2008 (PPA) for the construction farm when the agreement paper were signed. Such as:

1. It is mandatory for the construction firm to test the material in the laboratory of KUET.
2. The design of the work will supplied from the engineering office of KUET, if there is any change in design the farm will be bound to complete the work according to the new design without any extra money.
3. The total work should be completed within 180 days.
4. The farm has to start the work within three days from the day they get work order.
5. If the farm fails to complete the work within the time limit the KUET authority will find at least 0.1% to maximum 1% amount of money of the amount of total work order.
6. The farm has to deposit 10% of the work order amount as a security money, but if the Total Quoted Rate is more than the estimated rate of engineering department, the farm has to deposit extra 10% money of the total work order amount (i.e. they has to deposit 20% money). This security money will be returned to the farm after one year from the

day of site handover at two installments (1st one at 6 months later and 2nd at 12 months later).

7. If the quality of the work is not good enough then KUET authority will deduct 30% money of the Quoted Cost of the total work.
8. To get the running amount bill at least 30% work should be completed.
9. The farm has to provide primary medical service to the labor and take necessary measures against the environmental and sound pollution. The work progress will investigate by a reliable person on behalf of KUET authority.

By submitting ten percent performance gratuity by bank draft of pay order the farm has been started their work. Up to this KUET authority performed very well. Then the field management has been started. The management before the demolition is an important part of the work. The success of the work also depends on this management. It is also said as official management for any construction work.

### 6.2. Management during the Demolition and Renovation Work

This part has been started by completing some preliminary work such as: no new student were allotted seat after the passing out of the old student, the kitchen was shifted to a temporary shade, the dinning was shifted to the paper room, paper desks to the corridor, and game room was closed for the time of work. An external temporary stair and a shade (for the workers and the instrument) were built. Afterward the work of demolition was started. The total works was divided in to three phases (North block “N”, Kitchen “K” and South block “S”). At first work of block “N” was started. In demolition work, lime terracing layer was demolished manually prior to demolish the main R.C.C slab (Fig 5). The slab was demolished by the same procedure but, in that case top surface of the bottom floor were covered by wooden pieces beneath the straw so that the concrete debris from the roof could not destroy the floor finish. The reinforced bar were cut off by grinding machine. Site cleaning was performed parallel to the demolition work. While demolished the structures then the parts of the building material such as reusable bricks, bats, concrete debris etc. and recyclable reinforced bar were separated from the waste. Thus the demolition work has been completed and renovation work has been commenced. The total renovation work is completed by dividing the work into small parts of work. Different types of workers with different rate were employed for different part of the renovation work. Centering and shuttering were done by a group of workers. Afterward a group of masons were involved for micro concrete work, stripping of unserviceable plaster and slab casting. After 28 days of curing a group of labors were employed to remove the shuttering and few workers were employed for fixing the doors and windows. Masons were employed for plaster work and masonry work and few sanitary workers were employed for fixing and fitting the water tanks and sanitary works. A group of tiles workers has been employed to complete the tiles and mosaic work. Afterward painting works has commenced. Thus the work of renovation was completed under the supervision of the KUET authority.

Fig 5a:Demolition of lime terracing layer

Fig 5b:Demolition of R.C.C slab

Fig 5c:Curtailment of corroded reinforcing bar

Fig 5d:Demolition of R.C.C beam

Fig 5: Demolition process of roof top

Table 2: Amount of running amount bill given to the construction farm with deduction

| Sl No | Justification (Date) | | Total bill (Lakh TK) | Money Deduction (Lakh TK) | | | Net Payment (Lakh TK) | % of work completed |
|---|---|---|---|---|---|---|---|---|
| | Investigation by Authority | Check Issued | | VAT | Source of tax | Security money | | |
| 1 | 27-06-10 | 30-06-10 | 14.98 | 0.67 | 0.37 | 1.50 | 12.43 | 30% |
| 2 | 07-11-10 | 09-11-10 | 10.58 | 0.48 | 0.47 | 1.05 | 8.58 | 45% |

Similar work has been completed for the south block and kitchen block. The cost of the works paid by the KUET authority during the work is known as running amount bill (R/A bill). According to the agreement signed by the farm, 1st running amount bill was given to the farm after completing 30% of total work. The R/A bill were paid by deducting the amount of VAT, source of tax, and security money (Table 2). This security money will pay after the completion of the work if any fault will found after the construction. the contractors will have to repair that works otherwise they will lose their security money. After the completion of the work an inspection team on behalf of KUET authority was investigated the site so that if any fault will found they could complain against the construction farm. The construction farm has to handover the site to the KUET authority and the farm will get their security money after one year from the day of handover at two installments such as first one after 6 months and second one after 12 months. The farm made a program chart (Table 3) prior to work started. Each month they have drawn the progress of the work on that program to compare their work progress and goal. It was also useful for the site engineers to investigate the work of the farm.

Table 3: Time chart of work for the North block

| Sl No | Item of Work (for North block) | Date of start | Date of end | Duration (day) | No: of workers per day |
|---|---|---|---|---|---|
| A | Mobilization | 01-06-2010 | 05-06-2010 | 5 | 10 |
| B | Demolition of roof top | 06-06-2010 | 21-07-2010 | 46($S_1$) | 18 |
| C | Stripping of unserviceable plaster | 07-06-2010 | 27-06-2010 | 21 | 9 |
| D | Micro concrete | 09-06-2010 | 28-06-2010 | 20 | 9 |
| E | Electrical fitting and fixing Phase-1 | 09-06-2010 | 04-07-2010 | 26 | 8 |
| F | Electrical fitting and fixing Phase-2 | 14-10-2010 | 18-10-2010 | 5 | 8 |
| G | Centering & shuttering | 28-07-2010 | 29-08-2010 | 33 ($S_2$) | 11 |
| H | R.C.C. work | 30-08-2010 | 01-09-2010 | 3 | 85 |
| I | De-shuttering | 28-09-2010 | 13-10-2010 | 16 | 15 |
| J | Brick work (125mm and 250mm) | 12-10-2010 | 27-10-2010 | 16 | 8 |
| K | Plumbing work | 22-11-2010 | 06-12-2010 | 15 | 6 |
| L | Door & window work | 10-11-2010 | 30-11-2010 | 21($S_3$) | 7 |
| M | 6mm & 12mm plastering work | 10-10-2010 | 10-11-2010 | 31 | 16 |
| N | Tiles work | 06-12-2010 | 14-12-2010 | 8 | 6 |
| O | White wash | 12-10-2010 | 12-11-2010 | 31 | 5 |
| P | Painting work | 26-11-2010 | 25-12-2010 | 20 | 4 |
| Q | Distemper work | 08-11-2010 | 16-11-2010 | 9 | 4 |
| R | Weather coat | NSY | NSY | - | - |
| S | Site cleaning | 05-09-2010 | 23-09-2010 | 19($S_3$) | 10 |
| T | Lime Terracing work | NSY | NSY | - | - |
| U | Mosaic work | NSY | NSY | - | - |

Here, NSY stands for the item of work which is not started yet.
**“$S_1$”** stands for split of work for 10 days due to shortage of workers.
**“$S_2$”** stands for split of work for 2 days to check the level of center of reinforcement.
**“$S_3$”** stands for split of work for 5 days due to the vacation of Eid.

### 6.3. Reasons for Delay and the Difficulties Faced by the Farm

The farm should complete the work within 180 days but they did not complete their work within this time limit due to some causes. According to the agreement, the farm has to start the work within three days after the agreement but within these three days all the students from the north block did not shift to the south block so the farm failed to start their work in due time. Since the work was started in rainy season, the progress of work was slow. During rainy season the production of brick was stopped and the rate of brick during rainy season was high. Therefore contractor had to depend on only the stocked bricks for the construction. Moreover two Holly Eid vacations did cause 12 days delay. In the winter season the farm suffered to the deficiency of workers which had a significant effect on delay. In winter season the rate of cement and fine aggregates were increased so the farm had to depend on the stored materials. Once again, the transfer of the students from south block to the north block caused delay for few days.

## 7. SAFETY MANAGEMENT

In any demolition and construction work safety measures should be a great concern for the workers. Otherwise a simple mistake can make a great suffer for the workers. It may cause even death of the workers. The construction farm did not facilitate any safety measures to the workers and the site. No celluloid glass, gloves were given to the workers while they used to cut off the corroded reinforcing bars (Fig 6). No safety belts were provided to the workers while demolishing the R.C.C beam (Fig 7). On the contrary, no safety fences and platforms were used to protect the site from the falling debris (Fig 8). Therefore it could cause an accident to the pedestrians. However there was no sever accident occurred. The workers were conscious about accident and they have shown their skill to work in a dangerous site, though it is not a good practice.


Fig 6: No gloves and celluloid glass


Fig 7: No safety belt

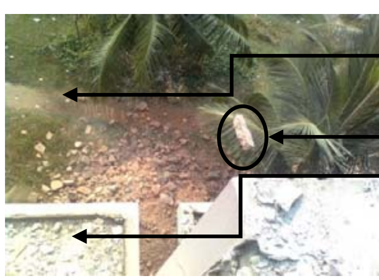


Fig 8: No safety measures has taken around the site

## 8. REUSABLE AND RECYCLABLE MATERIAL MANAGEMENT

Reuse means to use any previously used material without changing its original formation. Recycle means use of any previously used material by changing its original formation throughout heating, cooling, or changing chemical property etc. In the demolition site bricks, stripping plaster, concrete debris, reinforced bar etc were separated. These materials can be used for another or same purposes. Bricks, stripped plaster and concrete debris are reusable material. Bricks are used in construction work as brick chips and concrete debris and stripped plaster are used as filling material of the roadway sub base and low lying land. On the other hand reinforced bars are recyclable material. Screws and new reinforced bars are manufactured from these corroded reinforcing bars through recycling. The authority was conscious about these reusable and recyclable materials. According to the agreement the owner of these wastes was the construction farm. The farm sold these reusable materials and the recyclable materials. Thus the reusable and recyclable materials were managed in the site.

## 9. SITE CLEANING

A huge amount of construction and demolition (C&D) waste was generated from the site. Hence it was essential to remove these wastes from the site from time to time during the demolition and construction period. It was done for easier movement and working of labours, pedestrian passing beside and to keep the other services beside the site. It was also done for beautification purpose and to facilitate quick recycling of these wastes. To clean the site the farm did involved two people to separate the concrete debris, reinforcement bars and brick pieces. The farm sold the reinforcement bars to the recycling agency, the concrete debris and bricks to the customer for further use. These C&D waste are carried by some vehicles such as: truck, pick up van and rickshaw van with different capacity. Truck was used to carry the reinforced bar whilst pickup vans and rickshaw vans were used to carry the concrete debris and bricks. In table 3, the capacity, dimensions and rate of these vehicles are given.

Table: 3: The comparative data of the waste removal efficiency

| Vehicle Types | Dimensions | | | Capacity | Rate of vehicles | No. of trips | Price of waste |
|---|---|---|---|---|---|---|---|
| | Length (ft) | Width (ft) | Height (ft) | (ton) | (Tk/km) | required | (tk/trip) |
| Truck | 18 | 7 | 3 | 5 | 130 | 25 | 500 |
| Pickup van | 6 | 4 | 3 | 1.5 | 30 | 230 | 50 |
| Rickshaw van | 3 | 2 | 1.5 | 0.3 | 20 | 120 | 8 |

## 10. CONCLUSION

The main objective of this study was to manage the work in time as well as more cost effective with adequate safety measures. According to the agreement, the work should complete within 180 days ($27^{th}$ November, 2010) but the work was not completed in this time limit due to some reason, such as: lack of experience about demolition, ignorance about the time management, shortage of labors, delay of shifting students from one side to another side, environmental cause (rain fall decreased the speed of the work), vacations of two Eids etc. The KUET authority has to extent the time up to March 2011 by considering these limitations. Cost management is the most important part of any construction management. The cost of total work was estimated by the engineering section and the farm agreed to perform the work at a rate of 12.7% less of the estimated rate. The cost of stone chips increased so the farm has to pay more money for buying stone chips than before. According to the agreements the farm must has to provide adequate safety for the workers. But there was not adequate safety management provided by the farm. So in a word it can be said that the farm was failed to achieve the goals of the construction management.

## 11. RECOMMENDATION

Now a day with the increasing of the importance of the liquid money construction management takes a great role in any construction site. It is because liquid money can make a balance economy and brings more revenue. So the importance of management in construction is a great. In this report a great importance is given to the time management, cost management and safety measures. The critical time was found out by CPM analysis. No crashing was done to reduce the time by increasing the no of workers. So for a further analysis the crashing could be done to find out more effective management that is the PERT analysis could be done [5].

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# SOLID WASTE REUSES IN KHULNA CITY

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## ABSTRACT

A survey on existing reuse of solid materials is performed in the Khulna, the third largest city of Bangladesh. Questionnaire survey is carried out on shops of reusable solid waste materials at different places of Khulna. For this survey a standard questionnaire form is developed based on the previous study conducted under KUET. Primary visit is performed throughout the city to locate the shops specially deal reuse activity. It is found that a large number of the shops are located near Khulna Railway market and Powerhouse area. Most of the shops are small in size and identified as retail shops. There are few large dealers, who mainly import old cloths. From primary findings, it is known that about 152 shops for reusable material (SFRM) are located near Khulna Railway market and powerhouse area. Majority of the SFRM are deal with old clothes. Besides, SFRM exist for shopping bags, books and electronic home appliances. Maximum portion of reusable materials are collected and sell in Khulna. Clothes are generally imported from abroad and sell sold at local market. Papers are generally sold at local market and processed locally. In this study the type, amount etc. of reusable solid materials, and also their collection, transportation and further uses are discussed.

**Key Words:** Waste materials, Collection, Recycle, Reuse, Dealer, Shops, Use.

## 1. INTRODUCTION

Increasing living standards of the human being through technological development and population growth lead to an increase in the generation rate of solid wastes. Waste is produced everywhere from small houses to large industries. As the population and use of resources is high in the city areas, the rate of generation of waste is also high. The municipalities and local governments are under heavy pressure to find sustainable and cost-effective waste management policies. Some wastes such as polythene is not rotten. These types of wastes remain unchanged in the soil over years and causes soil pollution. Besides it may cause clogging and hamper the drainage system. For that a proper management of waste is very important. A part of management can be done by reusing the reusable portion of the waste as the present waste management hierarchy emphasizes reduce, reuse, recycle, recover and stable residue. Reuse does two jobs simultaneously as it reduces wastes and longer the life cycle of resources. Reuse means using used materials again and again. Such as books, scrap irons, machineries, crockery, clothes, shoes etc can be used again and again. In Khulna City, a huge amount 465 ton/d of solid waste is generated [1]. Many reuse and recycling

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shops are established in Khulna including some factories. There are many documents on recycling of solid waste in a developing country [2,3,4]. However, less writings are available on reuse, although it has been running smoothly in the society. Therefore, it would be interesting to perform a complete investigation of reuse and some related features of recycling of solid waste in Khulna city. Finally in this study the type, amount etc. of reusable and related recyclable solid wastes, and also their collection, transportation and uses are discussed.

## 2. METHODOLOGY

For this survey a selected questionnaire form is developed based on the previous study [5]. Primary visit is performed throughout the city to locate the shops specially deal reuse activity that is they are selling and buying the valuable part of solid waste as the waste retain their almost all original properties for their further reuse. It is found that most of the shops for reusable material (SFRM) are located near Khulna Railway market and Powerhouse area. From questionnaire survey a thorough classification of SFRM was performed on the basis of their size and the types of waste handling.

## 3. RESULTS & DISCUSSION

There are 120 shops of used/old garments, 20 shops of shopping bags (made from used cement bag, plastic bag, jute bag etc.), 7 shops of paper bag and paper carton (used/old papers) in Power house area, Dakbanglo area and railway station areas in the City. Most of the shops are small in size with 2 to 3 workers. From the field survey it can be said that the major reusable materials are Bags (cement and plastic), Papers, Packets, Books, Garments, Electronic and small home appliance, Fridge, Tents etc.

### 3.1. Shopping bag and cartons

There are 10 SFRM identified under this category and 9 SFRM are surveyed. Among these three SFRM are dealing with cement bags. They are trading about 1350 number cement bags everyday as calculated from Table 1. They produce different types of shopping bags from the used cement bags as shown in Figure 1. Selling price of large shopping bags varied from 8 to 9 tk per bag. Four SFRM are dealing with plastic bags means they produce different size of shopping bags from the larger plastic bags other than cement bags such as used bags of rice, fertilizer etc. They deal 100 to 2000 numbers of plastic bags everyday with total 3000 number. The buying price varied from 2 to 12 taka depending on the size and the quality of the bag. They earn profit from 0.5 to 2.5 tk per bag.

### 3.2. Cartons

Selling and buying of different types of cartons or packaging box are conducted by four SFRM. Mostly they deal from 300 to 500 kg cartons everyday for each shop as shown in Table 1. They buy the cartons with cost 9 tk per kg and sell for 10 tk per kg. Three are trading total about 1300 kg cartons everyday. One deals with 5000 number of carton everyday with selling price of 20 to 21 tk per piece of carton.

Table 1. Waste materials and products for reuse**:** shopping bag and cartons

| Shop No. | Waste | | | Product | |
|---|---|---|---|---|---|
| | Types | Amount(Per Day) | Price (Tk) | Types | Price (Tk) |
| 01 | Cement bag | 300-400 nos. | 7 / nos. | Bag | 9 /nos. |
| | Cartons | 300-400 kg | 9/ kg | Cartons | 10 /kg |
| 02 | Cartons | 500 kg | 9/kg | Cartons | 10 /kg |
| | Cement bag | 600 nos. | 7/nos. | Bag | 8-9 /nos. |
| | Plastic bag | 100 nos. | 4.5/nos. | Bag | 5-6/nos. |
| 03 | Cement bag | 400-600 nos. | 4.5 /nos. | Shopping bag | 28-70 /nos. |
| 04 | Plastic bag | 1000-2000 nos. | 5/nos. | bag | 5.50/nos. |
| 05 | Plastic bag | 1000/nos. | 2-12 /nos. | bag | 2.50-12.50 |
| 06 | Cartons | 5000 nos. | 10-20/nos. | Cartons | 11-21 /nos. |
| 07 | Paper | 500-700 kg | - | Small Paper | - |
| 08 | Plastic bag | 500-600 nos. | - | Plastic bag | - |
| 09 | Cartons | 320-400 kg | 9.50 /kg | cartons | 10 /kg |

The activities are going on smoothly under a systematic chain and directly help to reduce the total waste generation with increasing the reuse of the materials as shown in Figure 1.

Collected bags for sale and processing

Production of smaller bags

Fig 1: Activities observed on collection and production of shopping bags in Khulna.

### 3.3. Old garments

Most of the permanent SFRM are found in Railway market area. Total 120 number old garments SFRM are identified in this area. Seven shops are surveyed among all and the information are presented in Table 2. Four SFRM deals for used shirt and T-shirt mainly imported from abroad with total 400 kg per week. Their buying price varied from 10000 to 35000 per 100 kg. Two SFRM deals with pant with total 600 kg per week and buying price varied from 12000 to 18000 per 100 kg. One SFRM deals with curtain with total 100 kg per week and buying price varied from 6000 to 12000 per 100 kg. There are also many footpaths possess SFRM for garments other than permanent dealer especially during the winter season.

Table 2: Waste materials and products for reuse: Old garments.

| Sl. no | Types | Amount (Per Week) | Price (tk) Per 100 kg | Nos. per 100 kg |
|---|---|---|---|---|
| 01 | Shirt | 100 kg | 30000-35000 | 400-450 |
| | Mixed | 50 kg | 10000 | - |
| 02 | Shirt | 100 kg | 10000-20000 | 400-450 |
| 03 | Shirt | 100 kg | 30000-35000 | 400-450 |
| | Pant | 200 kg | 12000-18000 | 140-160 |
| 04 | Pant | 400-500 kg | 14000-18000 | 140-160 |
| 05 | T shirt | 100 kg | 16000-20000 | 300-350 |
| 06 | Bag | 100 kg | 15000-18000 | - |
| 07 | Curtain | 100 kg | 6000-12000 | - |
| | Bag | 100 kg | 14000-18000 | - |

Old Garments

Old Garments

Fig 2: Shops specialized for buying and selling of old garments imported from abroad.

### 3.4. Old book

Most of the permanent SFRM for old books are found near Power House and Ferry Ghat area of Khulna City. Total 13 numbers of SFRM for old books are identified. Five SFRM are surveyed among them as shown in table 3. Usually they deal with all kinds of books. Their buying capacity is varied from 400 to 1000 Tk/day and selling is varied from 600 to 1600 Tk/day. Most of the good out looking books are bought by the students and the others are bought by different shopkeepers for packaging purposes.

Table 3: Waste materials and products for reuse: Old Book Shop.

| Serial no. | Types | Buy | Sale |
|---|---|---|---|
| 01 | All types book | 600 – 700 Tk /day | 700-1000 Tk/day |
| 02 | All types book | 30000 Tk/month | 50000 Tk/month |
| 03 | All types book | 500 Tk/day | 600-700 Tk/day |
| 04 | All types book | 600-700 Tk/day | 1000 Tk/day |
| 05 | All types book | 400-500 Tk/day | 800-1000 Tk/day |

### 3.5. Electronic goods and small home appliance

There are some SFRM for electronic goods and small home appliance and two are surveyed as shown in Table 4. They are located in Power House and Railway Market area. They are dealing with charger light, table light, table fans, clock, compact disk, blender mills, etc. Their buying capacity is varied from 200 to 500 Tk/day and selling is varied from 300 to 800 Tk/day.

Table 4. Waste materials and products for reuse: Electronics

| Serial no. | Types | Buy | Sale | Serial no. |
|---|---|---|---|---|
| 01 | Power house | Charger light, table light, clock, compact disk , etc | 500 Tk /day | 600-800 Tk/day |
| 02 | Railway market | Charger light, table light, clock, compact disk , etc | 200 – 250 Tk/day | 300- 500 Tk/day |

### 3.6. Paper Recycling

There is one paper-recycling factory in Khulna. They consume scrap paper to reprocess the paper product. The paper materials are second highest by the weight (9.5%) of the total waste components generated in the city. Waste paper is collected by Tokais, Fariwala, from waste bin, house hold, road sides and dumping site. Including corrugated cardboard, high grade paper and mixed paper typically represents 39 percent of the total recyclable waste collected by different collectors and dealers. Grocer reuses one portion of discarded paper by making different sizes of packets**.** Paper-recycling factory have always recycled damaged product and scrap from converters. They purchase additional post consumer waste paper based on fiber strength**,** fiber yield and brightness according to the type of product produced. From these recycled papers, the products such as packet of sweets, hardboard, and bookbinder covers, cartons, shopping bags etc are produced.

## 4. FORMULATION OF MATERIALS FLOW PATHS FOR REUSE

Everyday about 4000 to 5000 numbers of old bags (plastic, jute and cement), more than 1300 kg of carton, and 200 kg of old garments are traded in surveyed SFRM. They supply there product in local market or to some larger shops. For recycling, there is a chain system in collecting recyclable waste and huge number of man power is directly or indirectly connected here. Mainly private sector deals with this system. Everyday huge amount of solid waste collected from many places. The waste materials from larger shop are partially consumed in recycling factories in Khulna and the rest amount is exported to factories in Dhaka.

The main objective of this study is to formulate a general physical model to explain the existing reuse process based on the situation in selected area of khulna city. Based on the data collected in the survey a general materials flow paths for reuse can be developed as presented in figure 3. Generated waste after the utilization of the materials is flown to the primary level

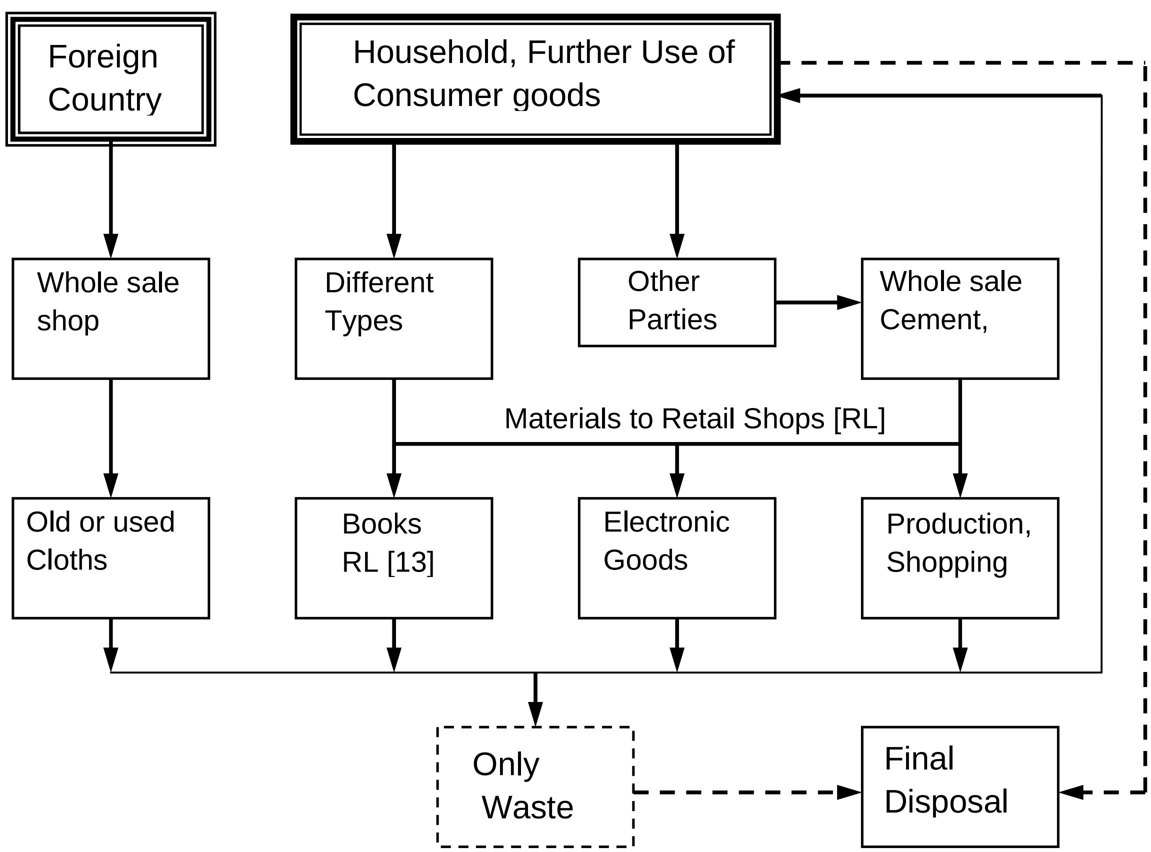


Fig 3: Identified existing materials flow paths for reuse.

collectors. The primary level collectors are material specific hawker. From the primary level the materials are goes the secondary level for processing or marketing. In these material flow different types of bags, cartons, old books, electronic goods are important. Used bags of cement of rice, fertilizer etc. Undergo for processing to produce different size of shopping bags. Finally these bags are again used by the peoples means there exists a strong chain of material flow for reusing purpose. Every year especially in the winter season a hues amount of old garments are imported in the country from the abroad. The wholesale dealers distribute the garments throughout the country. There are many permanent as well as temporary sfrm can be seen. These garments are re-utilized by a large fraction of the population. Whatever the objectives, surely this activity increases the life period of these garments means the produced resources are efficiently utilized by the people. This has a significant positive impact on the environment when the people are talking about the renewable resource utilization. That there would be very little harm on the environment and it would be livelier for our future generation. Reuse saves energy and resources of the world and can contribute to the betterment of the future environment and generation.

## 5. CONCLUSION

A silent systematic, smooth and clean reuse chain exists in Khulna city completely under private sectors. This is a successful example of running the reuse part of the waste management (5R) under informal private sector. Actually the above mention sector can be treated as an alternative formal sector as their sustainability is confirmed over the years in the country without depending on the government funds.

There 120 no retail old cloth shops; 13 no old book shops; 15 no of bags shops; and 4 no of old electronic shops are identified in Khulna city.

There is sufficient number of reuse waste wholesale shops in the city which are adjustable with its upper and lower chains.

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# STUDIES ON WATER QUALITY PARAMETERS AND FEASIBILITY OF BIOSENSOR FOR ARSENIC DETECTION IN WATER

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## ABSTRACT

Arsenic (As) and some water quality parameters were investigated of 220 tube-well water (TW) samples from highly arsenic-affected areas of different four districts in Bangladesh. Of them 58, 53, 56 and 53 samples were from Sagordari of Jessore, Koyra of Satkhira, Kathali of Chandpur and Noapara of Narayanganj respectively. As content in water samples were analyzed by Merck field test kit, ARSOlux biosensor and well established and precise Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Results observed by biosensor are very close to those for ICP-MS. On an average, water samples of sagordari are the most affected by As while those of Noapara are the least. Among the 220 samples the highest As content is 701μg/L at sagordari and that for the lowest is 15μg/L at Koyra. Only 1.36% water samples have As content less than 50μg/L which are within the permissible limit for Bangladesh standard according to World Health Organization (WHO). The investigated water quality parameters were pH, conductivity, iron, chloride, hardness and dissolved oxygen. The values of pH, hardness and dissolved oxygen are within the standard limit while the values of conductivity, chloride and iron exceed the standard value with respect to WHO guideline. No Significant interference of the tested water quality parameters was observed on As detection by biosensor or other techniques.

**Key Words:** Arsenic, Biosensor, water parameter

## 1. INTRODUCTION

Until the early 1970s, the 100 million-plus inhabitants of Bangladesh and neighbouring West Bengal drank from shallow hand-dug wells, canals, rivers and ponds. Surface water sources in Bangladesh have been contaminated with microorganisms, causing a significant burden of disease and mortality, notably cholera, diarrhea, dysentery, typhoid etc. So during the 1970s the United Nations Children's Fund (UNICEF) worked with the Department of Public Health Engineering to install tube-wells to provide what was apparently a "safe" source of drinking-water for the population. At the time the wells were installed, arsenic was not recognized as a problem in water supplies, and therefore standard water testing procedures did not include tests for arsenic [1]. For this, infant mortality and diarrheal illness were reduced by fifty percent. Till now groundwater provides safe drinking water to over 97% of the rural population in Bangladesh. Today there are an estimated 8-10 million tube-wells in Bangladesh. Arsenic contaminated tube-well water was first detected in Bangladesh in early 1990s. Until the discovery of arsenic in the groundwater in 1993, well water was regarded as safe for drinking. The number of people drinking arsenic-rich water in Bangladesh has increased dramatically since the 1970s due to well-drilling and population growth. Therefore,

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a high-profile problem revealed in recent years due to the use of deep tube wells for water supply, causing serious arsenic poisoning to large numbers of people. Arsenic in drinking water remains a global problem. It is estimated that of the 125 million inhabitants of Bangladesh between 35 million and 77 million are at risk of drinking contaminated water [2]. However, the problem of arsenic contaminated water has only recently come to light due to the increasing number of tube-wells used over the past 20 years and the subsequent increase in the number of individuals drinking from them. But it is a matter of regret that though people got rid from one epidemic, groundwater arsenicosis problem has been broken out for last few years. The World Health Organization (WHO) has called it the "largest mass poisoning of a population in history" and a public health emergency [3]. School of Environmental Studies (SOES) has surveyed groundwater arsenic contamination status in different districts of Bangladesh. They have so far analyzed 50,515 hand tube-well water samples from Bangladesh by AAS, of which 43% contained arsenic above 10 μg/L and 27.5% above 50μg/L. So far they have screened 18,991 people in Bangladesh for arsenical skin lesions from 244 villages and 19.8% peoples have been registered with arsenical skin lesions. According to WHO survey in 2007, a total of 4.7 million tube-wells in Bangladesh have been tested by different government and non-government organizations and 1.4 million of those were found to contain arsenic above the Government drinking water limit of 50 ppb. [4]. Although significant numbers of tube wells were tested for arsenic but still a large number of tube wells remain untested. Even continuous monitoring of arsenic level in ground drinking water is necessary as the ground water is moving and concentration of arsenic is changing. Though Field test kits are simple and easy to use but it is available with varying levels of complexity. It required a 30-minutes incubation time while the arsenic in the sample is reduced to arsine gas, which is very harmful to the environment and human health also. On the other hand 30-minutes is a great time saving. However, if we have a large number of samples to test kit test is not desirable. Its cost is too high. The average price per test between \$1.50 to \$2.40. In this paper we are trying to use a fast, less expensive and less labor intensive method. Bacterial biosensors are an interesting alternative as they are easily produced, simple, and highly accurate devices. Here, we describe the development of a set of bacterial biosensors.

## 2. EXPERIMENTAL

### 2.1 Determination of pH, Conductivity and Dissolved Oxygen:

The pH, Conductivity and Dissolved Oxygen of water is determined by a pH Meter (Model- HI 96107), conductivity meter (Model- HI 98304) and dissolved oxygen meter respectively. For very precise work the instruments were calibrated before each measurement.

### 2.2 Determination of chloride

50 ml of the sample water was taken into a conical flask. 3-5 drops of potassium chromate indicator was added into the flask. Then the solution will turn yellow in color. Standard silver nitrate was added from a burette until the appearance of first permanent reddish color. Each titration was performed thrice and the mean value was taken. Calculation was done by using the following equation:

$$1 \text{ mL } 1\text{N } AgNO_3 = 0.03546 \text{ g of } Cl^-$$

## 2.3 Determination of Iron

25 ml of the sample water was taken into a conical flask. A little bit sulfuric acid was added and heated it. Then potassium permanganate was added from a burette. When the color of the solution became pink addition of potassium permanganate solution from the burette was stopped. Each titration was performed thrice and the mean value was taken. Calculation was done by using the following equation:

$$1 \text{ mL } 1\text{N } KMnO_4 = 0.0559 \text{ g of Fe}$$

## 2.4 Determination of Total Hardness

25 ml of the sample water was taken into a 250 ml conical flask. Draw 2 ml buffer solution with a pipette and transfer this into the conical flask. 100-200mg (one fifth of a spoon or a pinch) of Eriochrome Black – T was added into it. The solution will turn wine red in color. After that, took up the EDTA solution in a burette. This solution was added slowly into the conical flask. While doing gently rotate the flask, taking care not to fall the solution. When the color starts becoming violate add the EDTA solution drop by drop. Stop adding the EDTA solution from the burette, when the color of the solution just becomes blue.

## 2.5 Arsenic test:

Three methods for Arsenic test were adopted. Methods are as follows:

2.5.1 Merck Kit Test:

At first, 60mL sample water was taken in the reaction bottle. Then two drops As-1 reagent was added and swirl. After that one level red dosing spoon As-2 reagent was added and swirl until the reagent was completely dissolved. Then one level green dosing spoon reagent As-3 was added and immediately was closed the reaction bottle with the screw cap. Immediately the test strip was inserted into the opening reaction zone as far as the mark and flips the test strip holder down completely. Then it was kept for twenty five minutes, swirling was done two or three times during the reaction period and contact between the test strip and the sample was avoided. After 30 minutes the strip was removed and briefly dipped into the water. Excess liquid was shaken off and color was compared with comparator chart to obtain a quantitative measure for arsenic in the tested sample. The result was obtained in mg/L.

### *2.5.2 Biosensor Test:*

At first, a series of known concentrations of arsenic containing water was prepared for preparation of standard curve. 1 milliliter of each concentration was injected into the biosensor containing vials. Each concentration was duplicated twice. Luminescence of all inoculated biosensor vials was measured after one and two hours incubation with a luminometer. The readings were put into a graph against the known concentrations of arsenic and a calibration curve was constructed. Then the water samples were tested in the same procedure; by inoculating 1 ml of each in the biosensor vials and measuring luminescence after 1 hour incubation. These were also duplicated.

### *2.5.3 Inductively coupled plasma–mass spectrometry (ICP–MS):*

This technique combines the ICP as the ion source with a mass analyser. Quadrupole mass filters are the most common mass analyser; double-focusing magnetic/electrostatic sector instruments and time-of-flight mass analysers are also used.

## 3. RESULTS AND DISCUSSIONS

The TW water, 220 samples from arsenic-affected areas in Bangladesh were collected and were analyzed. Of them 58, 53, 56 and 53 samples were from sagordari of Jessore, Koyra of Satkhira, Hajigong of Chandpur and Araihazar of Narayangonj respectively. Table 1 shows the water quality parameters of pH, conductivity, chloride, iron, hardness and dissolved oxygen $(O_2)(aq)$. The pH range were found to be 7.0 – 8.1 at different locations within safe limit for drinking and other purposes. The lower limit is quite accurate for drinking water and the higher pH value may be resulted from the abundance of Ca, Mg, Na and carbonate $(CO_3^{2-})$. According to United States Public Health Drinking Water Standard (USPH) the maximum permissible limit of pH for drinking and other purposes is 8.5 [5]. The conductivity values of the investigated samples varied from 0.4 to 63.0 mS. According to United States Public Health Drinking Water Standard (USPH) the standard specific conductance values is 300 µs/cm [5]. The high conductivity values indicate the high mineralization of the water. The chloride content of the samples water varies from 7.1 to596.4 ppm. According to United States Public Health Drinking Water Standard (USPH) the maximum permissible limit of chloride is 250 ppm [5]. So the present investigation indicates that the chloride content of the some samples is within the safe limit while the some samples exceed the limit. The higher values for the chloride content due to the presence of chloride based salts present in the water samples. This result also correlates the higher conductivity values. Hardness values of water samples in different locations varied from 10 to 24 ppm as $CaCO_3$ which was safe for drinking use. Waters with a total hardness in the range of 0 to 60 mg/L are formed soft; from 60 to 120 mg/L moderately hard; from 120 to 180 mg/L hard; and above 180 mg/L very hard [6]. So the present investigation indicates that the hardness values of all samples are within safe limit. Iron values of water samples varied from 1.9 to 20.5 ppm while the permissible limit of iron for drinking purpose is 0.3 ppm [5]. The investigated samples have high iron content. DO values for the investigated TW samples varied from 1.4 to 3.2 ppm. Although DO values in natural water is 4-6 ppm but TW just after collection always contain less DO

| Parameter | Range | Sagordari | Koyra | Hajiganj | Araihajar |
|---|---|---|---|---|---|
| pH | Minimum | 7.0 | 7.0 | 7.0 | 7.0 |
| | Maximum | 7.9 | 8.1 | 7.8 | 8.0 |
| Conductivity (mS) | Minimum | 0.4 | 0.4 | 0.4 | 0.4 |
| | Maximum | 63.0 | 2.4 | 2.7 | 2.5 |
| Chloride (ppm) | Minimum | 7.1 | 7.1 | 14.2 | 7.1 |
| | Maximum | 333.7 | 511.2 | 596.4 | 560.9 |
| HCO3- as CaCO3 | Minimum | 0.4 | 0.4 | 0.3 | 0.2 |
| | Maximum | 2.6 | 1.9 | 2.4 | 1.3 |
| Iron | Minimum | 1.9 | 2.1 | 1.8 | 2.1 |
| | Maximum | 18.1 | 18.4 | 17.9 | 20.5 |
| DO | Minimum | 1.4 | 1.4 | 1.4 | 1.3 |
| | Maximum | 3.0 | 1.9 | 3.2 | 2.2 |

Table-1: Water quality parameters of different investigated areas.

DO values in natural water is 4-6 ppm but TW just after collection always contain less DO [7]. The mentioned results for DO of TW samples are derived from water samples just after collection. So the values for DO are quite acceptable for drinking water.

The samples of TW located at Sagordari of Jessore, Koyla of Kolaroa; Hagigong of Chandpur and Arihazar of Narayangong were tested for As contamination using Merck field test kit, ARSOlux biosensor and ICP-MS method. In our study area Jessore was highly contamineted with As while those for Narayangong was the least contaminated.

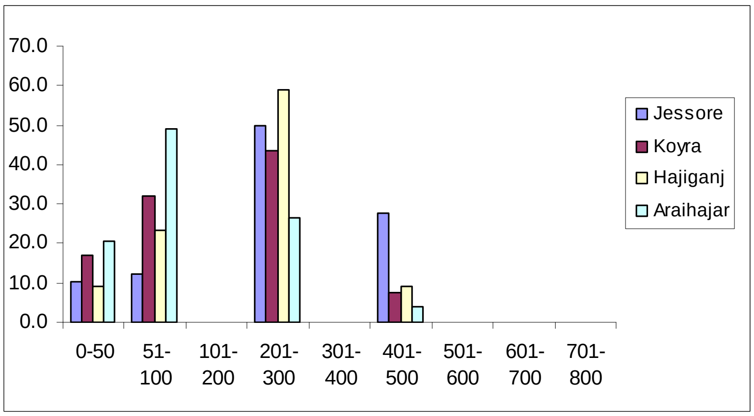


Figure 1: Arsenic concentration in TW samples determined by Merck field test kit

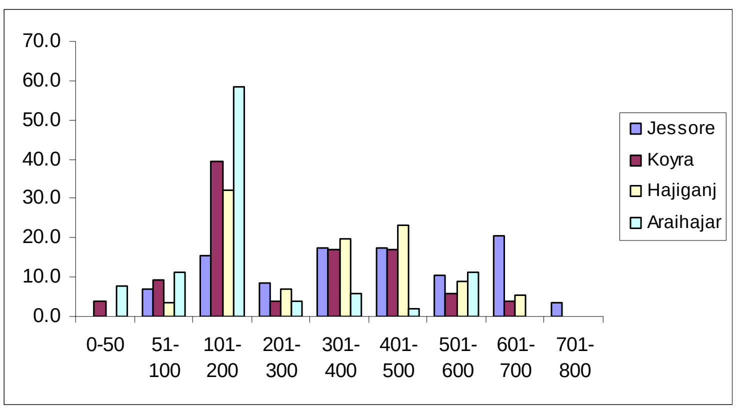


Figure 2: Arsenic concentration in TW samples determined by ARSOlux biosensor

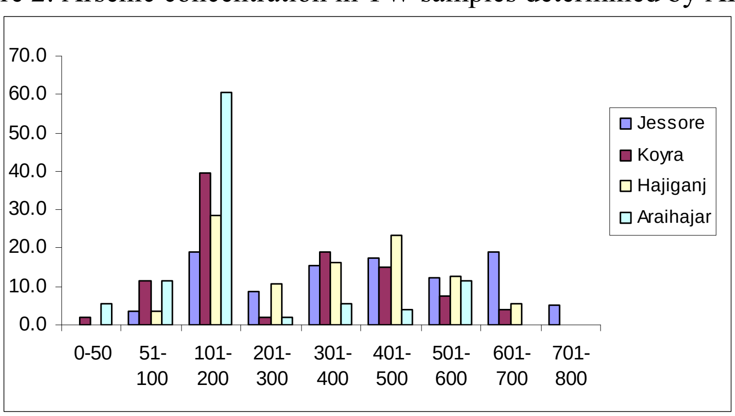


Figure 3: Arsenic concentration in TW samples determined by ICP-MS.

Most of the TWs were contamineted and As levels had over 50 µg/L, the accepted level for Bangladesh as guided by WHO. Three samples of Jessore have As levels > 700 µg/L as detected by ARSOlux biosensor and ICP-MS method but it could not be detected by Merck field test kit. From the Figure it is clear that Merck field test kit showed a rough estimation of As concentration within some ranges such as 0-50, 51-100, 201-300 and 401-500. The results of Merck field test kit method varied a lot than those of well accepted ICP-MS. On the other hand results of ICP-MS method and ARSOlux biosensor method are very close to each other.

## 4. CONCLUSION

The results obtained from biosensors are compatible with and comparable to chemical analysis, while being free of chemical extractions and analytical procedures. Biosensors can also be more sensitive than chemical methods. Bacterial biosensors are an interesting alternative as they are easily produced, simple, and highly accurate devices.

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# PERFORMANCE OF CONCRETE USING STONE DUST AS FINE AGGREGATE

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## ABSTRACT

Conventionally concrete is a mix of cement, sand and aggregate. There is a large variation in strength of concrete due to variation in strength of aggregate used. There is scarcity of natural sand due to heavy demand in growing construction activities. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large scale depletion of these sources creates environment problems. As environmental, transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. More research studies are being made on stone dust concrete necessary for the practical application of stone dust as fine aggregate. The cheapest and the easiest way of getting substitute for natural sand is by crushing natural stone to get artificial sand of desired size and grade which could be free from all impurities. Stone dust is used in large scale in the highways as a surface finishing material and light weight concrete prefabricated elements. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in any areas, whose continued use has started posing serious problems with respect to its availability, cost and environment impact. Mining the sand, from river bed is hazardous to environment. The dip pits dig in the river bed for sand mining effects on ground water level and erode the nearby land. In such a situation stone dust can be an economic alternative to the river sand. Strength of concrete is one of the most important characteristics of hardened concrete mix besides its durability and the compressive strength represents the best indication to the state of strength of a particular concrete. This study represents feasibility of the uses of the artificial sand obtained by crushing stone over natural river sand, considering technical, environment and commercial factors. For the purpose of experimentation, concrete mixes are prepared by 100% replacement of river sand or natural sand to artificial sand/stone dust in three different mixing ratios such as 1:3:6, 1:2:4 and 1:1.5:3. Compressive strength test were conducted to study the strength of concrete using artificial sand or stone dust and the results are compared with that of natural sand or river sand. From the laboratory test it was found that the strength of concrete made of stone dust as fine aggregate is slightly lower than the strength of concrete made of sylhet sand as fine aggregate. It is true only when the F.M value

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of the stone dust near to the F.M. value of the sylhet sand. But when the above condition is not satisfied, there is a lot of variation in strength between these two types of concrete.

**Key Words:** Stone dust, natural sand, impurities, F.M., environmentally hazardous, hardened concrete, commercial factors

## 1. INTRODUCTION

In recent years, tremendous efforts have been taken in the area of concrete engineering and technology to research and study the utilization of by-products and waste materials in the production of concrete. The successful utilization of these materials will result in the reduction of environmental load, waste management cost and concrete production cost, besides enhancing the properties of concrete in both fresh and hardened state. Efforts in this area have been focused in identifying and optimizing the benefits of different types of cement replacement materials as well as identifying alternative materials as aggregates in concrete. As for alternative materials as aggregates in concrete, numerous types of by-product such as recycled concrete aggregate, quarry dust, stone dust, fly ash and slag, as well as several types of manufactured aggregates have been studied by many researchers.

Stone dust, a by-product from the crushing process during quarrying and subsequent activities is one of those materials that have recently gained attention to be used as concreting aggregates, especially as fine aggregates. Stone dust has been used for different activities in the construction industry such as for filling utility trenches, building excavations, underground storage tanks, abandoned sewers and utility lines, underground mine shafts and pavement sub-bases/bases and manufacture of building materials such as lightweight aggregates [4]. Cement concrete provides an excellent opportunity to make use of industrial waste materials. [6]. Naidu et al. investigated the influence of partial replacement of sand with stone dust and cement with mineral admixtures on the compressive strength and pull-out force of concrete, whereas Celik and Marar investigated the influence of partial replacement of fine aggregate with crushed stone dust at varying percentages in the properties of fresh and hardened concrete. As an engineering material, fine aggregate plays an important part in engineering constructions. In the construction of buildings and other infrastructures, concrete plays a vital role and a large quantum of concrete is being utilized [8]. River sand which is one of the constituents used in the production of conventional concrete is becoming expensive and a strong demand for alternative sources is felt important [3].

The utilization of stone dust which can be called as “manufactured sand” has been accepted as a building material in the industrially advanced countries of the west for the past three decades [7]. As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of stone dust in the industrialized nations like Australia, France, Germany, and UK has been reached more than 60% of its total production. The use of manufactured sand in India has not been much, when compared to some advanced countries [7]. This paper focuses on the use of stone dust in concrete. The main objective of this paper is to check the suitability of using stone dust materials as fine aggregate in concrete and also to minimize the construction cost so that we can save our resources and environment.

## 2. METHODOLOGY

2.1 **Sample Collection**:

2.1.1 Stone dust was collected from Nawapara Alamin Ghat
2.1.2 Stone dust was collected from Rupsha Stone House
2.1.3 Sylhet sand was collected from Nawapara Alamin Ghat

2.2 **Test**:

2.2.1 Determination of some physical properties of aggregate such as unit weight, specific gravity, fineness modulus, percentage of void.

**2.3 Scope of Test**

2.3.1 A rotating pan type mixer was used for the mixing of the constituent materials.
2.3.2 Fresh concrete was sampled immediately after completion of mixing for determination of slump and entrained air content.
2.3.3 A minimum slump of 50 mm and a minimum entrained air content of 1.5 % were maintained to ensure excellent workability of the freshly mixed concrete.
2.3.4 The fresh concrete was then cast into 6”X12” cylindrical moulds in three layers.
2.3.5 Immediately after casting, the specimens were stored in the curing room at $20\pm2^{o}C$.
2.3.6 The cylindrical specimens were demoulded after 1 day and were allowed for water curing. For water curing, specimens were immersed in water in a curing tank and the water temperature was maintained at $20\pm2^{o}C$.

## 3. EXPERIMENTAL STUDY

**a)** Crushed stone dust **b)** Natural sea sand

Fig 1: Enlarged appearance of fine aggregate.

**3.1 Concrete Mix Design (ACI Method)**
**3.1.1 Required Information:**

**a.** Specific gravity of cement 3.15
**b.** F.M. value
  **a.** Stone dust of Nawapara Alamin Ghat 1.67

- **b.** Stone dust of Rupsha Stone House 2.33
- **c.** Sylhet sand of Nawapara Alamin Ghat 2.62

**c.** Unit weight (kg/m$^3$)

- **a.** Stone dust of Nawapara Alamin Ghat 1550
- **b.** Stone dust of Rupsha Stone House 1604
- **c.** Sylhet sand of Nawapara Alamin Ghat 1644

**d.** Specific gravity

- **a.** Stone dust of Nawapara Alamin Ghat 2.47
- **b.** Stone dust of Rupsha Stone House 2.50
- **c.** Sylhet sand of Nawapara Alamin Ghat 2.56

**e.** Maximum aggregate size (mm) 20

**f.** Unit weight of coarse aggregate (kg/m$^3$) 1600

**g.** Specific gravity of coarse aggregate 2.64

**h.** w/c ratio 0.50

Table 1: Physical properties of fine aggregates

| Sample | Location | Unit weight (kg/m$^3$) | Percentage (%) of void | Specific Gravity | Percentage (%) of fine passing through No. 100 |
|---|---|---|---|---|---|
| Stone dust | Nawapara Alamin Ghat | 1550 | 37.10 | 2.47 | 23.15 |
| | Rupsha Stone House | 1604 | 34.8 | 2.50 | 19.27 |
| Sylhet sand | Nawapara Alamin Ghat | 1644 | 35.07 | 2.56 | 3.15 |

Table 2: Sieve Analysis of Stone Dust of Nawapara Alamin Ghat

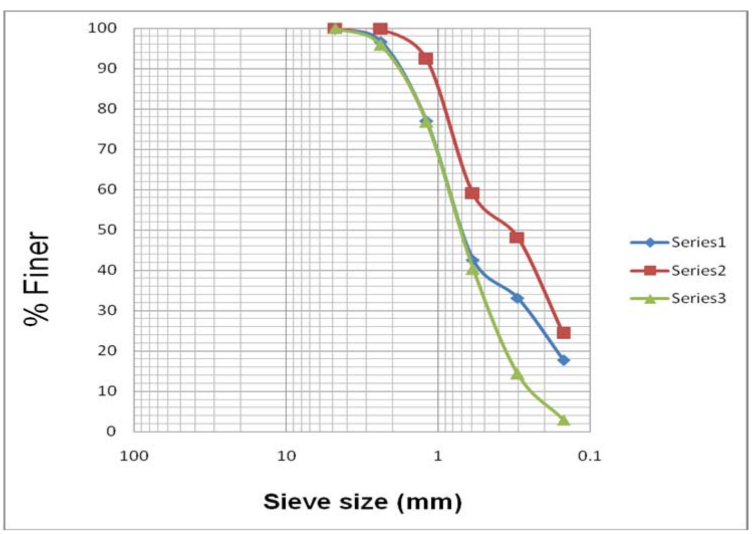
| Sieve No. | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative Weight Retained (%) | % Finer | F.M. Value |
|---|---|---|---|---|---|---|
| # 4 | 4.75 | 0.00 | 0.00 | 0.00 | 100.00 | 1.67 |
| # 8 | 2.36 | 0.50 | 0.50 | 0.10 | 99.90 | |
| # 16 | 1.18 | 34.00 | 34.50 | 6.90 | 93.10 | |
| # 30 | 0.60 | 107.30 | 141.80 | 28.36 | 71.64 | |
| # 50 | 0.30 | 127.00 | 268.80 | 53.76 | 46.24 | |
| # 100 | 0.15 | 119.50 | 388.30 | 77.66 | 22.34 | |
| Summation of Cumulative Weight Retained (%) = | | | | 166.78 | | |

Table 3: Sieve Analysis of Stone Dust of Rupsha Stone House

| Sieve No. | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative Weight Retained (%) | % Finer | F.M. Value |
|---|---|---|---|---|---|---|
| # 4 | 4.75 | 1.00 | 1.00 | 0.20 | 99.80 | 2.33 |
| # 8 | 2.36 | 16.00 | 17.00 | 3.40 | 96.60 | |
| # 16 | 1.18 | 98.50 | 115.50 | 23.10 | 76.90 | |
| # 30 | 0.60 | 171.50 | 287.00 | 57.40 | 42.60 | |
| # 50 | 0.30 | 47.50 | 334.50 | 66.90 | 33.10 | |
| # 100 | 0.15 | 77.00 | 411.50 | 82.30 | 17.70 | |
| Summation of Cumulative Weight Retained (%) = | | | | 233.3 | | |

Table 4: Sieve Analysis of Sylhet Sand of Nawapara Alamin Ghat

| Sieve No. | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative Weight Retained (%) | % Finer | F.M. Value |
|---|---|---|---|---|---|---|
| # 4 | 4.75 | 0.00 | 0.00 | 0.00 | 100.00 | 2.62 |
| # 8 | 2.36 | 20.50 | 20.50 | 4.10 | 95.90 | |
| # 16 | 1.18 | 76.00 | 96.50 | 19.30 | 80.70 | |
| # 30 | 0.60 | 186.00 | 282.50 | 56.50 | 43.50 | |
| # 50 | 0.30 | 145.50 | 428.00 | 85.60 | 14.40 | |
| # 100 | 0.15 | 56.00 | 484.00 | 96.80 | 3.20 | |
| Summation of Cumulative Weight Retained (%) = | | | | 262.30 | | |




Series 1: Stone dust of Nawapara Alamin Ghat
Series 2: Stone dust of Rupsha Stone House
Series 3: Sylhet sand

Figure 2: Combined Gradation Curve for Different Fine Aggregate

## 4. RESULTS

Table 5: Compressive strength of concrete by using stone dust of Nawapara Alamin Ghat as fine aggregate

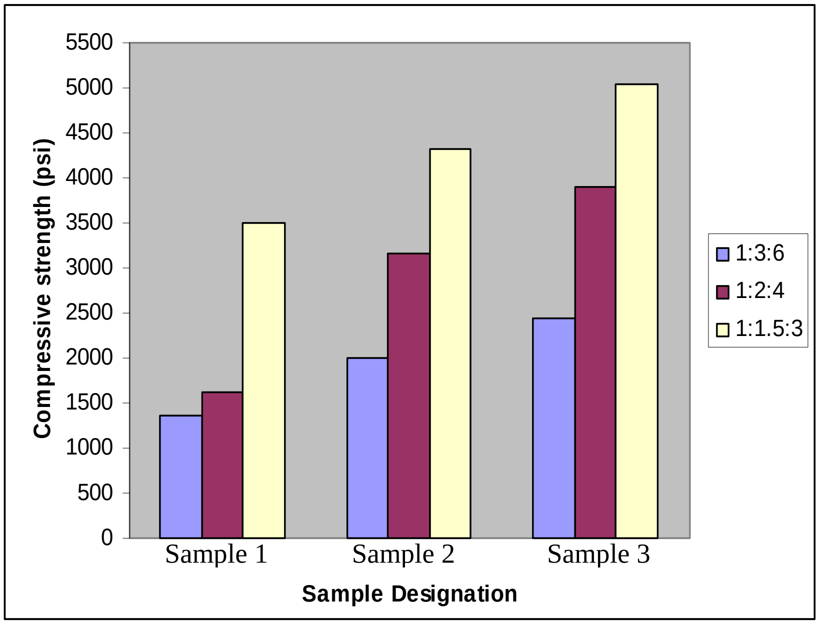
| Mixing Ratio | Concrete Age (Days) | Compressive Strength (psi) | Type of Coarse Aggregate | Type of failure |
|---|---|---|---|---|
| 1:3:6 | 28 | 1366 | Stone-chips | Mortar |
| 1:2:4 | 28 | 1625 | Stone-chips | Mortar |
| 1:1.5:3 | 28 | 3503 | Stone-chips | Combined |

Table 6: Compressive strength of concrete by using stone dust of Rupsha Stone House as fine aggregate

| Mixing Ratio | Concrete Age (Days) | Compressive Strength (psi) | Type of Coarse Aggregate | Type of failure |
|---|---|---|---|---|
| 1:3:6 | 28 | 2007 | Stone-chips | Mortar |
| 1:2:4 | 28 | 3161 | Stone-chips | Combined |
| 1:1.5:3 | 28 | 4325 | Stone-chips | Combined |

Table 7: Compressive strength of concrete by using Sylhet sand of Nawapara Alamin Ghat as fine aggregate

| Mixing Ratio | Concrete Age (Days) | Compressive Strength (psi) | Type of Coarse Aggregate | Type of failure |
|---|---|---|---|---|
| 1:3:6 | 28 | 2441 | Stone-chips | Mortar |
| 1:2:4 | 28 | 3901 | Stone-chips | Combined |
| 1:1.5:3 | 28 | 5033 | Stone-chips | Combined |




Sample 1: Stone dust of Nawapara Alamin Ghat
Sample 2: Stone dust of Rupsha Stone House
Sample 3: Sylhet sand

Figure 3: Graphical representation of compressive strength for different mixing proportion

## 5. DISCUSSION

- As per ACI code, the standard value of unit weight for fine aggregate in the concrete is more than 1600 kg/m$^3$. From the result of compacted unit weight, it can be seen that in case of stone dust of Rupsha stone house & Sylhet sand of Nawapara Alamin Ghat, the values are higher than 1600 kg/m$^3$ and for the stone dust of Nawapara Alamin Ghat, it is lower than the standard value. Percentage (%) of void is lower in case of stone dust of Rupsha than Nawapara.

- Strength of concrete is one of the most important characteristics of hardened concrete mix besides its durability, and the compressive strength represents the best indication to the state of strength of a particular concrete. The experimental results of compressive strength of concrete at the age of 28 days with the mixing ratio 1:3:6, 1:2:4 and 1:1.5:3 produced in this study are shown in table 5, 6, 7 & in figure 3. From the laboratory test it was found that the strength of concrete made of stone dust as fine aggregate is slightly lower than the strength of concrete made of Sylhet sand as fine aggregate. It is true only when the F.M. value of the stone dust near to the F.M. value of the Sylhet sand. But when the above condition is not satisfied, there is a lot of variation in strength between these two types of concrete.

- Since the shape of the stone dust is not similar with the river sand i.e. the most of the particle in stone dust are flaky shape & the gradation of the stone dust are normally gap graded, it cannot be compacted in proper way. Thus the strength of the concrete using stone dust as fine aggregate is less than the strength of concrete using river sand as fine aggregate.

## 6. CONCLUSION

It can be concluded that the stone dust can be used in concrete, but it should satisfying some properties. Different stone dust produced from various companies has F.M. value which is vary in large scale. The stone dust of higher F. M. Value can be used in concrete. The proper compaction is required to gain its strength. The Physical and chemical properties of stone dust is almost satisfied the requirements of code provision in properties. Natural river sand, if replaced by hundred percent stone dust may sometimes give slightly lower than the reference concrete made with natural sand, in terms of compressive strength studies. Thus, it can be concluded that the replacement of natural sand with stone dust, as full replacement in concrete is possible. However, it is advisable to carry out trial casting with stone dust proposed to be used, in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement. However, more research studies are being made on stone dust concrete necessary for the practical application of stone dust as fine aggregate.

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# STRENTH BEHAVIOUR OF FREE FLOW CONCRETE SUBJECTED TO DIFFERENT MIXING TIME

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## ABSTRACT

Free flow concrete is a form of the concrete which can be used in all types of structural construction. Development of free flow concrete is a very desirable achievement in the construction industry for overcoming problems associated with cast-in-place concrete. In consequence, knowledge of the mixing time effects on temperature in free flow concrete is of great importance. This paper focuses on comparing the compressive strength and the tensile strength of concrete cast with respect to different mixing time with admixture and without admixture and also to find out the amount of water needed for retemparing work at different mixing time casting. For achieving these purposes, cylinder samples were prepared with increasing mixing time at a temperature of 45ºC ± 1ºC for compressive strength and tensile strength test. Extra water was also added to the mixer at different mixing time. The compressive strength and tensile strength of samples were determined for 7 days, 14 days and 28 days. The result shows that in case of without admixture, there is no significant change of strength of concrete due to increasing of mixing time. But in case of samples with admixture, the strength is decreased due to increasing mixing time. However, when extra water is added in the samples at different mixing time for maintaining the initial workability, the samples with admixture is require more amount of water than the samples without admixture with respect to increasing of mixing time due to long time mixing at high temperature. From the study it is also recommended that for the longer mixing time of free flow concrete only water reducing admixture may not be used.

**Key word:** Free flow concrete, admixture, retemparing, compressive strength, tensile strength, mixing time, temperature effects.

## 1. INTRODUCTION

Concrete is the composite material obtained by using cement, coarse aggregate, fine aggregate, water and other additives [1]. Now a day's concrete is almost exclusively used as a construction material all over the world. Free flow concrete also known as the self

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compacting concrete, is a highly flowable, non-segregating concrete that can spread into place, fill the formwork and encapsulate the reinforcement without any mechanical consolidation [6]. Free flow concrete is a form of the concrete which can be used in all types of structural construction. Development of free flow or self-compacting concrete is a very desirable achievement in the construction industry for overcoming problems associated with cast-in-place concrete. Free flow concrete is not affected by the skill of workers, and shape and amount of reinforcing bar arrangement of a structure. The free flow concrete has high-fluidity and resisting power of segregation. This type concrete extends the possibility of use of various mineral by-products in its manufacturing. Due to the stone-like consistency of concrete that renders it ideal for constructing roads, bridges, water supply and sewage systems, factories, airports, railroads, waterways, mass transit systems, and other structures like brick/block walls and bases for gates, fences and poles etc [3]. The use of free flow not only shortens the construction period but also ensures quality and durability of concrete. This free flow concrete allows faster placement and less finishing time leading to improved productivity. Currently, the use of self-compacting concrete is being rapidly adopted in many countries. Use of this concrete should overcome concrete placement problems associated with the concrete construction industry.

The reason for the use of admixtures is that they are capable of imparting considerable physical and economical benefits with respect to concrete [8]. These benefits include the use of concrete under circumstances where previously there existed considerable, or even insuperable, difficulties. They also make possible the use of a wider range of ingredients in the mix. It should be stressed that, while properly used admixtures are beneficial to concrete, they are no remedy for poor quality mix ingredients, for use of incorrect mix proportions, or for poor workmanship in transporting, placing and compaction. Conplast RP 264 is one kind of water reducing admixture. It is used in concrete a) to improve the effectiveness of the water content of a concrete mix, b) To help maintain the workability of ready mixed concrete deliveries in hot weather, c) To extend working times of concrete, d) Particularly suitable for use in mixes with low cohesion [4]. Conplast RP264 is a chloride free water reducing admixture based on selected lignosulphonate materials. The normal dosage range is 0.3 to 0.8 liters/100 kg of cementitious material, including PFA, GGBFS or micro silica [4].

In consequence, knowledge of the mixing time effects on temperature in free flow concrete is of great importance. The different mixing time effect in a constant temperature was considered in this study. This study compares the compressive strength and tensile strength of concrete cast with respect to different mixing time with admixture and without admixture and also to find the amount of water is needed for retemparing work at different mixing time casting.

## 2. EXPERIMENTAL STUDY

In mixing concrete, a tilting concrete mixer having 1.25 cft capacities was used. Each granulometric aggregate was weighted and placed into the concrete mixer moistened in advanced for 3 minute with the addition of saturation water, for 3 minute with addition of cement, and thereafter, mixed for another 3 min without stopping to at the mixing water. Then keep the machine in a wooden box at around 45$^{o}$C about 90 min, 180 min as required for the test without stopping the mixing machine. Some percent water was added in the concrete after the rotation to get the initial slump and mixing was continuing about 3 to 5 min. The resulting concrete was placed in cylinder moulds. Nine (09) samples were prepared with a mixing ratio of 1:1.5:2.5 with admixture and without admixture in each production for making of cylinder specimen. For maintain the constant temperature about 45$^{o}$C, a heater was used to heat the mixing machine. A large wooden box was used for avoiding the air passing and increases the temperature of mixture quickly.

Fig 1. Wooden Box used to enclose the Mixing Arrangement

Fig 2. Free Flow Concrete

Table 1: Sieve analysis for Coarse Sand

| Sieve No. (ASTM) | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative weight Retained (%) | % Finer | F.M. Value | Sand Type |
|---|---|---|---|---|---|---|---|
| 4 | 4.75 | 0.00 | 0.00 | 0.00 | 100.00 | **2.45** | Sylhet Sand |
| 8 | 2.36 | 11.50 | 11.50 | 2.30 | 97.70 | | |
| 16 | 1.18 | 60.40 | 71.90 | 14.38 | 85.62 | | |
| 30 | 0.60 | 180.00 | 251.90 | 50.38 | 49.62 | | |
| 50 | 0.30 | 154.20 | 406.10 | 81.22 | 18.78 | | |
| 100 | 0.15 | 79.20 | 485.30 | 97.06 | 2.94 | | |
| Summation of Cumulative weight Retained (%) = | | | | 245.34 | | | |

Table 2: Sieve analysis for Fine Sand

| Sieve No. (ASTM) | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative weight Retained (%) | % Finer | F.M. Value | Sand Type |
|---|---|---|---|---|---|---|---|
| 4 | 4.75 | 0.00 | 0.00 | 0.00 | 100.00 | **1.75** | Kushtia Sand |
| 8 | 2.36 | 1.40 | 1.40 | 0.28 | 99.72 | | |
| 16 | 1.18 | 1.90 | 3.30 | 0.66 | 99.34 | | |
| 30 | 0.60 | 148.30 | 151.60 | 30.32 | 69.68 | | |
| 50 | 0.30 | 113.20 | 264.80 | 52.96 | 47.04 | | |
| 100 | 0.15 | 189.10 | 453.90 | 90.78 | 9.22 | | |
| Summation of Cumulative weight Retained (%) = | | | | 175.00 | | | |

Table 3: Sieve analysis for Coarse Aggregate

| Sieve No. (ASTM) | Sieve Opening (mm) | Weight Retained (gm) | Cumulative Weight Retained (gm) | Cumulative weight Retained (%) | % Finer |
|---|---|---|---|---|---|
| 3 inch | 75 | 0.00 | 0.00 | 0.00 | 100.00 |
| 1.5 inch | 37.5 | 0.00 | 0.00 | 0.00 | 100.00 |
| 1 inch | 25 | 0.00 | 0.00 | 0.00 | 100.00 |
| ¾ inch | 18.75 | 1820.20 | 1820.20 | 36.40 | 63.60 |
| ½ inch | 12.50 | 2726.20 | 4546.40 | 90.93 | 9.07 |
| 3/8 inch | 9.38 | 385.60 | 4932.00 | 98.64 | 1.36 |
| No. 4 | 4.75 | 48.40 | 4980.40 | 99.61 | 0.39 |
| No. 8 | 2.36 | 0.00 | 4980.40 | 99.61 | 0.39 |
| No. 16 | 1.18 | 0.00 | 4980.40 | 99.61 | 0.39 |
| No. 30 | 0.60 | 0.00 | 4980.40 | 99.61 | 0.39 |
| No. 50 | 0.30 | 0.00 | 4980.40 | 99.61 | 0.39 |
| No. 100 | 0.15 | 0.00 | 4980.40 | 99.61 | 0.39 |
| Summation of Cumulative weight Retained (%)= | | | | 823.62 | |

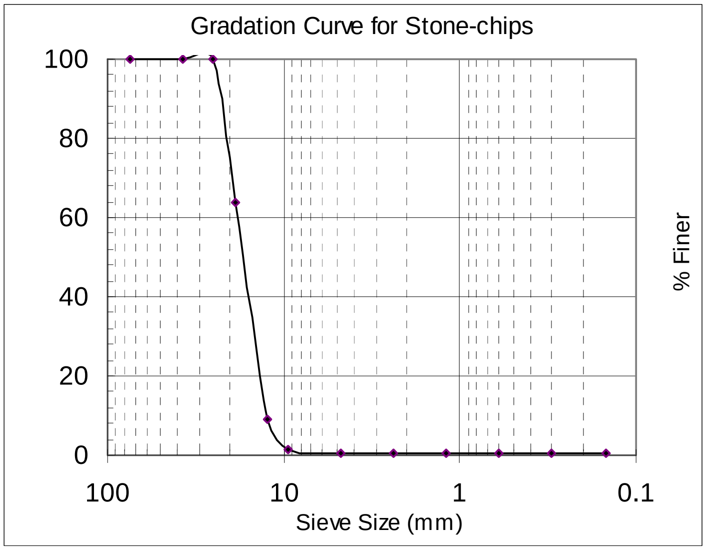


Figure 3: Gradation curve for Coarse aggeragate

Table 4. Physical properties of samples

| | Samples ID | Mixing Time (min.) | Slump Value (mm) | Spread Dia (mm) | % of water added |
|---|---|---|---|---|---|
| Sample-A (without admixture) | A1 | 5 | 263 | 715 | 0 |
| | A2 | 90 | 265 | 725 | 3 |
| | A3 | 180 | 255 | 570 | 7 |
| Sample-B (with admixture) | B1 | 5 | 257 | 630 | 0 |
| | B2 | 90 | 235 | 475 | 7 |
| | B3 | 180 | 227 | 438 | 13 |

## 3. RESULTS

Table 5: Compressive strength tests of concrete without admixture

| Samples ID | Mixing Time (min) | Compressive Strength (psi) | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| A1 | 5 | 1170 | 1511 | 2148 |
| A2 | 90 | 1313 | 1710 | 2267 |
| A3 | 180 | 1273 | 1671 | 2028 |

Table 6 : Tensile strength tests of concrete without admixture

| Samples ID | Mixing Time (min) | Tensile Strength (psi) | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| A1 | 5 | 448 | 486 | 796 |
| A2 | 90 | 492 | 534 | 875 |
| A3 | 180 | 424 | 462 | 765 |

Table 7 : Compressive strength tests of concrete with admixture

| Samples ID | Mixing Time (min) | Compressive Strength (psi) | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| B1 | 5 | 4084 | 4455 | 5251 |
| B2 | 90 | 3222 | 3898 | 5012 |
| B3 | 180 | 3022 | 3500 | 4508 |

Table 8 : Tensile strength tests of concrete with admixture

| Samples ID | Mixing Time (min) | Tensile Strength (psi) | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| B1 | 5 | 678 | 745 | 1233 |
| B2 | 90 | 595 | 662 | 1074 |
| B3 | 180 | 486 | 527 | 860 |

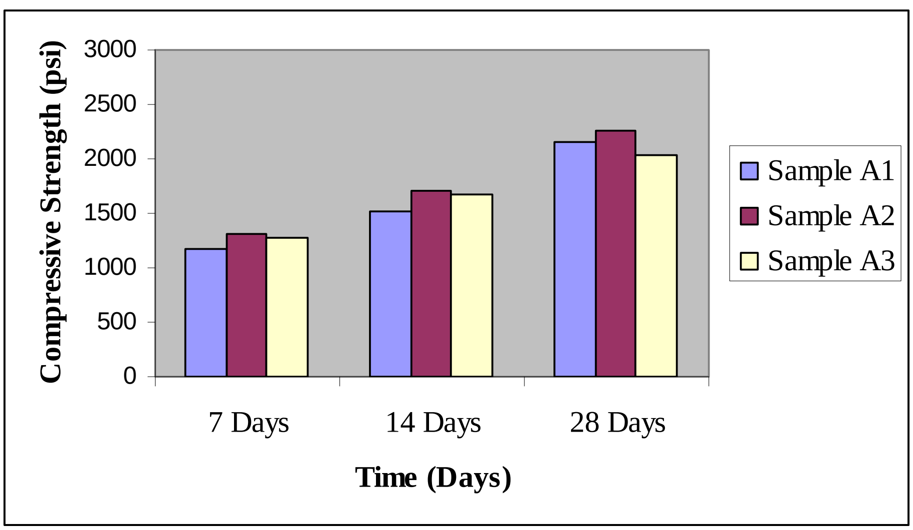


Fig 4. Graphical representation of Compressive strength without admixture

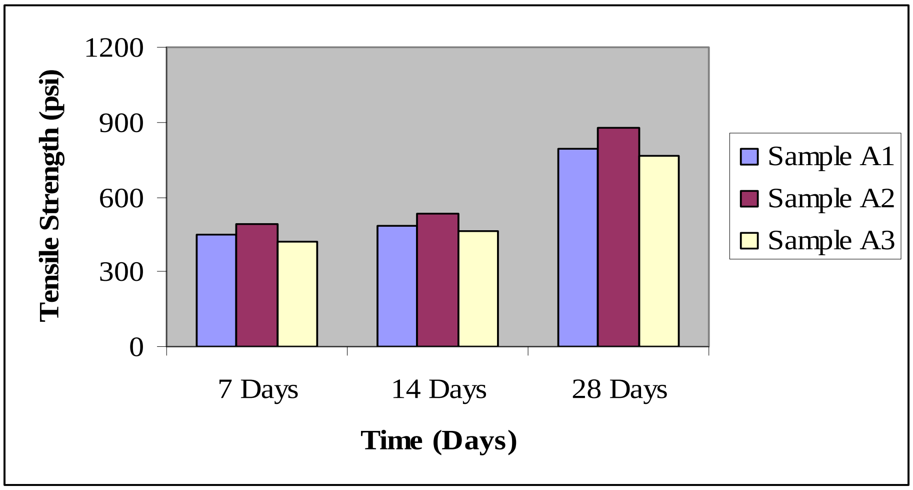


Fig 5. Graphical representation of Tensile strength without admixture

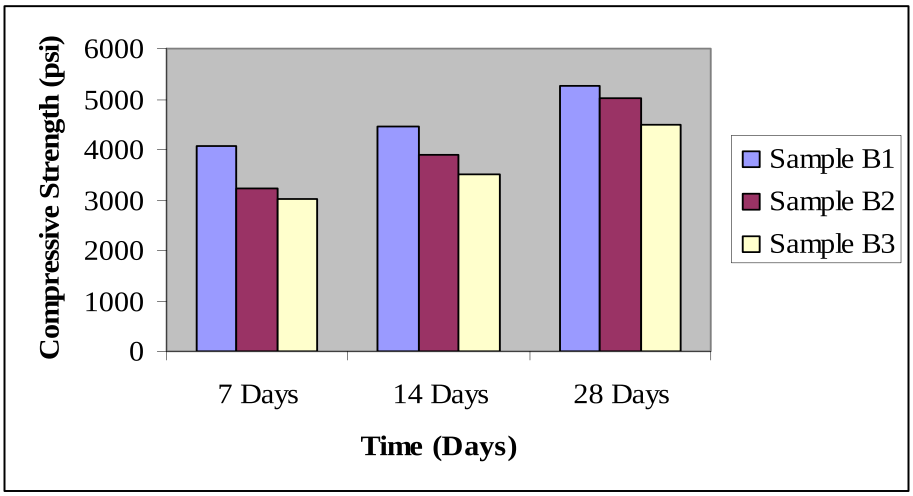


**Fig 6**. Graphical representation of Compressive strength with admixture

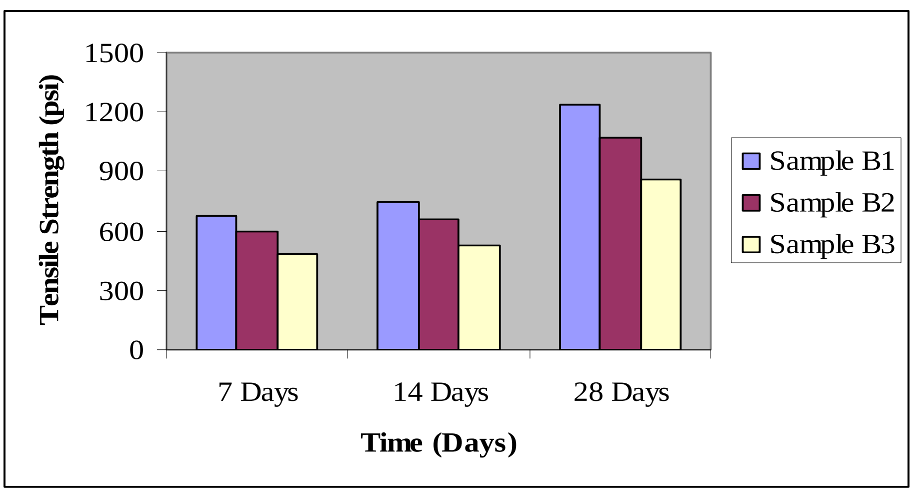


**Fig 7**. Graphical representation of Tensile strength with admixture

## 4. DISCUSSION

- It has been found that in the case of without admixture; the compressive strength and tensile strength of concrete is increased from standard mixing time due to increasing the mixing time, but the strength is decreased after mixing time 180 min. In the case of with admixture, the strength of concrete is decreased gradually with increasing mixing time.
- When extra water is added in the samples at different mixing time for maintaining the initial workability, the samples with admixture was required more amount of water than the samples without admixture with respect to increasing of mixing time due to long time mixing at high temperature.

## 5. CONCLUSION

It is clear that in case of samples without admixture there is no significant change of strength of concrete due to increasing of mixing time. But in case of samples with admixture the strength is gradually decreased due to increasing mixing time. From the study it is recommended that for the longer mixing time of free flow concrete only water reducing admixture may not be used.

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# WIND POWER TECHNOLOGY SCHEMES AS RENEWABLE ENERGY IN BANGLADESH

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## ABSTRACT

Wind energy is one of the renewable means of electricity generation that is a part of the worldwide discussion on the future of energy generation and use. Usage of wind energy has been increased in recent times especially because it is a running demand to use alternative energy sources and reduce fossil fuels consumption. This paper presents the schemes to use this technology in Bangladesh because it has a 724 km long coastline and many small islands in the Bay of Bengal, where strong southwesterly wind and sea breeze blow in the summer season and there is gentle northeasterly wind and breeze in winter months. It could be produced 2,000 MW of power in the coastal belt installing 30 windmills per square km. The windmills that can be installed in the coastal belts can sustain 250 km per hour cyclonic storm. The scope of setting large scale power plant in coastal areas will be discussed in this paper.

**Keywords:** Wind Power, Renewable Energy, Wind Turbines, Pressure Difference, Alternative Energy Sources, Cost Analysis, Wind Farm

## 1. INTRODUCTION

Bangladesh faces a severe crisis of electricity in the recent time due to increasing demand of it in every day. We have a good probability to increase our economic condition by utilizing our resources in a well manner. But we can’t keep pace with others due to shortage of electricity. So it is a vital issue to increase our production of electricity as soon as possible. In spite of high running cost (about 18TK. per unit electricity), we are bound to use diesel power plant due to high demand. But it is a matter of pleasure that per unit electricity has a role of 32Tk. in GDP. Therefore if we can generate electricity in a large scale with minimum cost it will be very profitable to us. Wind power technology is such a scheme that produces electricity with a very low running cost, in fact no fuel cost.

Wind power technology is one of the renewable energy which provides electricity using wind. Usage of wind energy has been increased in recent times especially since government bodies have suggested using alternative energy sources and reducing fossil fuels consumption. In fact out of all renewable energies, wind power energy has increase with

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more ratio than any other technology for past two decays with growth rate of 30 % percentage per year.

Sun is predominately the factor involved in providing solar power and wind power. Everyone knows that solar energy is provided by sun. Wind power is also form of solar energy because sun is reason for developing winds in atmosphere. When winds are produced it blows in different direction around, then these winds can be used to produce electricity which can be used for consumption. What actually happens is that sun's heat causes the air to warm up in patches, in result some patches of air becomes warm and some patches remain cold. Therefore a pressure difference is created. Hot air gets lighter in weight hence leaves it place and move towards upside, colder air patches are bit heavier there for they rushes to fill up the space which is left empty by hot air. This rapid movement of air around us produces winds which can be felt as movement of leaves on trees etc.

Wind turbine or motor with blades are installed on the lengthy tower. When wind passes through these blades it makes blades rotate and produce kinetic energy. Due to movement of blade, turbine is rotated which in result produces electricity. Electricity produced can be directly supplied to consumers or can be stored in batteries for later use. To produce more electricity with wind power, multiple wind turbines are installed in wind farm which produce more and more electricity in result.

## 2. WORKING PRINCIPLE OF WIND TURBINE

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetation.

The terms wind energy or wind power describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as

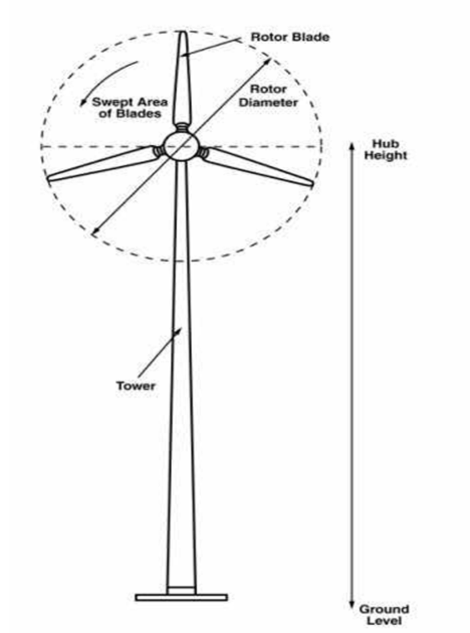


Fig. 1: Wind turbine schematic.

grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

So, to produce electricity a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission and distribution lines to homes, businesses, schools, and so on.

## 3. DESIGN OF WIND TURBINE POWER PLANT

### 3.1. Considerations for Designing Wind Power Plant:

There are few considerations which should be taken care of while developing wind power plant. To produce more electricity, increased number wind turbines are required in wind farm. Bigger blade size can also help in increasing the electricity generation capacity; therefore always choose to have bigger blades. Only those places are suitable for building up wind power plants where strong and steady winds are present in most of the time in a day, more wind cross through propellers, more rotation it will take hence produce more electricity. Coastal areas, higher areas, top of the mountain are best areas for developing wind power plant as it will encounter more wind at such altitudes. To receive satisfactory performance from wind power plants it should be located where it faces about minimum of 25 Km/p wind speed. Lower wind speed can also provide electricity however performance with consistency may suffer. Grid should not be build far from wind far, as this will increase costs of wire to provide electricity produced by wind grid station. Wind plant should keep closer to grid station for cost effectiveness.

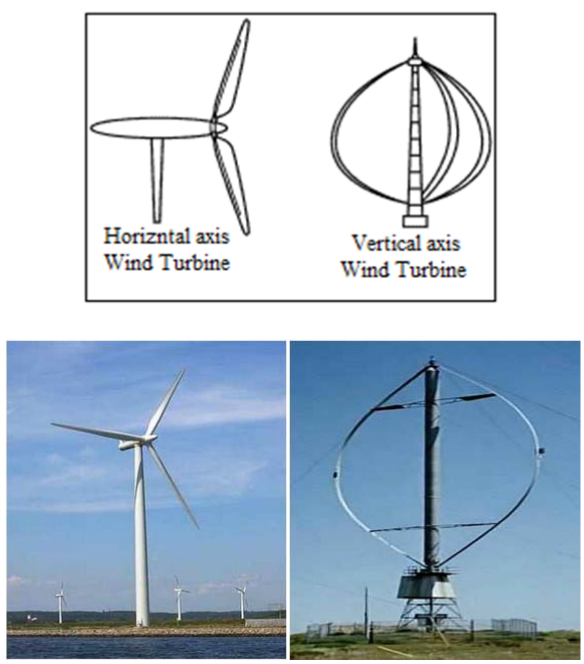


Fig. 2: Two basic wind turbines, horizontal axis and vertical axis

### 3.2. Selection of Wind Turbines:

There are two basic types of wind turbines: horizontal axis wind turbines and vertical axis wind turbines (shown in Fig. 2). Horizontal axis turbines (more common) need to be aimed directly at the wind. Because of this, they come with a tail vane that will continuously point them in the direction of the wind. Vertical axis turbines work whatever direction the wind is blowing, but require a lot more ground space to support their guy wires than horizontal axis wind turbines.

### 3.3. Factors in Designing Wind Turbine

An important factor in how much power that the wind turbine will produce is the height of its tower. The power available in the wind is proportional to the cube of its speed. This means that if wind speed doubles, the power available to the wind generator increases by a factor of 8 (*Fig 3*). Since wind speed increases with height (*Fig 4*), increases to the tower height can mean enormous increases in the amount of electricity generated by a wind turbine.

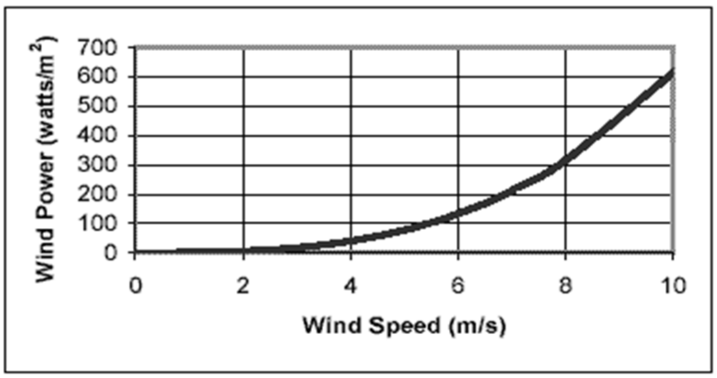


Fig. 3: Relationship between wind speed and wind power.

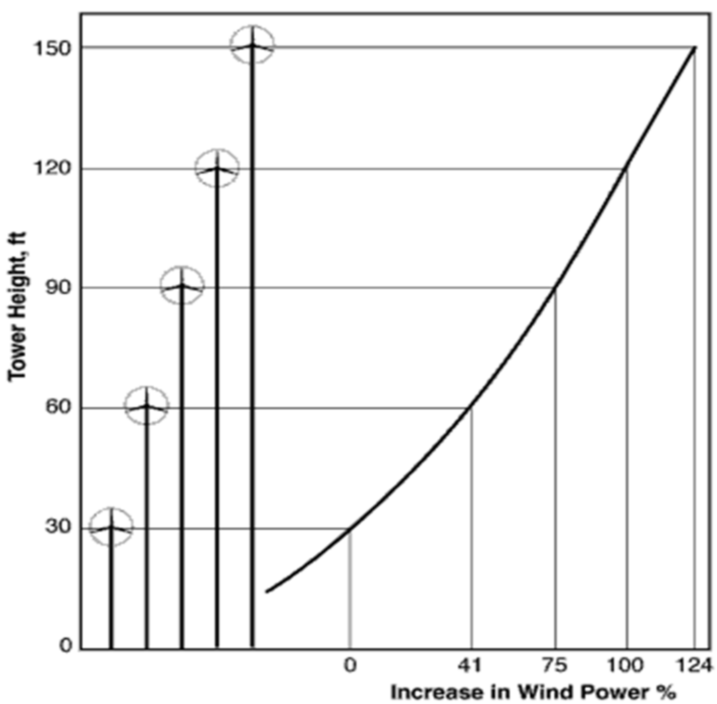


Fig. 4: Wind speeds increase with height.

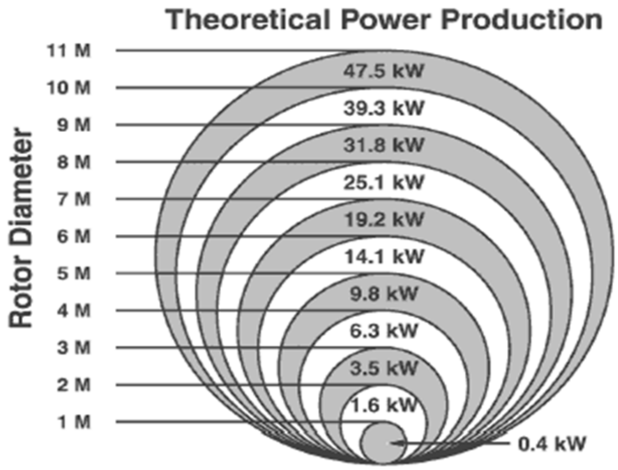


Fig. 5: Theoretical power production for small wind turbines when the wind speed is 10 m/s.

It has been recommended that towers be 24-37 m (80- 120 ft) high. Installing a wind turbine on a tower that is too short is like installing a solar panel in a shady area. At a minimum, mount a wind turbine high enough on a tower that the tips of the rotor blades remain at least 9 m (30 ft) above any obstacle within 90 m (300 ft).

A modest increase in the rotor diameter will lead to significant increases in both the swept area of a turbine and the amount of electricity that the turbine can generate (Figure 5). The values for power production shown on *Figure 5* are theoretical values, and only intended for illustrative purposes. The actual power production from a wind turbine will be influenced by many other factors, such as: the efficiency that the wind turbine is able to extract energy from the wind; the elevation at which the turbine is located; and other design characteristics of the wind turbine.

To get a preliminary estimate of the performance of a particular wind turbine, use the formula below:
AEO = 1.64 D2 V3

Where
AEO = Annual energy output, kWh/year
D= rotor diameter, meters
V = Annual average wind speed, m/s

**3.4. Supplying power to the grid**
The tower is connected to an underground metal object to ground the tower in case of a lightning strike. A disconnect switch is needed that can electrically isolate the wind turbine from the rest of the wind energy system. An automatic disconnect switch is necessary to prevent damage to the rest of the system in case of an electrical malfunction or a lightning strike. It also allows maintenance and system modifications to be safely made to the turbine. It may need batteries to store excess energy generated by the wind turbine. Because energy is stored in batteries as DC power, an inverter is needed to convert power from the batteries to the AC power.

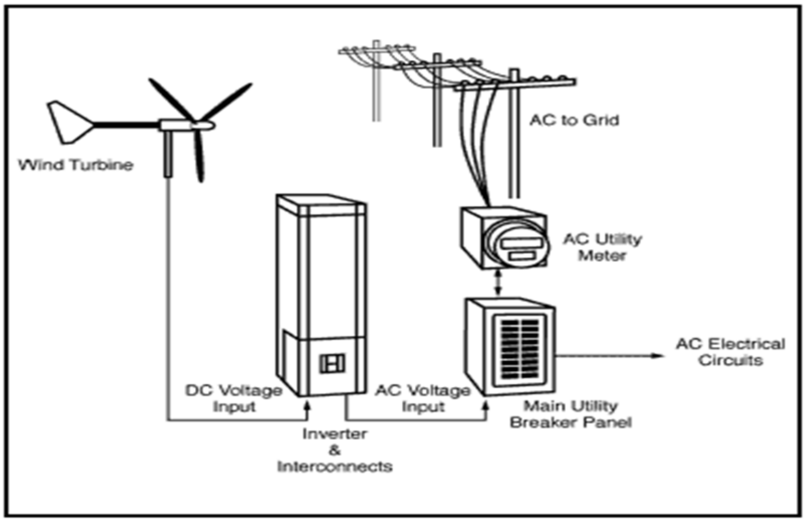


Fig. 6: Diagram of a grid-tied wind electric system.

To connect the wind turbine to the grid, it will require a transfer switch between the wind turbine and the utility line as well as a two-way meter to keep track of the energy that have stored in and taken from the power grid. It is very important that the wind generator meets certain standards and that it does not pose a risk to utility's personnel or equipment. It is also important that the quality of power coming from the turbine adequately matches the electrical characteristics in utility's power grid.

## 4. PROPOSED SCHEMES

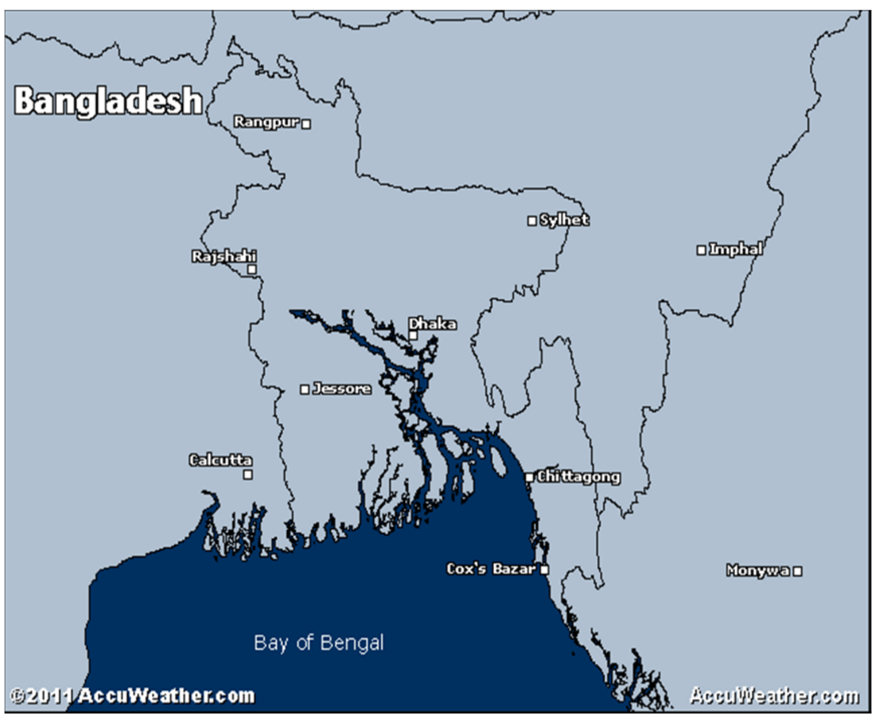


Fig. 7: Position of Bangladesh

Bangladesh is situated between 20°34'- 26°38' North Latitude and 88°01'- 92°41' East Longitude. The country has a 724 km long coast line and many small islands in the Bay of Bengal, where strong south-westerly tradewind and sea-breeze blow in the summer months and there is gentle north-easterly tradewind and land breeze in winter months. Wind speeds are higher in coastal areas. Wind speeds exhibit strong seasonal cycle, lower in the September to February period and higher in summer (March to August).Wind speeds exhibit a diurnal cycle, generally peaking in the afternoon and weakest at night.

Wind speed has been measured in Patenga, Cox's Bazar, Kuakata, Moheshkhali, and Noakhali by the computerized anemometers. The wind computers have been installed at 20 meters height. According to this study annual average wind speeds in the coastal regions of Bangladesh are greater than 6.5 m/s at the height of 20 meters. It has been observed that during day times (8 a.m. to 7 p.m.) wind speeds are about 30 to 40% higher than the average values. The value of the power exponent $\alpha$ has been determined in the above sites and it is 0.139. So, at 40 meters height the annual average wind speed is about 7.15 m/s. So, wind speeds in the coastal regions of Bangladesh are suitable electricity generation.

## 5. IMPLEMENTATION

Spacing between adjacent turbines needs to be at least several times the length of the turbine blades to prevent lowering the efficiency of the turbines due to one stealing wind from or causing turbulence for another. One rule of thumb is that placement between turbines should be about 3 to 7 diameters between adjacent turbines in a direction perpendicular to the wind, and 10 diameters spacing in a direction of the wind.

It is difficult to accurately measure the costs of wind plants. The costs for a commercial scale wind turbine ranged from \$1.2 million to \$2.6 million, per MW of nameplate capacity installed. Most of the commercial-scale turbines installed today are 2 MW in size and cost roughly \$3.5 Million installed. Wind turbines have significant economies of scale. Smaller farm or residential scale turbines cost less overall, but are more expensive per kilowatt of energy producing capacity. Wind turbines under 100 kilowatts cost roughly \$3,000 to \$5,000 per kilowatt of capacity.

Fig. 8: Placement of Turbines

If we use the rotor of diameter 8m then we can be able to obtain 25.1 kW from per turbine. We have long coastal areas of about 724 km.

Therefore, a scope of setting [(724000/ (5*8))] = 18100 turbines per row, assuming space between the poles are five times of their diameter.

If the sea shore has a width of two hundred meters on an average, then the number of row are = 200/ (10*5) = 4.

Total number of turbine = 18100*4
=72400.

So total energy produced = 72400*25.1
= 1817240kW or 1817.24MW

i.e. we can easily generate about 1820MW from our sea shore using wind turbine.

The total cost would be about (1820000*4000) or 7280 million US dollars (5100 crore Tk.) approximately.

## 6. COST COMPARISON

Table 1: Fuel, Transmission and Distribution Costs

| Energy Technology | Share of Fuel Cost in the Each kWh | Initial Investment, O& M Costs for Each kWh | Transmission and Distribution Costs for Each kWh | Total cost for Each kWh |
|---|---|---|---|---|
| Coal (at mine mouth) | Tk. 0.75 | Tk. 1.25 | Tk. 1.25 | Tk. 3.25 |
| Coal (imported) | Tk.7.00 | Tk. 1.25 | Tk. 1.25 | Tk. 8.50 |
| Oil | Tk. 17.89 | Tk.1.50 | Tk. 1.25 | Tk. 20.64 |
| Gas | Tk. 1.11 | Tk. 1.10 | Tk. 0.85 | Tk. 3.06 |
| Wind Energy (11KV, AC) | Tk. 0.00 | Tk. 5.91 | Tk. 1.75 | Tk. 7.66 |
| Solar PV (11KV, AC) | Tk. 0.00 | Tk.79.18 | Tk. 1.50 | Tk.80.68 |

We have seen from the above table that in case of wind energy we need not any fuel cost whereas it would require about 18 Tk. when using oil as fuel. Though total cost for each kWh is 7.66 Tk. in wind energy plant due to high investment but actual running cost is about 1.18 Tk. (2 US cent) only.

The comparison is shown on the following figure:

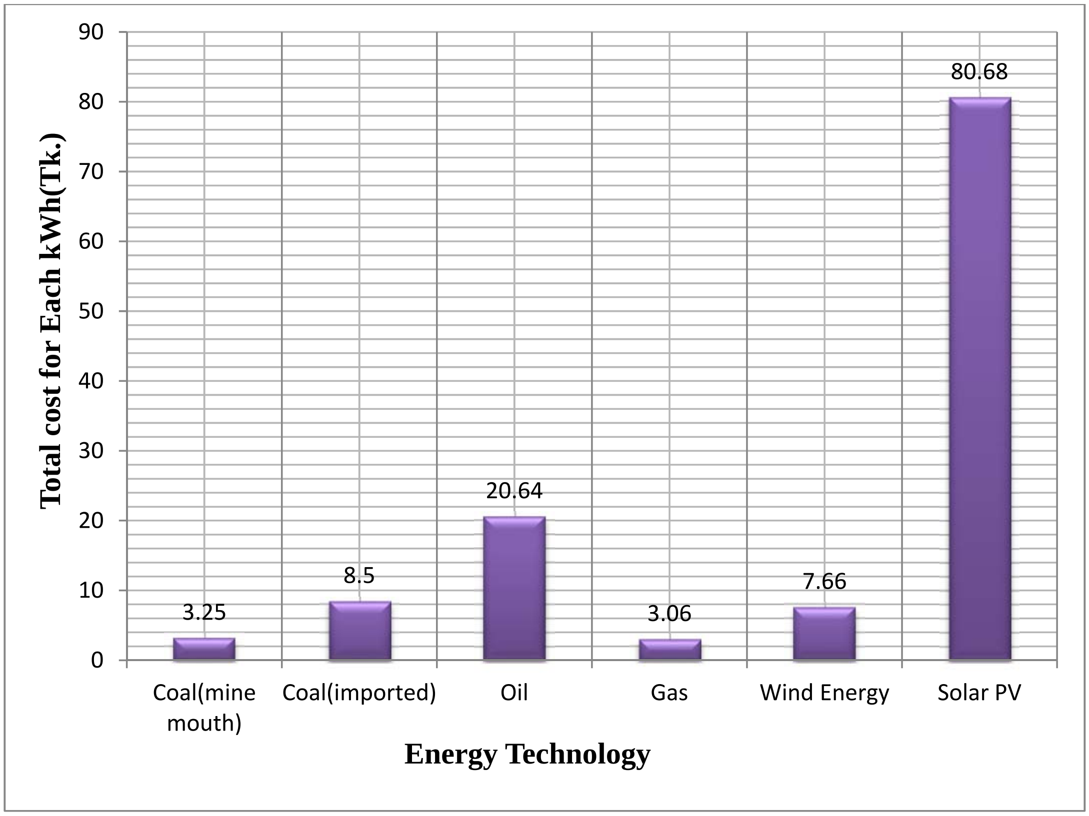


Fig. 9: Comparison of costs

## 7. CONCLUSION

In the near future, wind energy will be the most cost effective source of electrical power. In fact, a good case can be made for saying that it already has achieved this status. The major technology developments enabling wind power commercialization have already been made. There will be infinite refinements and improvements, of course. So the government body should come forward to set up the project of setting this type of power plant and remedy the crisis of power. The government can distribute the total work among different private companies so that the total project could be run within short periods. At the same time they must be sincere to proper maintenance of the ground equipments (especially from flood water) as from the past stories it has been found that due to lack of maintenance the wind turbine cannot give its maximum output.

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# A STUDY ON DISPERSIVITY OF ARSENIC THROUGH COHESIONLESS SOIL

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## ABSTRACT

Arsenic (As) is a well known pollutant of ground water in Bangladesh. The toxicity of arsenic compounds depends on the chemical and physical form of the compound. A lot of works has been done for removal, treatment and detecting the presence of As in ground water in Sylhet region. Transport mechanism is yet to understand clearly. Movement of Arsenic through different types of cohesion less soil media is the prime concern of this study. To fulfill the objective, Surma, Sari and Volaganj sand were selected. Five column leaching tests were conducted to reveal the dispersivity characteristics of Arsenic. Three of them were made by unique soil and rests of them were combination of these three according to hierarchy of particle size and its inverse order. Various physical properties of these soil samples were determined. From the collected data experimental and theoretical breakthrough curve (BTC) were prepared and compared with each other. The value of dispersion coefficient, Peclet no, Brenner's no, Index of dispersion were calculated. Dispersion coefficient (773.763 $cm^2$/min) and index of dispersion (844.3 $cm^2$/min) were higher for Surma sand. The Peclet no (3.48) and Brenner's no (13.92) were higher for Volaganj sand. The leaching rate was found higher for higher pore water velocity of the Volaganj sand. It was found that soil texture affects As leaching as different results were found for combined sample 1 and 2.

**Key Words:** Cohesionless soil, soil pollution, arsenic movement, dispersivity of Arsenic, dispersion coefficient, breakthrough curve.

## 1. INTRODUCTION

Arsenic (As) is potentially detrimental to human beings. It causes different diseases like skin and lung cancer [1]. High concentrations of As in soil can occur due to natural or anthropogenic processes. The natural occurrence of arsenic in groundwater is directly related to the arsenic complexes present in soils. Since arsenic in soil is highly mobile, once it is liberated, it results in possible groundwater contamination [2]. Several countries have reported high level of As in their groundwater resources such as Bangladesh, Cambodia,

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China, India, Lao PDR, Nepal, Pakistan, Thailand, Viet Nam [3, 4, 5, 6 and 7]. In Bangladesh, 40 million people are at risk to As poisoning [8]. Mounting demand of food production in densely populated countries like Bangladesh enhanced the use of As contaminated groundwater for irrigation leaving soil increasingly As rich. In addition to concerns over As contamination in water sources, it also alarms that dietary intake of As from contaminated soil [9] through the food chain may adversely affect human health and already groundwater arsenic contamination in Bangladesh is reported to be the biggest arsenic calamity in the world in terms of the affected population [10]. Therefore, As mobility/transport through soil is a topic of significant importance.

Soil is a mixture of mineral, plant and animal materials that form during a long process that may take thousands of years. But unhealthy soil management methods have seriously degraded soil quality, caused soil as well as ground water contamination. Many substances added to soils can build up to concentrations that become serious threats to plant and animal health. Materials accumulate when added in larger amounts than their decomposition rate [11]. Iron (Fe) oxides, clay minerals, and organic materials in soil will adsorb or desorb As when the ionic composition in soil water changes [12]. Flooding or transport of organic material or other reducing agents into soil can initiate reduction condition and subsequently lead to dissolution of ferric hydroxides [13]. One important mechanism through which the groundwater is polluted with As is the reductive dissolution of iron oxy-hydroxide (FeOOH) stimulated by microbial activity and organic materials [14, 15, 16, 17, 18 and 19].

The alluvial and deltaic sediments containing pyrite has favored the arsenic contamination of groundwater in Bangladesh. Most of the arsenic is occurring in the younger sediments derived from the Ganges Basin. The investigators found that there is a layer containing arsenic compound at a depth of 20 to 80 meters [20]. The groundwater in Bangladesh has declined progressively due to the excessive extraction of water for irrigation and domestic water supply, lack of water management and inadequate recharge of the aquifer. The groundwater declined beyond 8 meters in 12% areas of Bangladesh in 1986. This extent rose to 20% areas in 1992 and 25% areas in 1994 [21]. The study on forecasting groundwater level fluctuation in Bangladesh indicated that 54% areas of Bangladesh are likely to be affected up to 20 meters in some areas particularly in northern part of the country [22]. Excessive extraction may be the vital cause for creating a zone of aeration in clayey and peaty sediments containing arseno-pyrite. Under aerobic condition, arseno-pyrite decomposes and releases arsenic that mobilizes to the subsurface water. The mobilization of arsenic is further enhanced by the compaction of aquifers caused by groundwater withdrawal [23].

In Sylhet, arsenic naturally occurs in various geological formations. It is mainly found in shale rock, which points to arsenic’s preferential adsorption on clays, and in sulfide minerals (such as pyrite) that are prevalent in the earth’s crust. When water comes into contact with these rocks and minerals on the earth’s surface and in the subsurface, a fraction of arsenic dissolves.

Previously column leaching tests were conducted by other researchers to study As mobility through sand bed [24, 25]. The main objective of this study is the transport of arsenic through different types of sand media. To fulfill the objective, Surma, Sari and Volaganj sand were selected. Accordingly, five column leaching tests were conducted to reveal the dispersivity characteristics of Arsenic.

**2. BREAKTHROUGH CURVE**

It refers the relationship of leachate concentrations (or relative concentration) against time or pore volume or effluent volume. It expresses: (a) how fast a solute is moving towards the bottom of the soil column, (b) how long it will take for a solute to appear at the bottom, and (c) what kinds of transport mechanism are significant in solute transport. There are various factors that affect the shape of the solute breakthrough curve. These are concentrations of solute, mode of solute application, effect of flow velocity, water content of the media, cation exchange capacity of the media, etc. The Fig. 1 to 4 shows standard breakthrough curves for different types of solute transport [26].

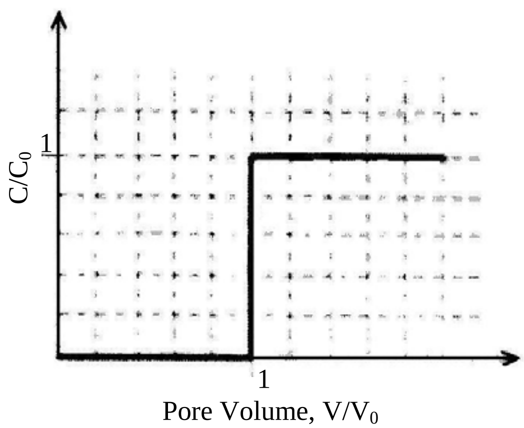


Fig 1: Typical BTC for non-reactive solute transport

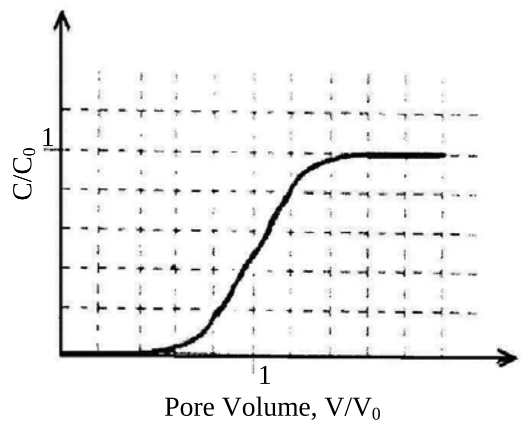


Fig 2: Typical BTC for non-reactive convective/dispersive solute transport

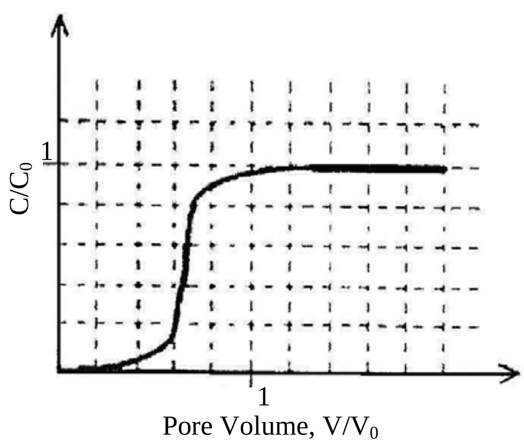


Fig 3: Typical BTC for reactive solute transport (linear sorption isotherm)

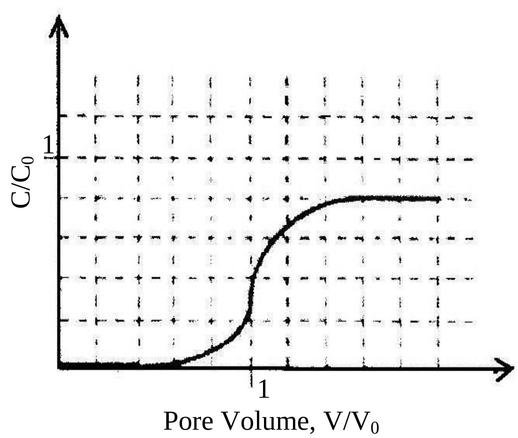


Fig 4: Typical BTC for reactive solute transport (first order degradation)

## 3. MATERIALS AND METHODOLOGY

### 3.1. Soil sample collection and preparation

Three soil samples were collected from three sources. Sari sand from river Sari, which is also known as Sylhet sand; Volaganj sand from Volaganj and Surma sand from Surma River. Plants, roots, organic debris etc. were removed carefully from the collected sample. The soil samples were then oven dried.

### 3.2. Analysis of Physical properties of soil

Specific gravity and dry density of soil were determined by Pycnometer method and particle size analysis was done by sieve analysis method as described by T. W. Lambe.

### 3.3. Experimental procedure of column test

1. The filter net was placed at the bottom of the column.
2. Soil sample was poured into the column by consecutive 3 steps (each step 4 inch) adding soil and distilled water to compact it up to 12 inch height.
3. In column, soil sample was washed two times by distilled water.
4. Initial concentration and seepage velocity was determined passing distilled water in third times.
5. Known concentration of Arsenic solution (0.5 mg/L) was prepared from standard solution. Then soil column and upper bucket was filled with the Arsenic solution.
6. For constant flooding depth the discharge rate of bucket was adjusted with the seepage velocity of the soil column.
7. Conical flask was placed at the bottom of the soil column and sample solution was collected. Time was recorded for each collection.
8. Each sample was filtered by filter paper. Arsenic solution was determined of each sample by standard procedure of SDDC (Silver Di-thio Di-ethyl Carbamate) method.

## 4. DATA ANALYSIS AND DISCUSSION

The experimental data of the physical properties of soil samples are shown in Table 1.

Table 1: Physical properties of the soil samples

| Property | Sari | Surma | Volaganj |
|---|---|---|---|
| Length of soil column, cm | 30.48 | 30.48 | 30.48 |
| Column diameter, cm | 6.0225 | 6.0225 | 6.0225 |
| Cross sectional area, $cm^2$ | 28.5 | 28.5 | 28.5 |
| Volume of soil in the column, $cm^3$ | 868.68 | 868.68 | 868.68 |
| Flooding depth over soil column, cm | 6 | 6 | 6 |
| Dry density, $gm/cm^3$ | 1.57 | 1.56 | 1.54 |
| Wet density, $gm/cm^3$ | 1.67 | 1.68 | 1.71 |
| Water content, % | 24.9 | 27.87 | 28.23 |
| Specific gravity | 2.73 | 2.76 | 2.54 |
| Degree of saturation | 1.00 | 1.00 | 1.00 |
| Air filled porosity | 0.3848 | 0.43479 | 0.4352 |
| Void ratio | 0.6256 | 0.7692 | 0.7707 |
| 1 pore volume, $cm^3$ | 334.26 | 377.69 | 378.05 |
| Coefficient of permeability, cm/s | 0.001365 | 0.000841 | 0.0142 |

### 4.1. Permeability and uniformity coefficient

The permeability of soil samples, shown in Fig. 5, shows that Volaganj sand is more permeable than the others. It has taken less time than the others to pass the solute.

The uniformity coefficient of the samples was 2.05, 1.54 and 2.13 for Sari, Surma and Volaganj sand respectively, as shown in Fig. 6, which reveals that Volaganj sand is more vulnerable for arsenic transport.

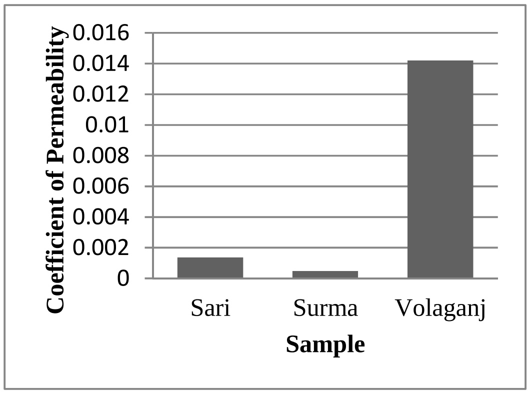


Fig 5: Coefficient of permeability

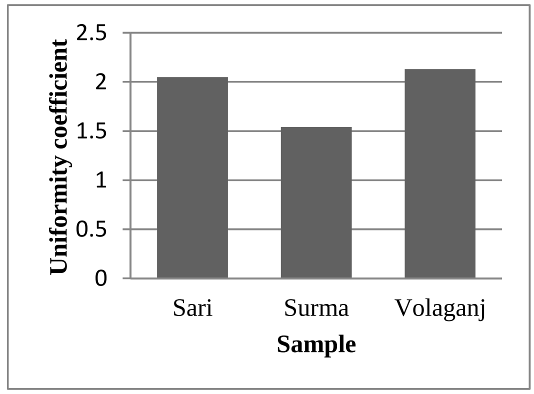


Fig 6: Uniformity coefficient

### 4.2. Dispersion coefficient and index of dispersion

In case of non-reactive convective/ dispersive transport, Dispersion coefficient and index of dispersion are $D = \frac{V_D L}{4\pi S^2}$ and $I = \frac{2D}{V_p}$ respectively. The highest value of dispersion coefficient, Fig. 7, and index of dispersion, Fig. 8, is for the Surma sand. So dispersion of arsenic within an area at a specific time is highest for this time.

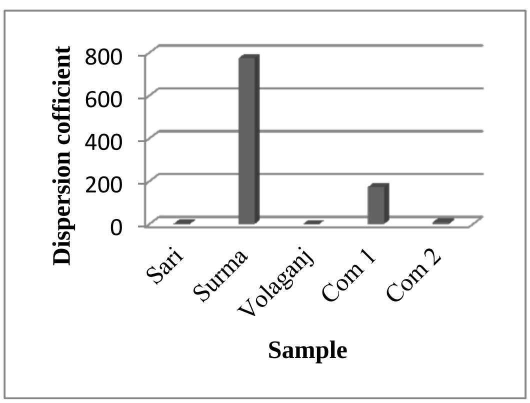


Fig 7: Dispersion coefficient

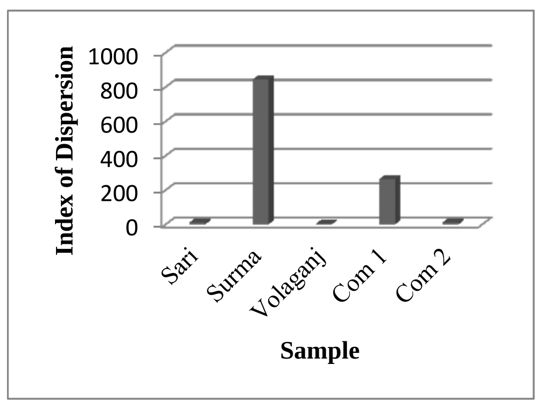


Fig 8: Index of Dispersion

### 4.3. Brenner's no. and Peclet no.

Brenner used the quantity $\frac{V_p L}{D}$, called Brenner's number. The quantity $\frac{V_p L}{4D}$ is called Peclet number. These numbers are used to characterize the flow medium. The higher the value of these numbers, the grater the flowness of the medium. Volaganj sand was the sample with highest value of these numbers as shown in Fig. 9 and 10.

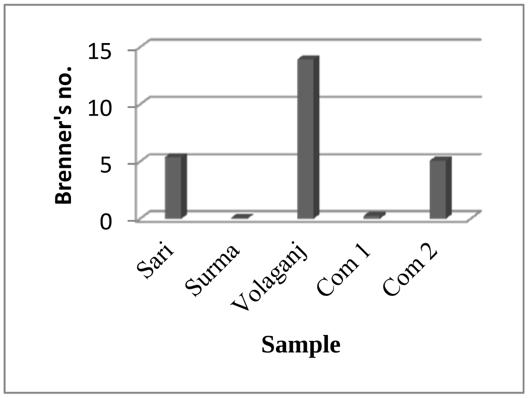


Fig 9: Brenner's no.

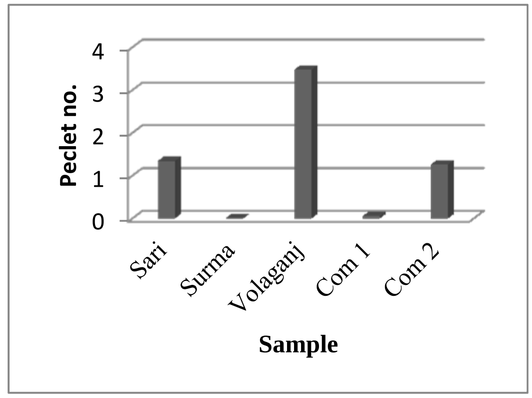


Fig 10: Peclet no.

### 4.4. Solute breakthrough curve

The breakthrough curves for Sari sand, Surma sand, Volaganj sand, combined sand 1 and combined sand 2 are shown in Fig. 11 to 15 and these are compared with the standard breakthrough curves (Fig. 1 to 4).

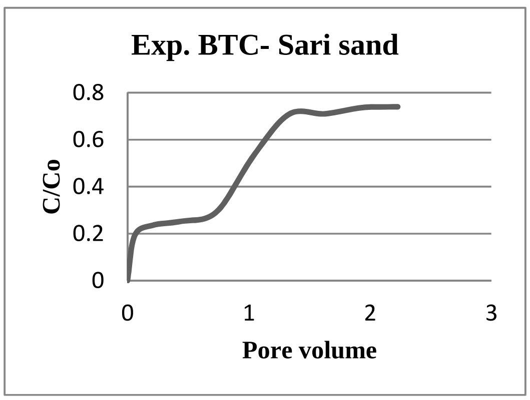


Fig 11: Breakthrough curve for Sari sand

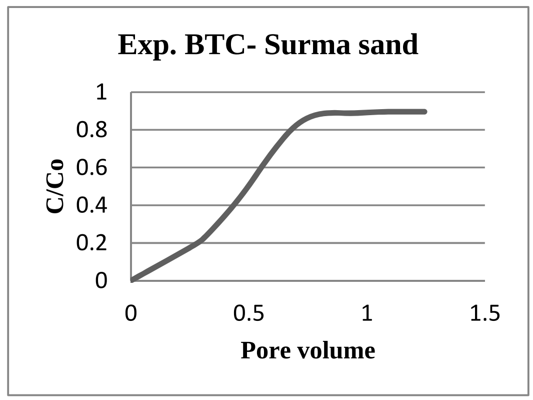


Fig12: Breakthrough curve for Surma sand

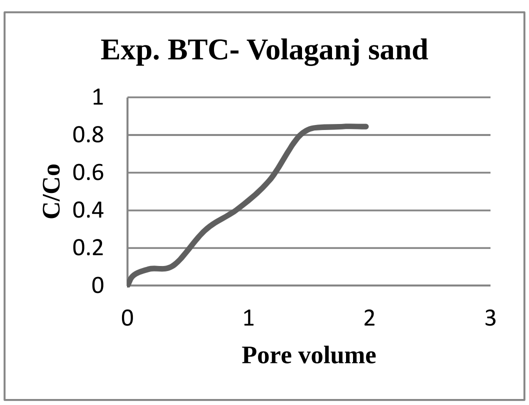


Fig13: Breakthrough curve for Volaganj sand

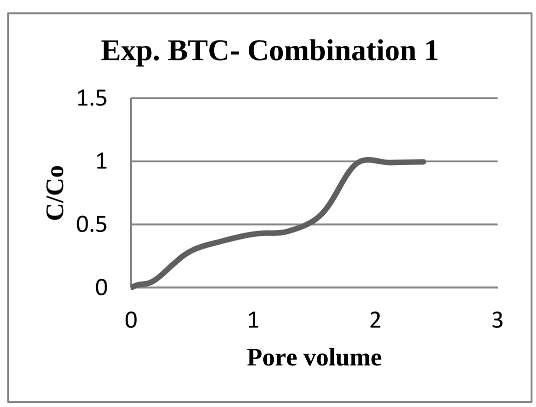


Fig14: Breakthrough curve for combined sand 1

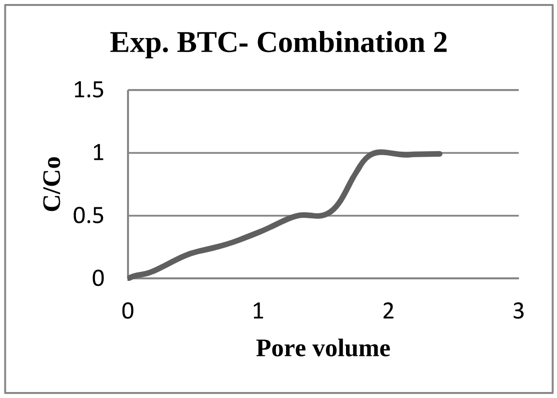


Fig15: Breakthrough curve for combined sand 2

**Sari sand**

Comparing the BTC of Sari sand with the standard curves, it has been seen that the longitudinal dispersion was dominant in this soil column. Some of the point looks inconsistent with the standard BTC. This might happen due to poor packing. Again the flow through boundary wall was ignored.

**Surma sand**

Surma sand was the finer among the soil sample. The BTC of it was more smooth than similar with the standard one. It had ended up before relative concentration was below 1. It surely indicates some chemical reaction had taken place in the soil column, because it was more similar with the typical BTC of relative solute transport. Also exclusion of solute by solute-solid interaction or velocity distribution with velocities near zero is taken place.

**Volaganj sand**

Again longitudinal dispersion was dominant for this sample like Sari sand. The BTC was very much steep. This might be happened due to continuous solute application. Because Volaganj sand was the coarser one, to maintain constant head, it was necessary to apply solute continuously.

**Combined sample 1**

This column is prepared by three consecutive layer of above samples according to grain size coarser to finer. Though some of the point of BTC looked inconsistent, longitudinal dispersion is dominant in this column. Various water contents for different layer has an effect on this curve.

**Combined sand 2**

This column is prepared by three consecutive layer of above samples according to grain size finer to coarser (inverse order of combined sample 1). Again longitudinal dispersion was dominant in this column.

### 4.5. Theoretical BTC of non-reactive convective/dispersion solute transport model

The theoretical BTC has been drawn, shown in Fig. 16 to 20, by solving CDE (convection dispersion equation) for all the sand samples.

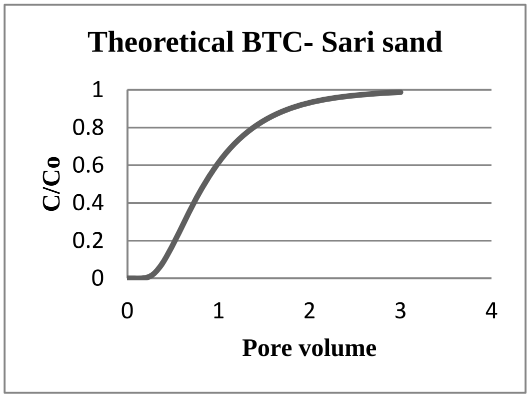


Fig 16: Theoretical breakthrough curve for Sari sand

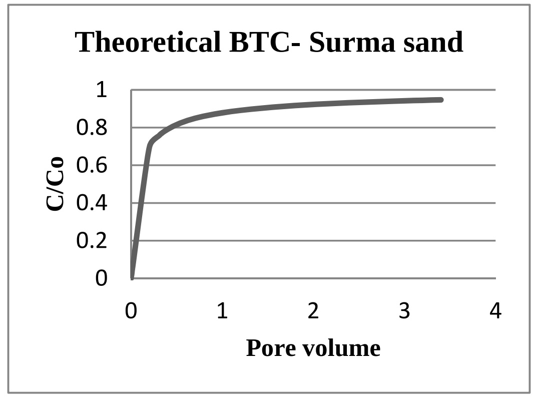


Fig 17: Theoretical breakthrough curve for Surma sand

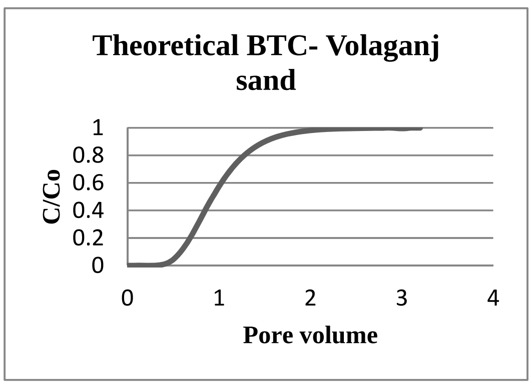


Fig 18: Theoretical breakthrough curve for Volaganj sand

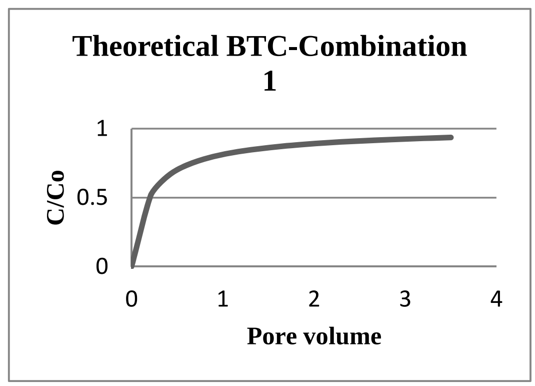


Fig 19: Theoretical breakthrough curve for combined sand 1

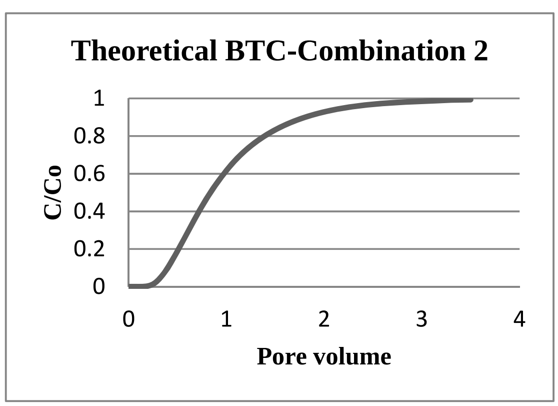


Fig 20: Theoretical breakthrough curve for combined sand 2

### 4.5. Comparison of theoretical and experimental BTC

Some dissimilarity has been shown in theoretical and experimental BTC of each sample which reveals that not only convection or dispersion is dominant in this sample but also other mechanism such as adsorption, reaction, ion exchange etc. also associated.

## 5. CONCLUSIONS

Volaganj sand is most vulnerable because the coefficient of permeability is highest and so arsenic takes less time to percolate. The dispersion coefficient and index of dispersion is greater for Surma sand and lower for Volaganj sand. The higher the volumetric water content, the higher the dispersion coefficient and the slower the arsenic will leach through the soil. Again Brenner's no. and Peclet no. is higher for the Volaganj sand. It denotes that flowness of this medium is higher than all other samples. Considering all things Volaganj sand is most vulnerable and Surma sand is less vulnerable than the others. Uniformity coefficient shows that, uniform particle soil is less vulnerable to arsenic transport. There are little dissimilarities between the theoretical and experimental BTC. Along with convection or dispersion, other mechanism of solute transport may be occurred. Future study is deemed to find other methods of arsenic transport is involved in this medium. Also this types of study should be applied to the real soil medium before taking decision about the transport of arsenic through this soil.

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# EFFECT OF MIXING TEMPERATURE ON POROSITY OF CONCRETE

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## ABSTRACT

Sample was prepared at different casting temperature for sorptivity test. The casting temperature was lowered and increased by adding cold and boiled water respectively. Sorptivity test was performed according to ASTM C1585 on concrete samples to measure the porosity indirectly. The result shows, the increase in casting temperature increase the porosity of concrete.

**Key Words:** Porosity of concrete, Sorptivity, Water absorption, Mixing temperature.

## 1. INTRODUCTION

Concrete is a composite material obtained by using cement, aggregate, water and other additives. Nowadays concrete is exclusively used as a construction material all over the world. As laboratory design of concrete is usually performed at a controlled temperature, the standardized temperature for casting is chosen generally in the region of 18 to 21$^{o}$C (64 to 70$^{o}$F) [1]. In practice, however, concrete is mixed at a wide range of temperatures depending upon the ambient temperature of the respective region and season. In consequence, knowledge of the temperature effects on concrete is of great importance. The main concern of the study is the variation of porosity of concrete mixed at high and low temperature. The porosity of concrete was measured indirectly by ASTM C1585 method. The test was performed on different samples which were cast in different temperatures to evaluate the effect of mixing temperature on porosity of concrete.

## 2. MATERIALS AND METHODS

### 2.1. Materials

Fine aggregate of Fineness Modulus 2.32 and crushed stone chips were used in production of concrete. The maximum aggregate size was 18 mm. pH of the course aggregate was 10.57. In production of concrete ordinary Portland cement was used. Chemical properties of cement are presented in Table 1.

Table 1: Chemical composition of cement

| Components | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | F/CaO | IR | LOI | Sum |
|---|---|---|---|---|---|---|---|---|---|---|
| % | 39.94 | 4.90 | 2.54 | 45.63 | 1.70 | 1.62 | 0.91 | 24.53 | 1.93 | 98.26 |

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## 2.2. Specimen Preparation and Test Procedure

In mixing concrete, a tilting concrete mixer having 1.25-cft capacity was used. Each granulometric aggregate was weighted and mixed until a uniform mixture of materials was found.

The resulting concrete was placed in cylinder (100mm×200mm) moulds at 3 stages and 6 samples were prepared in each production for making of cylinder specimen.

For raising the casting temperature, boiled water of temperature about 97°C was used. In this case, the aggregate was heated into oven. To compensate the moisture loss from aggregates due to heating, additional amount water was added. [2]

For lowering the casting temperature, water of about 5°C was used. In this case, aggregates of normal temperature were used and no additional amount of water was used, as there was no moisture loss from the aggregates.

The test specimens for sorptivity were prepared by cutting the cylindrical specimen into a small cylinder (100 mm × 50 mm) at 90 days age. Then the samples were preconditioned to a certain moisture condition by oven drying for four days and then allowed to cool in a sealed container for three days. The sides of the concrete samples were sealed with electrician's tape. The label, mixing ratio, water cement ratio and casting temperature of specimens are presented in Table 2.

Table 2: Details of Specimen prepared

| Sample | Mixing ratio (volumetric) | w/c ratio (by mass) | Casting temp. ($^{0}$C) |
|---|---|---|---|
| A | 1:2:3.5 | 0.50 | 52 |
| A´ | 1:2:3.5 | 0.50 | 16 |
| B | 1:2:3.5 | 0.60 | 64 |
| B´ | 1:2:3.5 | 0.60 | 18 |
| C | 1:2:3.5 | 0.70 | 62 |
| C´ | 1:2:3.5 | 0.70 | 18 |

## 2.3. Test Procedure

Determination of sorptivity in the lab was performed in according to the ASTM C1585. The initial masses of samples were taken and at the 0 time were immersed to a depth of 5-10 mm in the water. At selected time (1, 2, 3, 4, 5, 9, 12, 16, 20 and 25 minutes) the samples were removed from the water, kipping the stopwatch stopped, excess water was blotted off with a damped paper towel and samples were weighted. Then samples were replaced in water and stopwatch was started again. The gain in mass per unit area over the density of water were plotted the square root of the elapsed time. The slopes of the lines of best fit of those points were reported as the sorptivity. The experimental setup of sorptivity test is given in Fig 1.

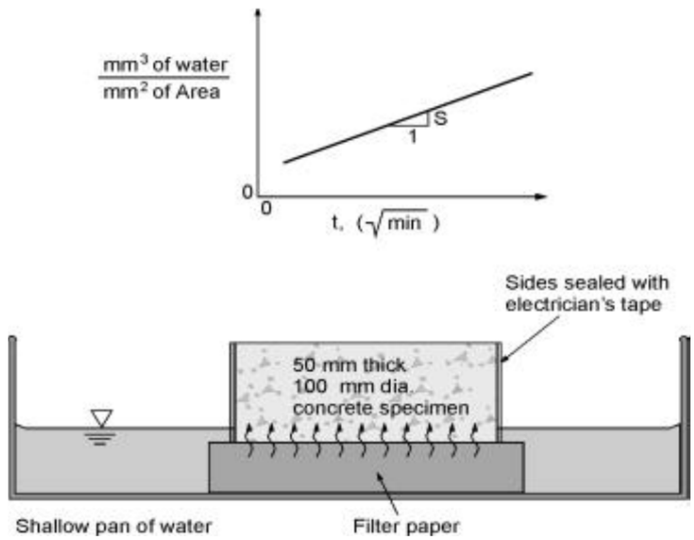


Fig 1: Experimental setup for sorptivity test.

## 3. RESULT AND DISCUSSION

A curve of cumulative mass gained per exposed surface area was drawn against square root of time and the slope of the best fit straight line was considered as sorptivity. Three samples were used to get an average value of sorptivity. The curves for different samples are presented below.

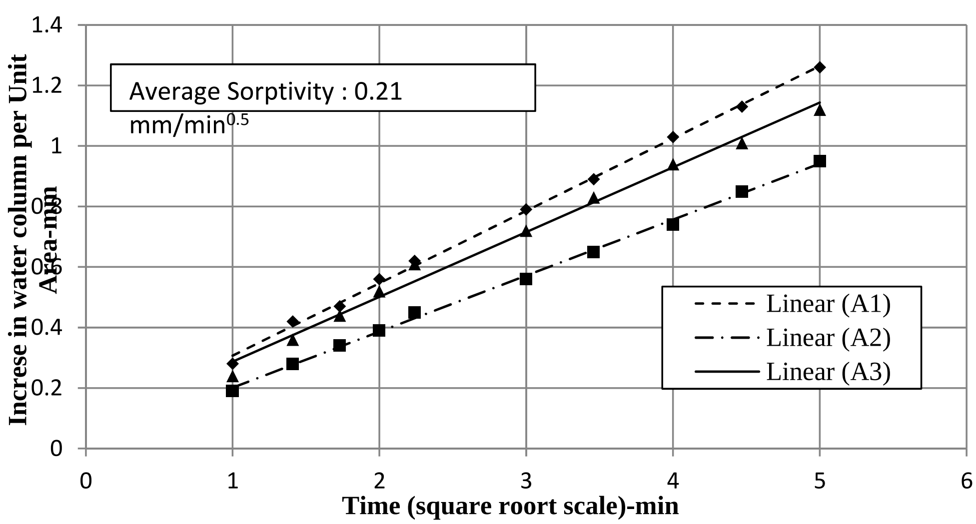


Fig 2: Increase in water column per unit area versus square root of time line for sample A

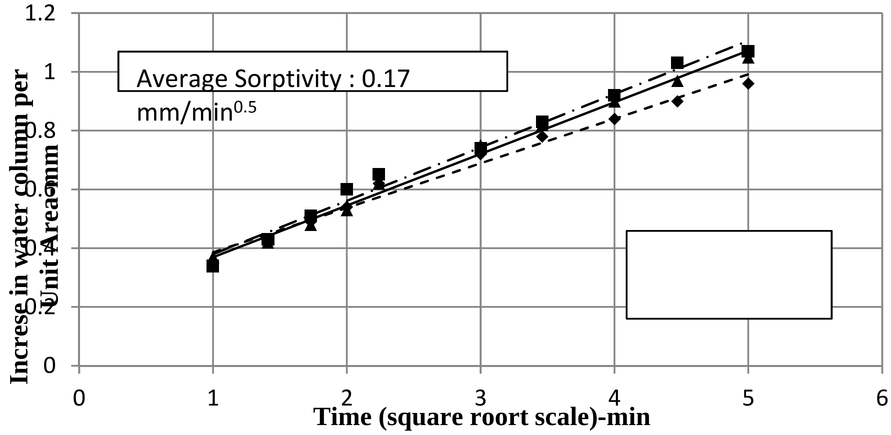


Fig 3: Increase in water column per unit area versus square root of time line for sample A´

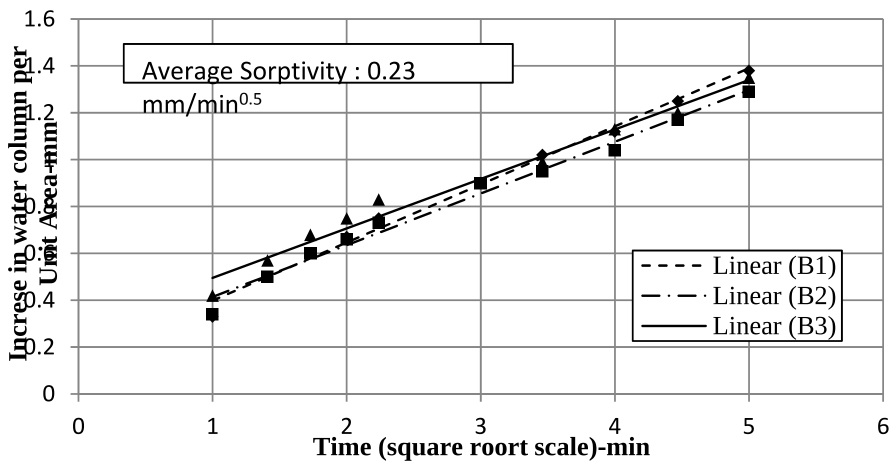


Fig 4: Increase in water column per unit area versus square root of time line for sample B

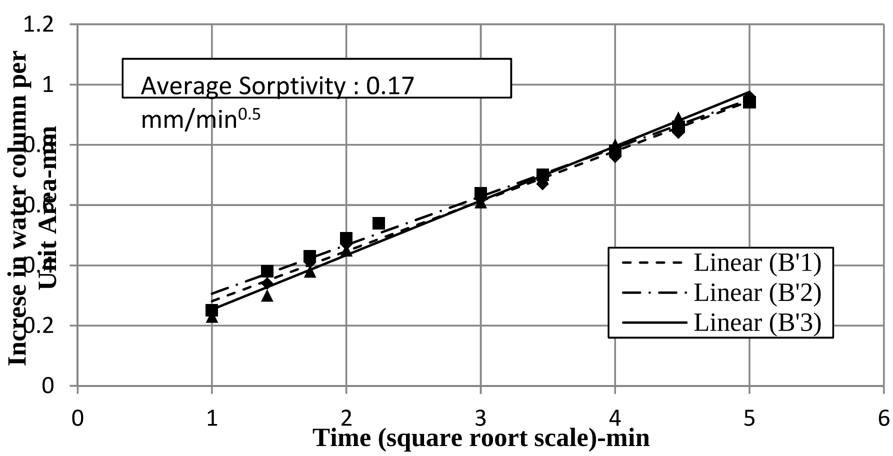


Fig 5: Increase in water column per unit area versus square root of time line for sample B´

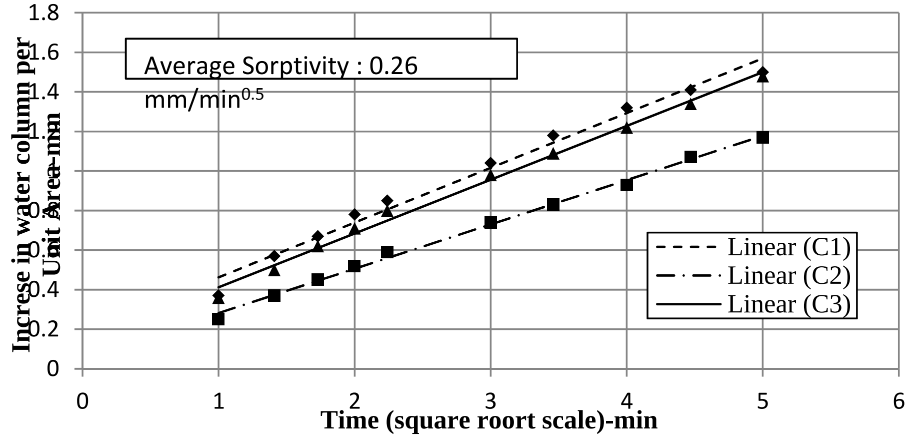


Fig 6: Increase in water column per unit area versus square root of time line for sample C

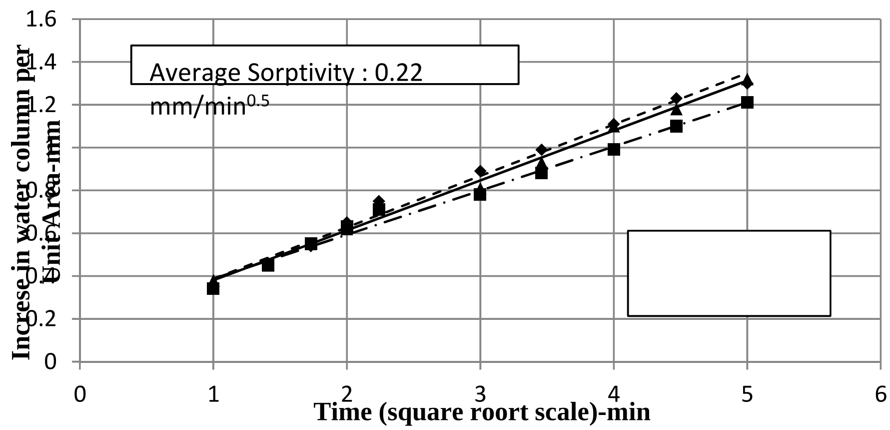


Fig 7: Increase in water column per unit area versus square root of time line for sample C´

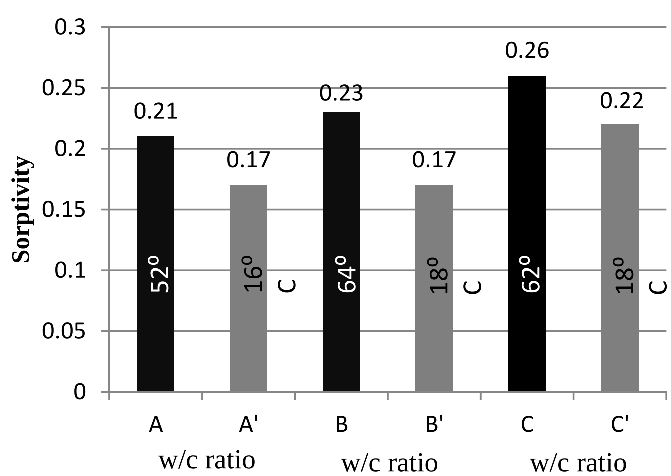


Fig 8: Variation of sorptivity of samples cast in different temperature & w/c ratios

Variation of sorptivity of different sample, which is cast in different temperature and different water-cement ratios are presented in Fig 8. Result shows that higher mixing temperature yields higher sorptivity value.

## 4. CONCLUSION

It can conclude form the result that, higher mixing temperature increase porosity of concrete and vice versa. That means high casting temperature reduces durability of concrete. [3]

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# DEVELOPMENT OF HOUSING VULNERABILITY FOR NATURAL HAZARDS BY USING GIS TECHNIQUE

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## ABSTRACT

Identifying the vulnerable areas with reference to natural hazards causing damage to the housing stock and the related infrastructure are most important for infrastructures development. In this study, four natural hazards which are the most common for damaging in Bangladesh, namely earthquake, cyclones, tornadoes and floods are considered to develop the district wise map on the basis of combination of local hazard intensity and vulnerability on observed performance by using Geographic Information System (GIS). Risk analysis as indicated in the district-wise are trying to be identified. Finally, vulnerability of housing for multi hazard has been identified and categorized.

**Key Words:** Vulnerability, natural hazard, GIS technique, risk score and hazard map

## 1. INTRODUCTION

Bangladesh is one of the most natural disaster prone areas in the World. The different types of disasters like flood, cyclonic storms, tidal surges, droughts, tornadoes, riverbank erosion, earthquake, etc. occur frequently in Bangladesh. The most devastating cyclones and floods of the world occurred in Bangladesh. The 1988 flood killed 1517 people and nearly half of the population was affected [1]. The 1970 cyclone killed almost 500,000 people [2]. About 1300 people were killed by tornado at Saturia of Manikganj district in Bangladesh in 1989 [3]. The 1897 Great Indian Earthquake with a magnitude of 8.7, which is of the strongest earthquakes in the world killed 1542 and affected almost the whole of Bangladesh [4]. Crop and livestock loss was extremely high. Major factors responsible for disasters in Bangladesh are flat topography, rapid run-off and drainage congestion, low relief of the floods plains, low river gradients, heavy monsoon rainfall, and enormous discharge of sediments, funnel shapes and shallow Bay of Bengal etc.

Cyclones and floods are the major disasters in Bangladesh. But other disasters are also creating severe damages. Drought leaves a permanent damage and encourages the desertification process that is going on in some parts of North Bengal. River erosion takes

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away thousands of hectares of land every year in a country where land is the scarcest resource of the country. Earthquakes may cause billions of Taka worth of damage. Perhaps the most disturbing but ignored fact about disasters is that they are all linked to each other. Natural calamities may be broadly grouped into major and minor types depending upon their potential to cause damage to human life and property. While natural hazards like earthquakes, droughts, floods, Tornadoes and cyclones could be regarded as major landslides, riverbank erosion, groundwater contamination, fires, tsunamis etc., whose impact is localized and intensity of the damage is much less can be categorized as minor hazards. So far as damage to housing and infrastructure is concerned, floods, cyclones, tornadoes and earthquakes turn out as the four major disasters confronting the country.

Generally, the outcome of a hazard assessment is presented on a map in which locations or zones with different levels of hazard potential are identified. Multi-hazard maps are practical tools in disaster mitigation planning, design of structures because they provide important guidance when it is not feasible to do the hazard assessment at particular sites. These maps give a good indication on the area extent of expected high risk areas for overall natural disaster. The risk score is the indicator of the severity of areas affected by overall natural disaster situation for a particular area. Intensity scales gives the damage severity of disasters. Vulnerability Atlas is a useful tool to evolve disaster mitigation and preparedness strategies in the region of natural hazard prone regions. This study aims to present the identification of multi hazard prone areas of Bangladesh as well as housing vulnerability tables for each district, indicates the level of risk to which different damage types could be subjected to during the occurrence of natural hazards in future.

## 2. HOUSING TYPE AND SITUATION IN BANGLADESH

The housing situation in Bangladesh is extremely poor. According to the 1991 housing census, the backlog in housing was 3.1 million units, composed of 2.15 million units in rural areas, and 0.95 million units in urban areas. By the year 2000, the housing shortage is likely to exceed 5 million. If we take into account the replacement needs of the rudimentary thatched houses, the target will be much more. About 90% of dwellings in rural areas and 60% in urban areas are non-durable which implies that even if they are not subjected to extreme natural hazards, they would have to be replaced. The latest data about the housing of Bangladesh is required for the study. The 2001 census report of Bangladesh did not consider the housing data. So 1991 Census report was used. The census of houses gives the following details of houses based on materials of construction for walls and roofs. The distribution of houses based on predominant materials of roof and wall over different district of Bangladesh were categorized on the basis of construction materials like as (i) Types of roof: straw, bamboo, polythene, (ii) types of wall or material of wall: tiles, C.I. or metal sheet, cement and (iii) types of floor: mud or unburned bricks, C.I. or metal sheet, wood, cement/brick, various type like mud, stone, concrete etc. From the point of view of vulnerability to the earthquake, cyclone, tornado and flood hazards, it has been seen that the type of flooring has hardly any significance, hence it is omitted in the study.

## 3. METHODOLOGY

A proper methodology is always necessary for the successful completion of a research work. It is helpful regarding the organization of the experiences, observations, examinations and analysis of found data and information and their logical interpretation in a systemic process to achieve the ultimate goal and the objectives of the research. An extensive survey of all the available and relevant literature was made to analyze the findings and recommendations from different journals, research publications and study reports related with this research topic were considered. At the same time this tool of literature survey has been used to collect secondary data and information also. Secondary data and information have been collected from the census report as well as various government, non-government and international organizations such as Bangladesh Meteorological Department (BMD), SPARRSO, Disaster Management Bureau (DMB), CDMP/UNDP and concerned non-government organizations (NGO). Flowchart for the development of GIS data, development of multi hazard map and vulnerability analysis for housing is shown in Figure 1. Individual digital hazards maps for flood, cyclone, tornado and earthquake were developed by using historical events, and housing map from census data was developed. A multi-hazard map for cyclone, flood, tornado and earthquake was developed on the basis of Eg. 4.1-4.6 by using GIS technique. Finally, housing map consist of various type of houses is superimposed onto the multi hazard map for vulnerability analysis.

### 3.1. Identify the disaster prone areas for Estimation of relative risk score

The study has been executed exploring the historical disaster events, duration and damages information, and GIS. As GIS is a powerful planning tool which has been used to identify the disaster prone area in Bangladesh, the large amount of disaster data were collected from different organizations and sources. The zoning maps prepared by different organization in different time were also used in this study. Further the disaster data and zoning maps were analyzed and comparing the data and zoning map, all the zoning maps were digitized and

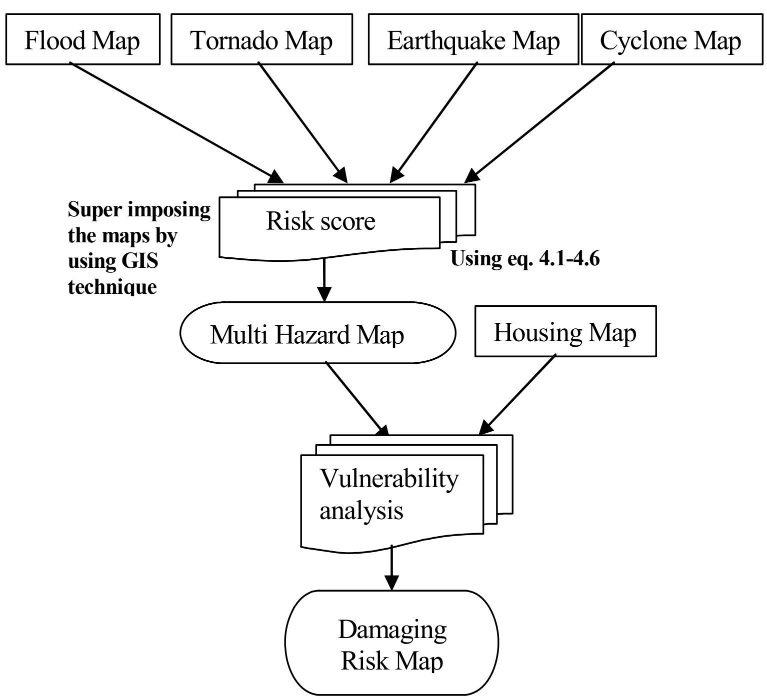


Fig. 1 Flowchart for vulnerability analysis of houses by using GIS

converted to geo-referenced maps separately and then the data were converted into GIS and finally superimposed to the base map. The location, type, year and damages etc were digitized to put the database into GIS system. The available historical data gathered from different sources for the disaster prone area of Bangladesh have been identified through GIS based analysis and finally a multi hazard map is prepared by using GIS technique.

Risk Score [for particular hazard e.g. Cyclone(c) / Flood (f)/ Tornado (t) / Earthquake (e)] = Weighting factor (WT), WT = ∫(Frequency (fr)) × Risk (R=potential damage magnitude)

$$TR\ (c/\ f/\ t/\ e) = WT = f \times R \tag{4.1}$$

<u>For Cyclone:</u>

$$TR(c)=R(c)_i \times 0.1WT(c)_j \tag{4.2}$$

$R(c)_i = \int (\boldsymbol{w}, \boldsymbol{h}, \boldsymbol{cp})$, $WT(c)_j = \int (\boldsymbol{fr})$

where i=0, 1, 2, 3, 4 ,5 and w=wind, h=storm surge, cp=central pressure

and j=1, 2, 3, 4 ,5, 6, 7, 8, 9, 10, and $\boldsymbol{fr}$ =frequency

<u>For Tornado:</u>

$$TR(c)=R(t)_i \times 0.1WT(t)_j \tag{4.3}$$

$R(t)_i = \int (\boldsymbol{w})$, $WT(t)_j = \int (\boldsymbol{fr})$

where i=0 and 5 and w=wind, and j=1, 2, 3, 4 ,5, 6, 7, 8, 9, 10 and $\boldsymbol{fr}$ =frequency

<u>For Flood:</u>

$$TR(c)=R(f)_i \times 0.1WT(f)_j \tag{4.4}$$

$R(f)_i = \int (\boldsymbol{hw})$, $WT(f)_j = \int (\boldsymbol{fr})$

where i=1, 2, 3, 4 ,5 and hw=water height, and j=1, 2, 3, 4 ,5, 6, 7, 8, 9, 10

and $\boldsymbol{fr}$ =frequency

<u>For Earthquake:</u>

$$TR(c)=R(e)_i \times 0.1WT(e)_j \tag{4.5}$$

$R(e)_i = \int (\boldsymbol{m}, \boldsymbol{p})$, $WT(e)_j = \int (\boldsymbol{fr})$

where i=2, 3, 4 and m=magnitude, p=peak ground acceleration

and j=1, 2, 3, 4 ,5, 6, 7, 8, 9, 10, and $\boldsymbol{fr}$ =frequency

<u>Total Risk Score:</u>

$$TR = \sum_{\boldsymbol{k=1}}^{\boldsymbol{n}} \mathbf{TR}_k \tag{4.6}$$

where k=1 for cyclone, k=2 for tornado, k=3 earthquake, k=4 for flood, and k=n disaster. In these equations, two of the hazards have locations with a risk score of 0 (Cyclone and Tornado). In case of Cyclone, the maximum extent of the hazard risk does not realistically include the entire county and is limited to proximity to coastal waters. Tornado may always have high risk, i.e score 5 for all the tornado prone area. For the locations with no consideration of risk for Tornado was given a score of 0. Again earthquake hazard of Bangladesh was expressed as minimum by 2 and as maximum by 4.The minimum risk score for each of the remaining hazards is 1 since there is some potential that each of these hazards could occur anywhere throughout the county. This scoring system has been used according to our district-based database. For particular district of Bangladesh the hazard for Earthquake, Tornado, Cyclone and Flood is calculated. Then adding those scores, then the total risk score for each of the 64 districts was determined. The detail methodology and risk score for 64 districts have been described in previous publication [5].

## 4. DISTRICT WISE RISK SCORES

Total Risk Scores for four individual hazards (Tornado, Earthquake, Cyclone and Flood) for each of 64 districts were estimated using the above mentioned methods. The summation of four individual hazard score were calculated by using Eq. 4.1-4.6. From the proposed risk score, a district risk-ranking map for Bangladesh was developed, which indicates the risky districts of Bangladesh for multi hazard (Cyclone, Flood, Tornado and Earthquake). The risk areas were combined and the scores were added together to create summary scores for every location in the county. These summary scores were used to develop a summary risk area map. The summary scores also provide the foundation for ranking high-risk areas in the remainder of the assessment.

## 5. PROPOSED MULTIHAZARD MAP OF BANGLADESH

By using the individual maps for different hazard (Cyclone, Flood, Tornado and Earthquake), a multi hazard zonation map for Bangladesh was developed, from which one can easily identify the hazard area with the hazardous type and intensity. This map will be easily comprehensible to everybody. This proposed a multi hazard map of Bangladesh based on a recently compiled disaster database. For this purpose initially Tornado, Earthquake, Flood and Cyclone zonation data were considered and updated. This multi hazard map can be used by policy makers to take decision for disaster management and preparedness. A multi hazard map developed for Chittagong district is shown in Figure 2.

## 6. IMPACT OF HAZARD ON HOUSING

The effects and consequences of some of the major natural hazards on housing are shown in Table 1. Normally in Bangladesh, straw, bamboo, polythene, tiles, C.I. or metal sheet and cement are used as roof materials, and mud, un-burnt brick, wood and cement, sand and bricks are used as wall materials. Therefore, the type of housing for the whole Bangladesh can be classified by collecting the data from the census report of Bangladesh according to the reference of

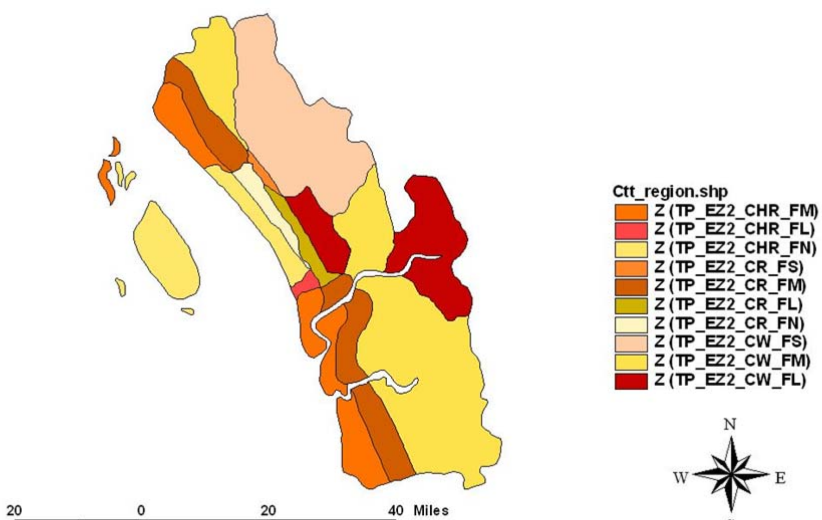


Fig. 2: Multi-hazard map for Chittagong district

Vulnerability Atlas of India (1997). The Table 2 shows the categories of housing of Bangladesh on the basis of 1991 census. Dwelling households by material of wall and material of roof of the main structure, wherein the wall and roof combinations are categorized in three types “Type A”, “Type B” and “Type X” those are shown in Table 1. The burnt brick wall and the cement concrete wall are not categorized in 1991 census.

### 6.1 Risk due to hazards on various type of houses

The risk due to hazards on various houses is based on their average performance observed during the past occurrences of damaging events. In view of numerous variations in the architectural planning, structural detailing, quality of construction and taking care in maintenance, etc. the performance of each category of houses for a given event can vary substantially from the average of observations.

### 6.2 Housing vulnerability analyses

The categories of housing after the Indian census are shown in Table 2. To correlate the various types of houses, the hazard intensities on the multi hazard map and the damage risk levels, the housing damage risk levels have been generated for the whole country. Overall risk table has been developed for each of the districts of Bangladesh. Each table provides hazard intensities, the percentage of total area of the country or district laying under the various intensities which is shown in Table 3. The table provides the maximum possible damage risk of different categories of dwelling, according to intensity scale for tornado, earthquake, cyclone and flood. Thus the concerned administrative or professional authority can visualize the extent of damage risk of existing houses to any hazard at a time.

### 6.3 Housing Vulnerability for Chittagong District

According to the Population and Housing Census, 1991, total number of households enumerated in the Chittagong district was 919,677. In Chittagong 33.18% of households

Table 1: Effects of major natural hazards on housing

| Hazard | Effects | Impact on Housing |
|---|---|---|
| **Flood** | Inundation | Damage to human settlements: walls may collapse, foundations may fail. Forces evacuation. |
| **Tropical Cyclone, Tornado, Thunderstorm** | High winds | Damages to buildings and other man-made structures: roofs blown away, collapse of walls & frames. |
| **Storm Surge** | Inundation and wave action | Collapse of walls due to inundation: foundation failure; collapse of walls and roof due to wave action |
| **Earthquake** | Tremors(ground shaking) Liquefaction Ground failure (horizontal displacement) | Damage to buildings, unreinforced brick masonry and mud-walled housing. Buildings on surface sink into soil. Damage buildings on the rupture lines |
| **River erosion** | Loss of ground support | Collapse of foundation |

Table 2: Categories of Housing of Bangladesh

| | | |
|---|---|---|
| Category | A1. | Mud wall with all roofs sloping |
| | A2. | Un-burnt Brick wall with all roofs sloping |
| Category | B1. | Burnt Brick wall with sloping roof |
| | B1. | Burnt Brick wall with flat roof |
| | B2. | Cement-Brick Wall with sloping roof |
| | B2. | Cement-Brick Wall with flat roof |
| | B3. | Wood wall with all roof sloping |
| Category | X1. | C.I/Metal Sheet with all roofs sloping |
| | X2. | Straw/Bamboo with all roofs sloping |

made of cement as the material of wall and roof and another 67.09% of the households have their wall of the main structure made of cement. The main houses in rest of the households were semipucca (half done by cement concrete), tin shed, tiles or any other combination of construction materials. The various numbers of houses with hazard intensities of total number of wall type and roof material of main house with according to census 1991 are shown in Table 3. The results for the district of Chittagong with the distribution of houses by predominant materials of roof and wall and level of damage risk are given in Table 4. Total numbers of dwelling household of Chittagong district are 854, 450. According to 1991 census among the dwelling households, 32.66% of which are of category “A” (weak type) and 16.17% of category “B” (moderate/ strong types). The risk of damage from earthquake to Category “A” houses is ‘very high’, and to Category “B” it is ‘moderate’. Chittagong lays in the zone II of Earthquake, hence the life and the property of 100% living population area is in at high seismic risk. This district is located in tornado prone area. 25% of this district is under cyclone high risk zone, 15% is under risk zone and 60% is under high wind area for cyclone. Almost the whole district is also under flood threat. 25% area of this district is under severe flooding area, 60% is under moderate flooding area, 10% of the whole district is under normal flooding and only 10% area is non-flooding.

From the Table 4, it is also visually clear that the housing of this district is how much vulnerable for the natural hazards. Hence serious attention has to be paid to the district from earthquake, tornado, cyclone and flood disaster prevention, and mitigation and preparedness points of view. The whole scenario of vulnerability of housing for different disaster of any particular district of Bangladesh can be identified with this similar type of Table 4.

### 6.4 Use of Housing Vulnerability Table

The table provides some ready information for use of the authorities involved in the task of disaster mitigation, preparedness and preventive actions. At a glance at the hazard maps will bring to the notice of the district authorities, the location and percent areas of the districts most susceptible to hazard occurrence, the probable maximum hazard intensities, the type of housing and its vulnerability and risk to the hazards. It must be realized that most of the human problems arise due to loss of the houses; deaths mostly occur in collapsed houses; rescue, evacuation, relief and rehabilitation become more acute when houses get lost.

Knowing the extent problem of future disasters with the vulnerability atlas, the administrative authority can formulate the development plans for: (i)Preventive actions like hazard resistant construction, retrofitting and upgrading of existing buildings, (ii) Mitigation the intensity and extent of the disaster, (iii) Warning system installation drills for its use, (iv) Training of manpower in various tasks in the emergency and (v) Implementation of land zoning regulations in flood plains and coastal and building byelaws with disaster resistant features in various towns and cities, etc.

The authorities can create the necessary awareness leading to self help. The hazard zoning can be improved at local levels by specific studies carried out in the district particularly for minimizing the flood havoc by measures such as suitable vulnerability analysis, hazard reduction measures, and risk mapping, and improved resistance of buildings wherein the local technical institutions and professionals could also be involved.

## 7. CONCLUSIONS

The prime objective of this study was to identify of vulnerable areas with reference to natural hazards causing damage to the housing stock for earthquakes, cyclones, tornadoes and floods. As a basic requirement in this regard a complete database of those natural hazards of Bangladesh was prepared. The collected damage data, damage scenario and models were used to develop intensity scales for earthquake, flood, cyclone and tornado for Bangladesh. The housing types of Bangladesh were categorized based on the basis of data collected from Bureau of Statistics. The housing vulnerability table for each district was based on risk of damage for different housing types prepared (results for Chittagong district is only shown in this study). At a glance the tables will show the percent areas of the district most susceptible to earthquake, cyclone, tornado and flood hazards for different housing categories. The result can be used for the development of the most vulnerable and susceptible areas on the priority basis. This information will also be helpful to establish the need of developing housing designs to resist the combination of such hazards.

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Table 3: Damage risk to housing under various hazard intensities

| Category | Type of Wall and Roof | Tornado Intensity | | | | | Earthquake Intensity | | | | | Cyclone Intensity | | | | | Flood Intensity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **F6-F5** | **F4** | **F2 –F3** | **F1** | **F0** | **≥IX** | **VIII** | **VII** | **VI** | **≤V** | **Category 5** | **Category 4** | **Category 3** | **Category 2** | **Category 1** | **>3m above D.L** | **<3m above 50cm D.L** | **Upto 50cm Above D.L** | **Within 50cm D.L** | **Below 50 cm D.L** |
| **A1** | Mud wall with all roofs sloping. | | | | **VH** | **H** | | | **VH** | **H** | **M** | | | | **VH** | **H** | **VH** | **H** | **M** | **L** | **VL** |
| **A2** | Unburnt Brick wall with all roofs sloping. | | | | **VH** | **H** | | | **VH** | **H** | **M** | | | | **VH** | **H** | **VH** | **H** | **M** | **L** | **VL** |
| **B1.(a)** | Burnt Brick wall with sloping roof | | | **VH** | **H** | **M** | | **VH** | **H** | **M** | **L** | | | **VH** | **H** | **M** | **M** | **L** | **VL** | | |
| **B1.(b)** | Burnt Brick wall with flat roof | | | **VH** | **H** | **M** | | **VH** | **H** | **M** | **L** | | | **VH** | **H** | **M** | **M** | **L** | **VL** | | |
| **B2.(a)** | Cement-Brick Wall with sloping roof | | **VH** | **H** | **M** | **L** | **VH** | **H** | **M** | **L** | **VL** | | **VH** | **H** | **M** | **L** | **L** | **VL** | | | |
| **B2.(b)** | Cement-Brick Wall with flat roof | **VH** | **H** | **M** | **L** | **VL** | **VH** | **H** | **M** | **L** | **VL** | **VH** | **H** | **M** | **L** | **VL** | **L** | **VL** | | | |
| **B3** | Wood wall with all roof sloping | | | **VH** | **H** | **M** | **VH** | **H** | **M** | **L** | **VL** | | | **VH** | **H** | **M** | **H** | **M** | **L** | **VL** | |
| **X1** | C.I/Metal Sheet with all roofs sloping. | | | | **VH** | **H** | **VH** | **H** | **M** | **L** | **VL** | | | **VH** | **H** | **M** | **H** | **M** | **L** | **VL** | |
| **X2** | Straw/Bamboo with all roofs sloping | | | | **VH** | **H** | **VH** | **H** | **M** | **L** | **VL** | | | **VH** | **H** | **M** | **VH** | **H** | **M** | **L** | **VL** |

Table 4: Distribution of houses by predominant materials of roof and wall and level of damage risk (Chittagong district)

| Wall and roof combination | | Census Houses | | Level of Risk Under | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of Houses | % | Tornado | | | | Earthquake | | | | Cyclone | | | | Flood | | | |
| | | | | ST | MT | TP | N | VI | VII | VIII | N | HRA | RA | HWA | N | SFA | MFA | NFA | N |
| | | | | Area in % | | | | Area in % | | | | Area in % | | | | Area in % | | | |
| | | | | | | 100 % | | | 100 % | | | 25 % | 15 % | 60 % | 0 % | 25 % | 55 % | 10% | 10 % |
| **CATEGORY-A**<br>A. Mud/ Un-burnt Brick wall with all roofs sloping | Urban | 63336 | | | | VH | | | VH | | | VH | H | M | | VH | VH | VH | VH |
| | Rural | 215749 | | | | | | | | | | | | | | | | | |
| | Total | 279085 | | | | | | | | | | | | | | | | | |
| **Total** | | **279085** | **32.66** | | | | | | | | | | | | | | | | |
| **CATEGORY-B**<br>B2. (a) Cement-Brick wall with sloping roof | Urban | 34745 | | | | M | | | M | | | M | L | VL | | M | M | M | M |
| | Rural | 8974 | | | | | | | | | | | | | | | | | |
| | Total | 43719 | | | | | | | | | | | | | | | | | |
| B2. (b) Cement-Brick wall with flat roof | Urban | 77355 | | | | L | | | M | | | L | VL | | | L | L | L | L |
| | Rural | 11762 | | | | | | | | | | | | | | | | | |
| | Total | 89117 | | | | | | | | | | | | | | | | | |
| B3. Wood wall with all roof sloping | Urban | 2626 | | | | H | | | M | | | H | M | L | | M | M | M | M |
| | Rural | 2692 | | | | | | | | | | | | | | | | | |
| | Total | 5318 | | | | | | | | | | | | | | | | | |
| **Total** | | **138154** | **16.17** | | | | | | | | | | | | | | | | |
| **CATEGORY-X**<br>X1. C.I/Metal Sheet wall with all roofs sloping | Urban | 7846 | | | | VH | | | M | | | H | M | L | | M | M | M | M |
| | Rural | 15614 | | | | | | | | | | | | | | | | | |
| | Total | 23460 | | | | | | | | | | | | | | | | | |
| X2. Straw/Bamboo wall with all roofs sloping | Urban | 183973 | | | | VH | | | M | | | H | M | L | | H | H | H | H |
| | Rural | 229778 | | | | | | | | | | | | | | | | | |
| | Total | 413751 | | | | | | | | | | | | | | | | | |
| **Total** | | **437211** | **51.17** | | | | | | | | | | | | | | | | |

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# CHANGES OBSERVED IN THE HISTORICAL TREND OF LOCAL RAINFALL AS A CLIMATIC FACTOR AND ITS EFFECT ON THE STREAMFLOW OF THE TURAG AND BURIGANGA RIVER SYSTEM

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## ABSTRACT

A study was conducted to investigate the impact of climate change on the stream flow of Turag and Buriganga river system as these are the major flowing rivers near Dhaka city. Changes in rainfall pattern are studied as the only climatic factor affecting the streamflow parameters (water level and discharge). The study includes graphical analysis of average daily rainfall; average daily water level and average daily discharge data (of selected stations of the river system) of a particular month against historical time span (1960 to 2008). Correlation of rainfall vs. water level and rainfall vs. discharge analysis were developed in the study.

**Key Words:** Climate Change, Turag and Buriganga river system, Dhaka city, Changes in Rainfall Pattern, Historical Trend, Streamflow pattern, Water level and Discharge

## 1. INTRODUCTION

Buriganga and Turag were previously called the "Lifeline of Dhaka" and now they are the "dying rivers"(Khan 2009). Due to uncontrolled waste dumping by numerous industries that were established by the side of the rivers, the rivers now suffer serious water pollution. The pollution increases during the winter as then the water level and discharge are very less due to low upstream flow and almost no rainfall. Recent studies from most of the international and nationally acclaimed environmental organizations (IPCC, 2007) suggest that the hydrological condition of the rivers around the world will worsen in recent future if the trend of climatic change continues. The rise and fall of rainfall pattern, extreme unseasonal rainfall, high upstream flow due to glacier melt will cause serious changes in the river systems aided by human interventions in the river flow like bank encroachment or waste dumping. Large number of small and marginal changes in climate parameters at local or regional level has global impact while global trends also lead to local effects. Hence a study is made on these two local rivers which are two vital rivers for Dhaka city and the study focuses primly on how climate change, namely the changes in rainfall pattern is effecting their flow.

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## DATA AND METHODOLOGY

### 2.1.Collected Data

The Turag-Buriganga river system begins from Kaliyakoir, the upstream point of Turag. It then extends towards more downstream to Mirpur. After a while, Turag meets Buriganga and travels more downward to Mill Barrack and further downstream to Hariharpara where the river system meets the Dhaleshwari river. The rivers are hydraulically connected with Balu, Lakhya, Kaliganga, Karnatali, Tongi Khal and Dhaleshwari (Rahman and Rana,1996). Kaliyakoir representing Turag and Mill Barrack representing Buriganga are the water level and discharge stations from where water level and discharge data are collected. Rainfall stations are of areas near the river system which act as catchment areas for the collection of runoff that add to the river system’s streamflow. Hence for analysis of water level and discharge data of station Kaliyakoir and Mill Barrack, rainfall data from nearest rainfall stations Mirzapur and Dhaka (respectively) are used.
Rainfall and water level data of selected stations of the river system were collected for 1960-2008, where discharge data was found from 1991-2009 (Kaliykaoir) and from 2005-2009 (Mill Barrack). All the discharge and water level data are gauged by BWDB and the rainfall data are point rainfall data also gauged by BWDB.

### 2.2 Methodology

The collected data of different years for each of the stations are on a daily basis. For each month these daily data were averaged to one single daily average data. The method of averaging the 30 days daily data into one daily average for a specific month is similar to arithmetic mean method (Subramanya 2009). So each year of each station and parameter produced 12 daily average data for 12 months. Daily average data of a specific parameter (water level, discharge or rainfall) for the same month of different years were plotted against time-history span to visualize its trend. The trend was found by adopting graphical analysis of least square approach, which gives a linear trendline showing whether the parameter under consideration, has a decreasing or increasing trend over the years for a specific month.

## 3. ANALYSIS AND RESULT

From all of the graphical analysis done for each individual month for different stations, some specific observations were made.

### 3.1 Analysis of Rainfall

Mirzapur is the upstream rainfall station of the river system near Kaliyakoir (Turag). Dhaka is the downstream rainfall station near Mill Barrack (Buriganga). Table 1 demonstrates increase of rainfall by a plus (+) sign and decrease is denoted by a minus (-) sign. If there is no significant change then no sign is used. In Bangladesh, MAM (March-April-May) is considered pre-monsoon, JJAS (June-July-August-September) and early October as monsoon, ON (late October-November) as post monsoon and DJF (December-January-February) as winter season. In figure 1 and 2 some of the rainfall analysis are shown.

Table 1: Increase or Decrease of rainfall in different months for the specific stations for the time span 1960-2008

| Station | March | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|---|
| **Mirzapur** | | + | - | - | | - | + | + |
| **Dhaka** | + | | - | | | | + | + |

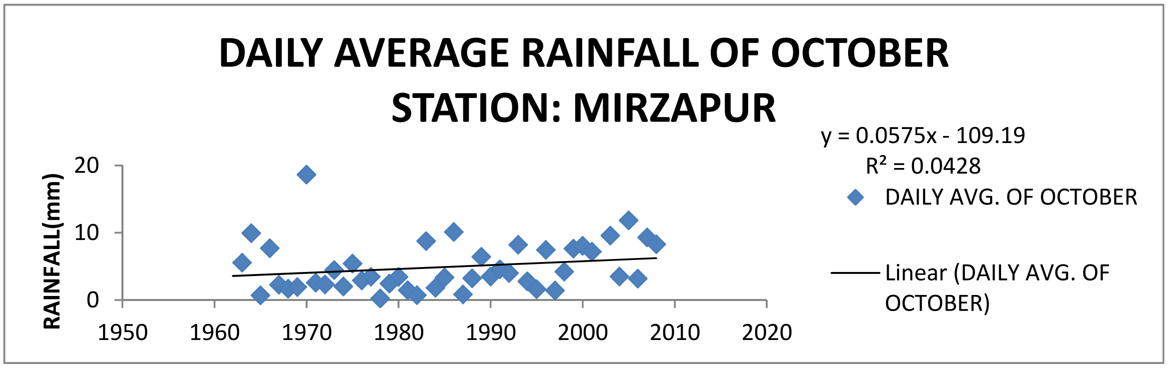


Figure 1: A graph of the rainfall station Mirzapur, October showing its trend line from year 1960-2008

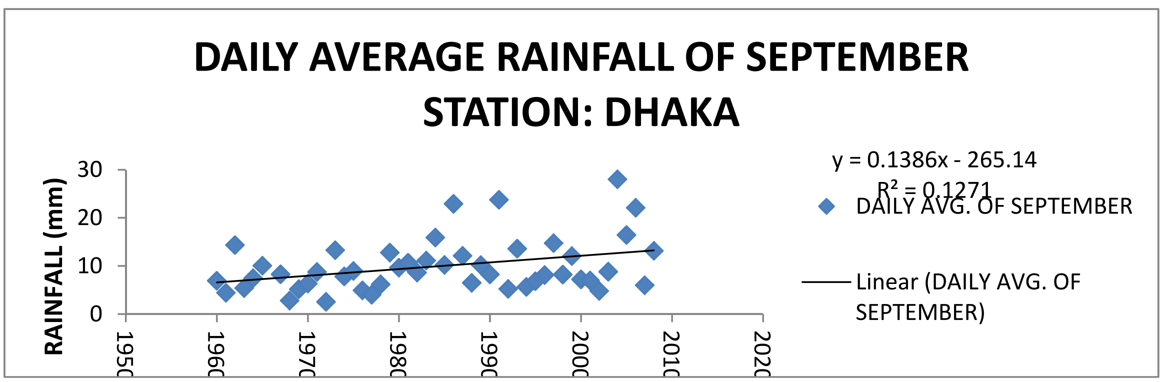


Figure 2: A graph of the rainfall station Dhaka, September showing its trend line from year 1960-2008

### 3.2 Analysis of Water Level

Table 2 demonstrates increase of water level by a plus (+) sign and decrease is denoted by a minus (-) sign. Some sample graphical analyses of water level are shown in figure 3 and 4.

Table 2: Increase or Decrease of water level in different months for the specific stations for the time span 1960-2008

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaliyakoir** | - | - | - | - | - | - | - | - | - | - | - | - |
| **Mill Barrak** | | | | | | + | + | - | - | - | - | - |

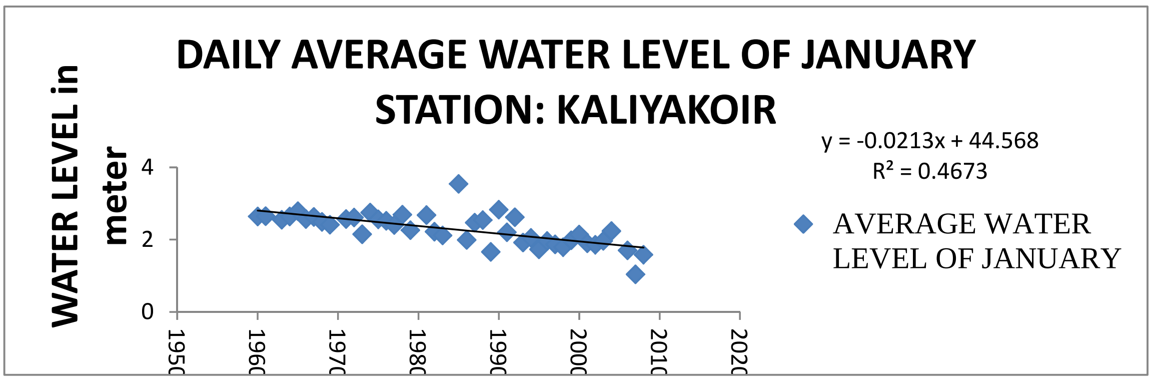


Figure 3: A graph of the water level station Kaliyakoir, January showing its trendline from year 1960-2008

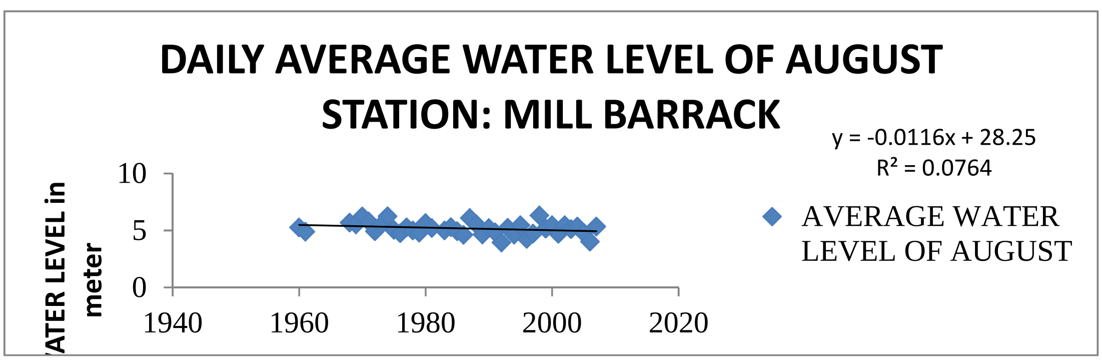


Figure 4: A graph of the water level station Mill Barrack, August showing its trendline from year 1960-2008

### 3.3 Analysis of Discharge

Table 3 demonstrates increase of discharge by a plus (+) sign and decrease is denoted by a minus (-) sign. A sample graphical analysis of discharge is shown in figure 5.

Table 3: Increase or Decrease of discharge in different months for Kaliyakoir for the time span 1991-2009

| Station | January | February | March | April | May | June |
|---|---|---|---|---|---|---|
| Kaliyakoir | + | + | + | + | + | - |
| **Station** | **July** | **August** | **September** | **October** | **November** | **December** |
| Kaliyakoir | + | + | + | + | + | - |

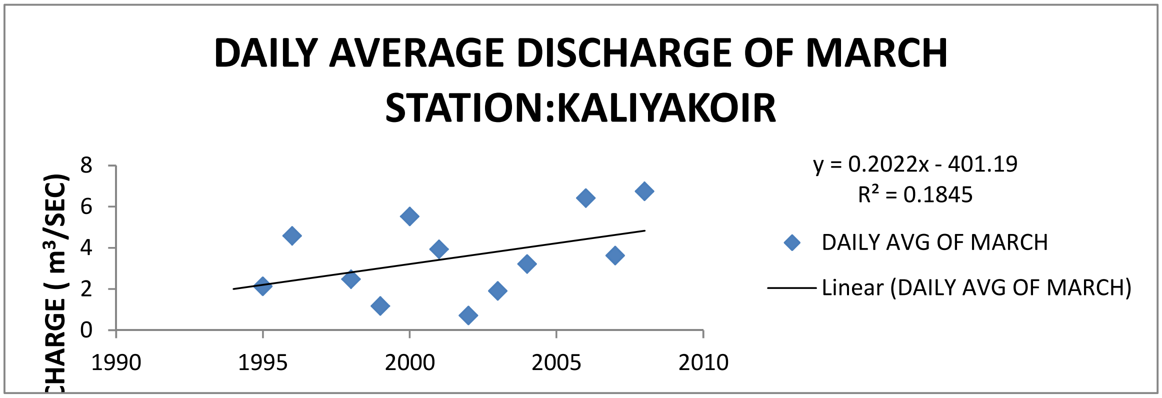


Figure 5: a graph of discharge station Kaliyakoir, March showing its trendline from year 1995-2009

### 3.4 Relation between Rainfall and Streamflow Parameters

In table 4 increase in water level along with increase in rainfall is denoted by (+) sign and decrease in water level along with increase in rainfall is denoted by (–) sign. A sample graphical analysis is shown in figure 6.

Table 5: Relationship of Rainfall and Water Level in historical time span

| Station | March | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|---|
| Mirzapur-Kaliyakoir | + | + | + | + | + | + | - | + |
| Dhaka-Mill Barrack | + | + | - | - | - | - | - | - |

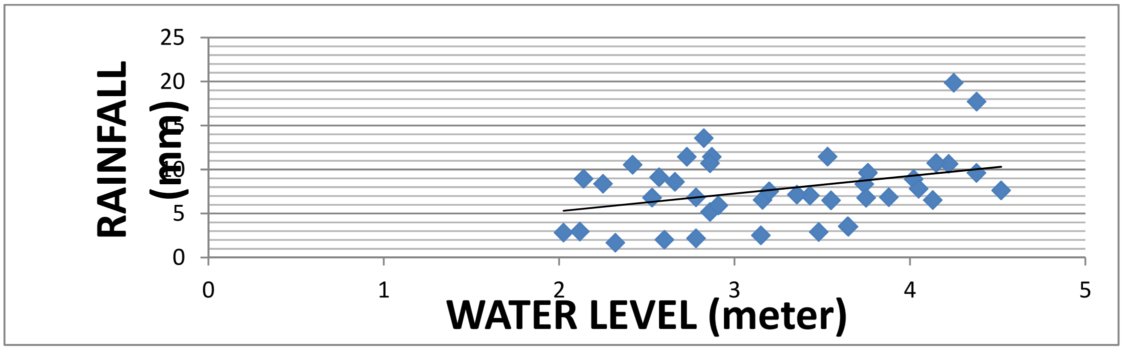


Figure 6: Inter-Relationship Of The Average (Daily) Rainfall And Average (Daily) Water Level Of Month May In Historical Timespan At Station Kaliakoir Of Turag

In table 5 increase in discharge along with increase in rainfall is denoted by (+) sign and decrease in discharge along with increase in rainfall is denoted by (–) sign. A sample graphical analysis is shown in figure 7.

Table 5: Relationship of Rainfall and Discharge in historical time span

| **Station** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** |
|---|---|---|---|---|---|---|---|---|
| **Kaliyakoir** | + | + | - | + | + | - | + | + |

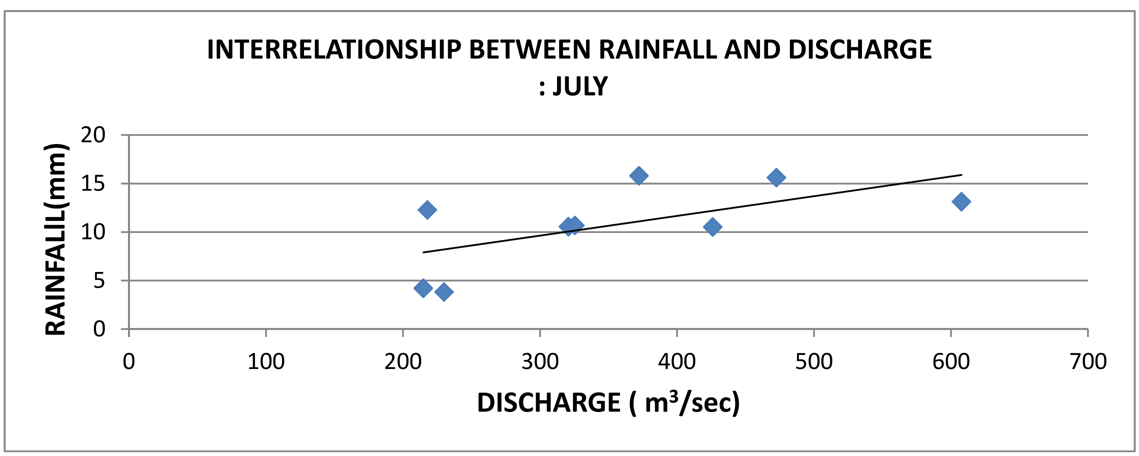


Figure 7: Inter-Relationship Of The Average (Daily) Rainfall And Average (Daily) Discharge Of Month July In Historical Timespan At Station Kaliakoir Of Turag

### 3.5 Discussion of Result

From the analysis it is found that rainfall has an increasing trend in pre-monsoon (Mar-Apr), late monsoon (September) and in post monsoon (October) both in the upstream and the downstream of the river. Early monsoon (May) and Monsoon season (Jun-Jul-Aug) is observing a slow and steady decrease in rainfall in the areas near the river system.

Water level data analysis demonstrated decrease of water level of the river system along the time span (1960-2008). Only in downstream Mill Barrack an increase is observed in June-July.

From analysis of discharge data we found an increase in discharge in upstream of the river system except for month June and December (for a time span of 1991-2009). Discharge data was not available for the downstream station Mill Barrack for a suitably long time span, hence no analysis was done.

From all these observations it appears that rainfall is increasing in pre monsoon and post monsoon season, but has a decreasing trend in monsoon season in the stations near the river system. These changes in rainfall pattern aided by other natural or human intervened parameters are affecting the water level and discharge of the river system. It is observed that water level has mainly a decreasing pattern and discharge data is not sufficient to draw any decision. Rainfall vs. water level and rainfall vs. discharge graphs show that they have positive relationship showing an increase in rainfall increases water level and discharge. This is not true in case of Downstream (Mill Barrack) as downstream Buriganga faces serious pollution and bank encroachment which might deteriorate streamflow capacity, causing a decrease in water level or discharge no matter how the rainfall changes. Bangladesh is naturally vulnerable due to the quantity and poor quality of water that flows into it from the upstream as all major rivers flowing through Bangladesh originate outside its borders ( Babel and Wahid, 2008). Thus, any interventions in the upper riparian regions can have significant impacts on Bangladesh. Hence we would recommend further research including other parameters like upstreamflow, bank encroachment etc. which could not be studied due to time constraints. But this study has a certain finding that reflects changes in precipitation pattern in a local level are occurring and changes in the streamflow parameter have also started. This study also suggests that rainfall has a significant impact on streamflow.

## 4. CONCLUSION

This study finds that changes in precipitation pattern in a local level, that is, in a small extent of a hydraulically connected river system of a deltaic country Bangladesh (Turag-Buriganga) is occurring. The study also finds that changes in the streamflow parameter of the river system have also started. To be more specific, rainfall has an increasing tendency in the pre-monsoon and post-monsoon whereas monsoon season has a decreasing trend of rainfall in areas near the river system. The river system has a decreasing water level trend over the year. This study also reveals that rainfall has a significant impact on streamflow as positive correlation between rainfall and water level and discharge is observed. But it must be kept in mind that rainfall is not the only driving parameter in the changes occurring in the streamflow of the river system.

## 5. ACKNOWLEDGEMENT

We sincerely express our thanks to BWDB (Bangladesh Water Development Board) for providing the necessary data to conduct the research work. Support from MIST (Military Institute of Science and Technology) and Prof. Dr. M. Monowar Hossain, BUET, is also greatly acknowledged.

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# SALINIZATION OF INLAND WATER SYSTEM OF COASTAL AREAS OF BANGLADESH DUE TO CLIMATE CHANGE

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## ABSTRACT

Global climate change, the major concerns of recent times is accentuating the salinization process. In this study salinization of the coastal areas of Bangladesh corresponding to climate change has been assessed using secondary data. The present situation of salinity of surface water in southern part of coastal zone of Bangladesh has been analyzed for selected stations. Based on this primary analysis, stations with significant salinity trend were identified & historical surface water salinity concentrations of these stations were analyzed. Rainfall regarded as a climatic factor has been analyzed through historical data of those stations. The analysis of rainfall for specific season & month shows a more reliable approach to identify change in climatic factor pattern. For every station, rainfall of August to December, May to July & all monthly rainfall are analyzed to observe change of patterns. Analysis of rainfall provides only a possible positive indication of change and a comparison between rainfall and present salinity condition has been represented

**Key Words:** Climate Change; Salinity Intrusion; Rainfall; Coastal Zone;

## 1. INTRODUCTION

Bangladesh is one of the most vulnerable countries facing the adverse impacts of climate change. This is due to its unique geographic location, dominance of floodplains and low low-lying topography, high population density, high levels of poverty, and overwhelming dependence on natural resources and services, many of which is climate sensitive. The coastal zone consists of 19 districts and 147 upazilla with a total area of 47,201 km$^2$, which is about 31% of the total area of Bangladesh, 147,570 km$^2$. Among the adverse impacts of climate change, water resource related impacts will likely be the most critical for Bangladesh, including coastal and river flooding, droughts and salinity intrusion in coastal zone.. Salinity in both soil and water is a major concern for the coastal zone of Bangladesh. Intrusion of salinity towards interior coast will cause direct impact on fresh water source and food production. The possible factors which can lead to increase in salinity intrusion are decrease of fresh water flow during the dry season, or due to penetration of tide into the river system. Intrusion may also be aggravated by upstream withdrawal of water or by climate change impacts like a decrease in dry season rainfall and sea level rise.

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## 2. DATA AND METHODOLOGY

In this study, salinization of coastal zone of Bangladesh is assessed using surface water salinity data. Present and historical salinity concentration data are analyzed to examine the change of pattern of salinization and rainfall is considered as the climatic factor related to salinity.

### 2.1. Present surface water salinity concentration

Salinity concentration data of surface water of selected stations (as illustrated in Fig 1) from Institute of Water Modelling for the year 2009 was analyzed to analyze the recent salinization pattern in coastal zone of Bangladesh. The dataset contains salinity concentration level in parts per thousands (*ppt*). Based on this preliminary analysis, stations with significant salinization trend were identified.

### 2.2. Historical salinity concentration data

Available historical surface water salinity data of stations with significant salinization trend were analyzed to review the change of pattern in salinization trend. Historical salinity dataset were collected from Bangladesh Water Development Board.

### 2.3. Rainfall analysis

Rainfall is considered as climatic factor related to salinization in this study, and the analysis of historical rainfall data was performed to address climate change. The rainfall data were collected from Bangladesh Meteorological Department (BMD). The dataset contains daily rainfall data for the year 2008, 2009 and historical monthly rainfall data of all available years ranging from 1949 and onwards in millimeter. The location of the raingauge stations are illustrated in Fig 2.

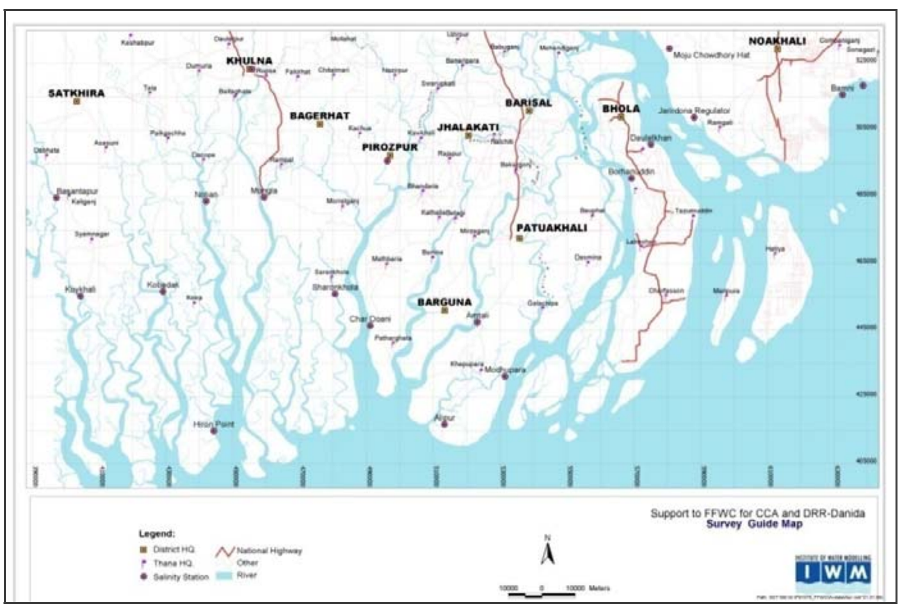


Fig 1: Location of salinity stations in coastal zone of Bangladesh

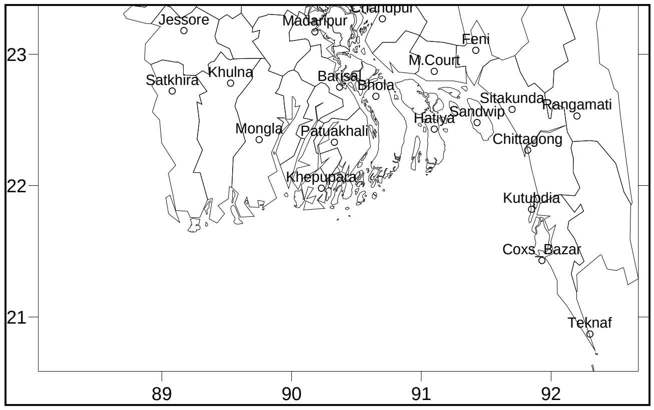


Fig 2: Location of BMD rain gauges in coastal zone of Bangladesh

## 3. ANALYSIS AND RESULT

### 3.1. Analysis of present situation of salinity

Total twenty (20) coastal station's surface water salinity data for the year 2009 was analyzed. For each station, measured salinity concentration in ppt was plotted against time to interpret the correlation between time and salinity level. Figure 3 shows the salinity against time plot for Khulna station. For this station, a linear trend lines is plotted for the whole data set. The value of coefficient of determination, $R^2$ is 0.968 which is nearly 1. The sharp uprising trend of the curve and the value of coefficient of determination suggest that Khulna has a significant impact on salinization trend. Based on this preliminary analysis, further historical salinity data is analyzed with rainfall. The same method is followed for the rest of the stations and stations with significant salinity trends are identified. However, the dataset of all the stations were collected during the dry period of the year (January-May) and there was obvious less freshwater flow to counterbalance the salinity. The summary of salinity level of all the station is presented in Fig 4.

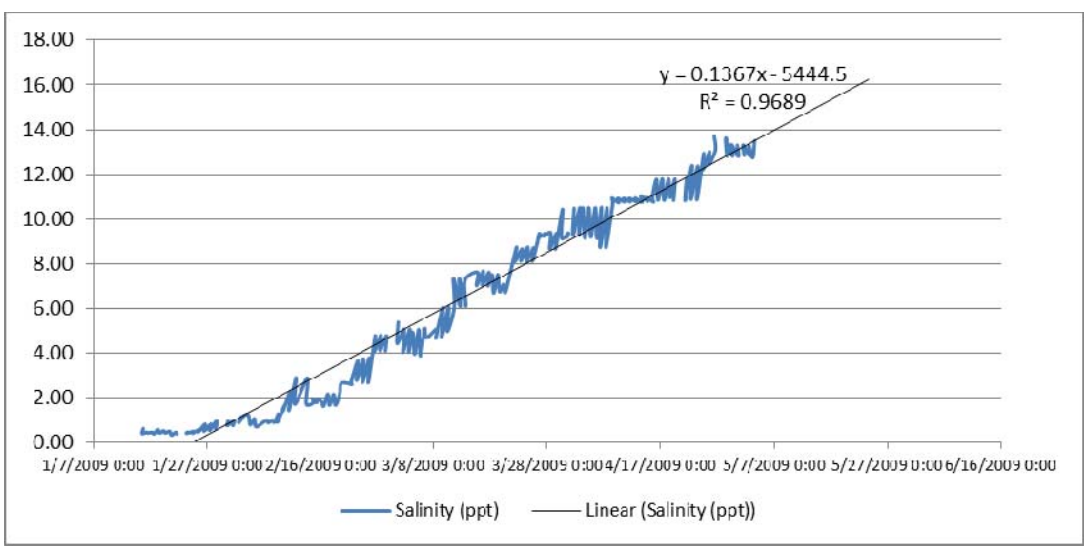


Fig 3: Salinity concentration VS time: Khulna station (2009)

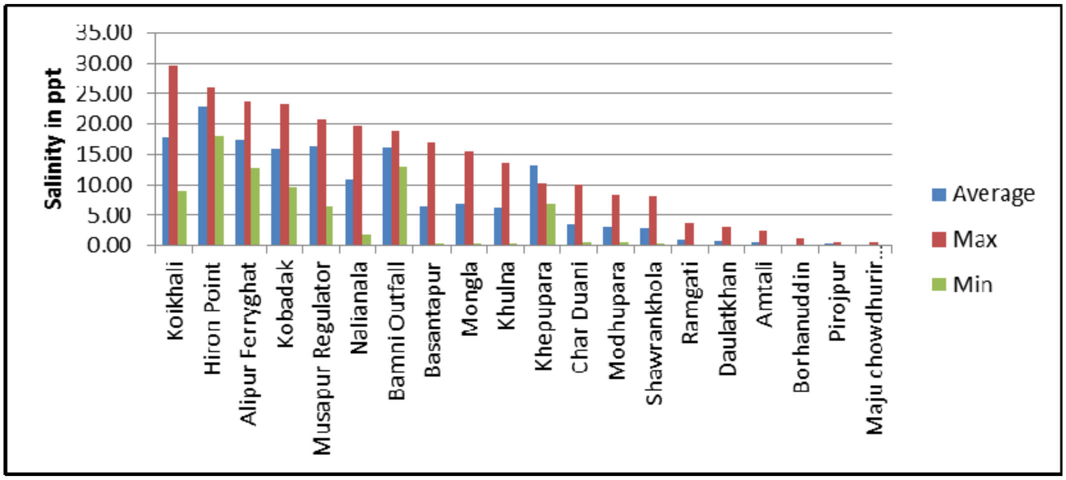


Fig 4: Summary of Salinity in ppt of all stations (2009)

### 3.2. Comparison of rainfall and present salinity

In order to analyze rainfall as a climatic factor and find the relation between salinity and rainfall, the salinity dataset of IWM (2009) with rainfall data of Bangladesh Meteorological Department is analyzed together. The two dataset has complete different pattern in time variation series, so to compare them, an average value of the parameter with same time variation is calculated. The comparison of salinity and rainfall for Khepupara station is presented in Fig 5. In Fig 5, the salinity curve from average salinity value shows a fluctuated pattern. The two rainfall event caused the salinity level to decrease significantly as there was more freshwater to counterbalance the saline water. The main problem of analyzing rainfall with salinity is that the location of raingauge station of BMD and the location of salinity station are not same. So while considering the salinity station, the nearest possible raingauge station's data was taken into account. Also, due to the difference in time variation interval for the salinity and rainfall, the stations having less or no rainfall didn't show any significant pattern of change in salinity level with rainfall.

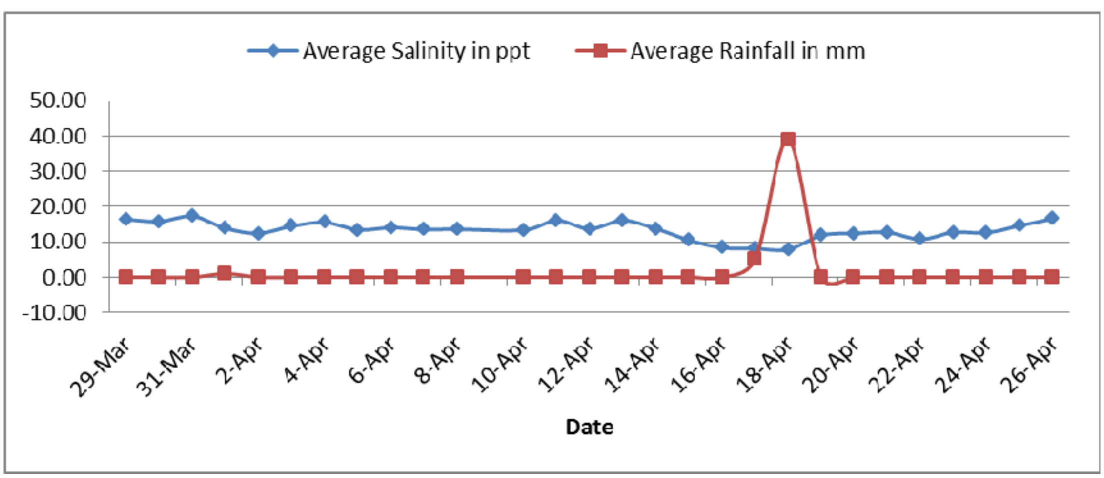


Fig 5: Comparison of Salinity and Rainfall of Khepupara (March -April 2009)

### 3.3. Analysis of Historical Salinity Data

In this study, historical salinity data was collected from Bangladesh Water Development Board and dataset of Kalapara, Narail, Gopalganj, Khulna, Barisal, Bagerhat and Barguna were analyzed. These stations were chosen based on the preliminary analysis from dataset of IWM. The main limitation in this analysis was the historical data set lacks in a complete range of data. There were too many blank/missing points. Only Khulna station has a data of a period of 32 years (1975-2007), and Gopalganj has a dataset of 15 years (1993-2008) with less missing/blank points. The trend of salinity concentration for Khulna for 1975-1979, 1980-1989, 1998-2000 and 2001-2007 are shown in Fig 6(a), 6(b), 6(c), 6(d) respectively. From the analysis, the seasonal change of salinity is clear in Fig 6(b), in particular year salinity increases in dry season and decreases in wet seasons due to freshwater counterbalance. Also, the yearly peak value of salinity has an increasing trend for 1980-1989 and 2001-2007. Fig 6(d) suggests that in recent years salinity concentration has increased significantly. However, for the period of 1998-2000, there is a non-uniform pattern of salinity with a sudden peak value of 251000. Since the data was collected from secondary source, in this study this point is taken as an erroneous point and the salinization process of Khulna is considered for the other three data set and the data set of 1998-2000 is discarded. The analysis of Bagerhat and Gopalganj station also shows an increasing trend of salinity, with clear increase in seasonal salinity band.

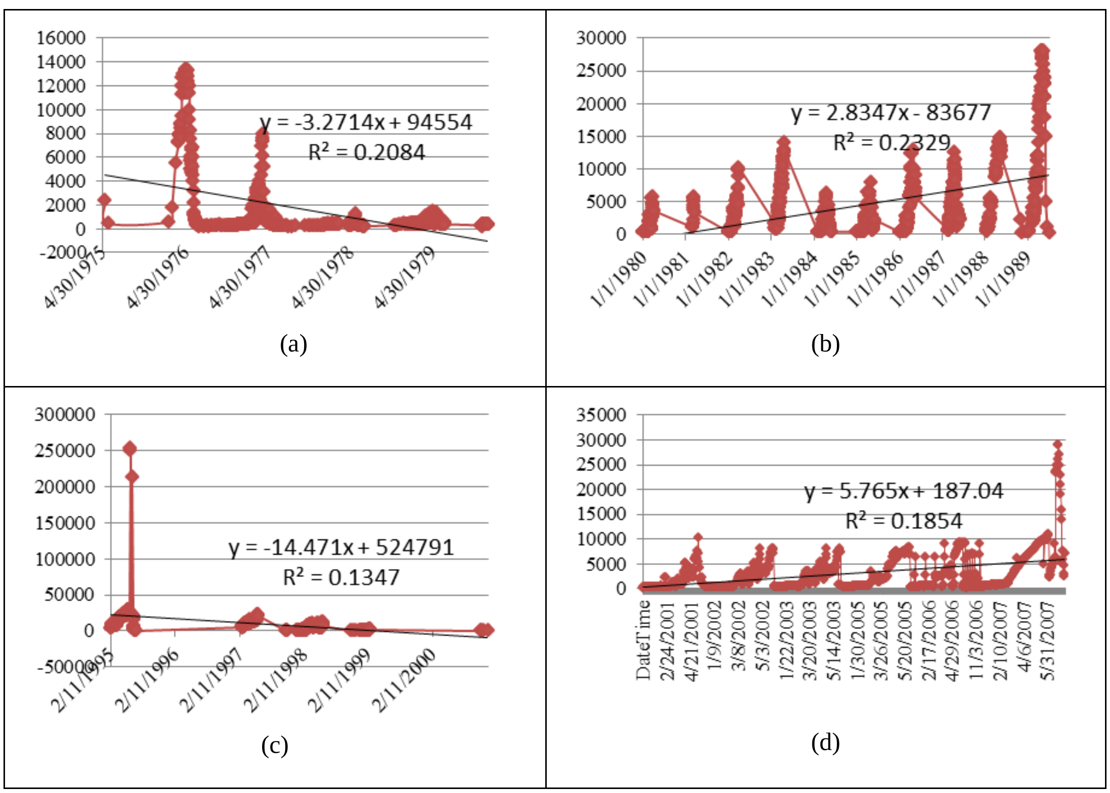


Fig 6: Trends of historical Salinity concentration for Khulna station (ConductivityHWmmohs) for the period of (a) 1975-1979 (b) 1980-1989 (c) 1998-2000 (d) 2001-2007

### 3.4 Analysis of historical rainfall

In this study, rainfall is considered as the climatic factor related to salinity concentration and historical data were analyzed to find the change of pattern of rainfall indicating possible evidence of climate change. The rainfall data used in this study were collected from Bangladesh Meteorological Department. Data of Mongla, Khulna, Potuakhali, Khepupara, Satkhira and Barisal were analyzed. For each station, monthly rainfall of May to July, December to August for each individual year was plotted as illustrated in Fig 7(a) and 7(b). Also, all monthly rainfall and total annual rainfall was also plotted. From the analysis, the change in total annual rainfall for each station does not provide a clear evidence of any significant change. But the pattern in seasonal band of May to July, and December to August indicates a more reliable evidence of possible change of patterns. Satkhira, Khepupara and Khulna station shows an erratic rainfall pattern, and the erratic rainfall pattern is taken as a positive evidence of possible change in climate.

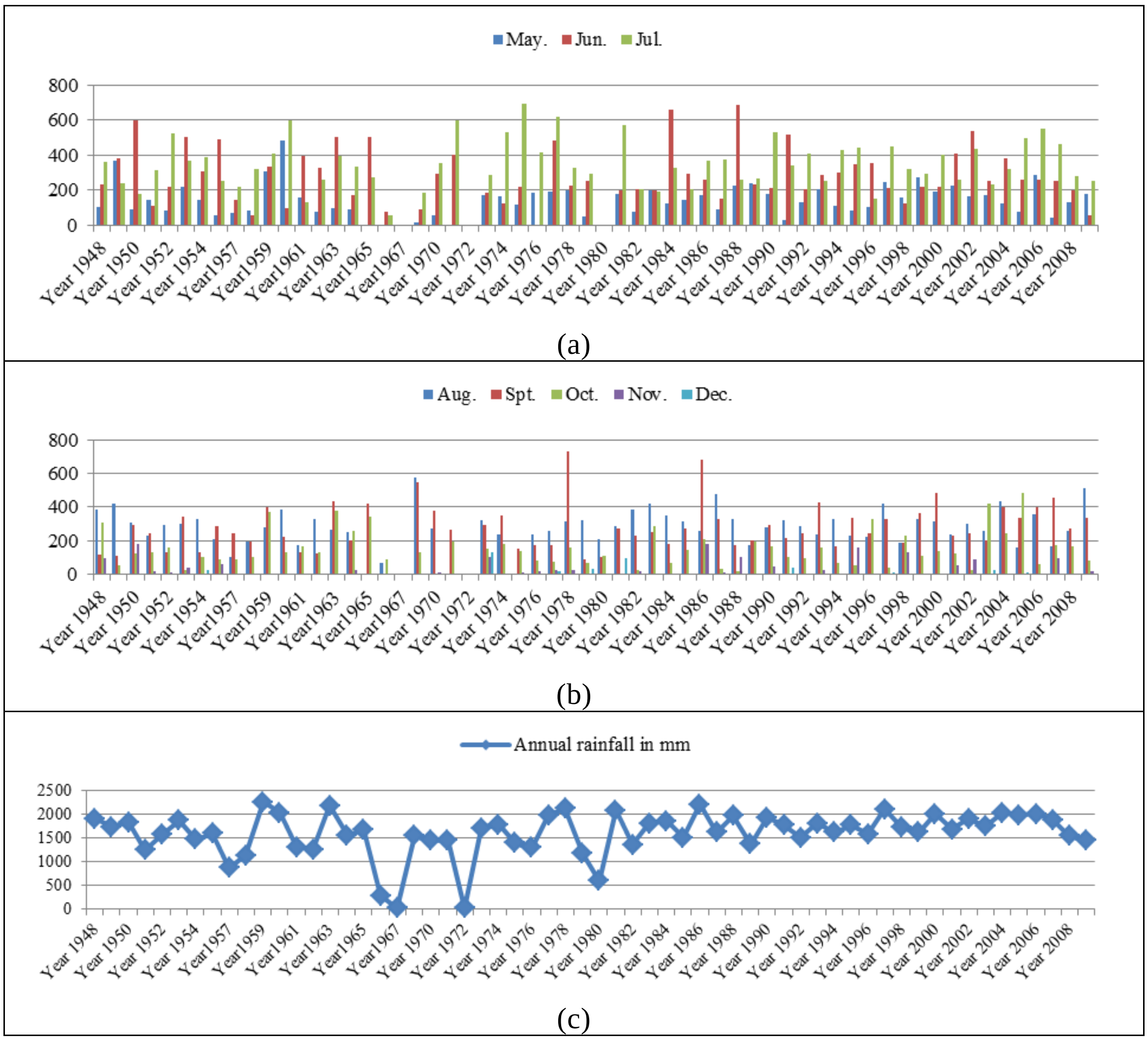


Fig 7: Historical rainfall of Satkhira station in millimeter from 1948-2008 (a) for May to July (b) for August to December (c) Total Annual rainfall

## 4. CONCLUSIONS

From this study, it is evident that increase of salinity level in surface water is gradually becoming more significant. The present situation analysis and available historical data indicates that the salinization trend is sharp in interior coastal zone. The exterior coast has a more high level of salinity and the trend is fluctuating. The study also suggests that the salinity is gradually intruding more towards inland and rainfall has a clear and significant relationship with salinity as a climatic factor. Historical rainfall analysis gives evidence that over the period rainfall pattern has changed both in magnitude and distribution, providing a possible evidence of climate change which influences salinity. In this study, only selected portion of the coastal region were analyzed based on available data. The coastal region of Bangladesh has a very complex hydro-geological nature and to understand the scenario of the entire coastal zone requires all hydrological system and climatic parameters to be taken into account.

## 5. ACKNOWLEDGEMENT

The authors would like to thank Brig. Gen. Md Gazi Ferooz Rahman, Dean of the Civil Engineering Department of MIST, Institute of Water Modelling (IWM), Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDB) for their support and cooperation.

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# REPRODUCTIVE ECOLOGY AND FISHERY OF MUD CRAB Scylla serrata (FORSKAL) (BRACHYURA: DECAPODA)

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**ABSTRACT**

Edible crab Scylla serrata (Forskal) is abundant in the coastal area and coastal rivers of Sundarbans, Khulna and Satkhira district. Observations were made on reproductive systems, reproduction, and also exploration for factors determining the breeding seasons and fishery of S. serrata. The ovary is "H" shaped and located dorsally just beneath the carapace. The peak breeding season of this species was from July to August. A sample survey of the crab fishing wards/villages and crab fishers population was undertaken during the years of March 2009 to February 2010 from various parts of Piakgacha Upazila. It may also be remarked that the total population engaged in crab fishery is 1,79,250. Monthly catchments including fattened of mud crab landing of the Piakgacha Upazila in March 2009-February 2010 were evaluated and estimated. Total estimated mud crabs was 3,60,000 kg (three lacks sixty thousands kilograms) during the experiments.

**Key Words:** Reproduction; Ovigerous; Mud crab

## 1. INTRODUCTION

Reproduction, a physiological phenomenon, is influence by several factors. Sexuality and sexual anomalies in differentiation are caused by genetic, environmental and hormonal factors, either singly or in combination. Sex differentiation is a slow, stepwise process in organisms, taking several steps (Adiyodi and Adiyodi, 1974). Sexual development involves the maturation of structural, physiological and behavioral machinery concerned with mating and reproduction. It is controlled by sex hormones (Adiyodi and Adiyodi, 1970; Hossain, 1976). In studying the reproduction of a species the question arises prominently: when and how many times the species breeds in a calendar year? It is reported that there are several types of breeders. According to Stephenson (1934), the habitants of the tropical water cab be classified as

i) Continuous breeders throughout the year,

ii) Discontinuous breeders,

iii) Annual breeders,

iv) Those breeding more than once a year.

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The development of gonads indicates the attainment of sexual maturity. S. serrata attains sexual maturity five months after hatching (Arriola, 1940). The maturation of the gonads and sexual receptivity in the females are controlled by the secretion of hormones. The soft females of this protunid species which copulate immediately after moulting normally retain sperms in the spermatheca for a longer time. The eggs, in such cases, are fertilized as they pass through the spermatheca on their way out. They are carried in a mass under the cephalothoraxes and are held in position by the flexed broad abdomen of the female. Such females with their broods adhering onto the pleopods are described as ovigerous or berried. S. serrata spawn throughout the year, with a peak, season from May to September in Philippines (Pagcatipunan, 1973). Several workers have studied the reproductive ecology of Scylla serrata. Shanmugam and Bensam (1980), Pillai and Nair (1973) made valuable contribution to the breeding biology of some crab from the south-west coast of India

A study of the reproductive system and reproduction of S. serrata was considered to be essential in the sense that it may provide information and clues to a tactful and skillful exploitation of these freshwater and saline water resources. But no work has been made of the reproduction of S. serrata in the perspective of Bangladesh. This is why, the present study has been undertaken to provide an account of reproductive system and reproduction of S. serrata.

There is no study have been done in Bangladesh on the reproductive ecology of S. serrata. Meanwhile Sarker et al. (2009) have done the work on the artificial insemination and early embryonic development of the mangrove crab Perisesarma bidens.

The determination of breeding periods is governed by a complex interaction of endogenous and exogenous factors, allowing both intra and interspecific variations regarding the duration of the reproductive season (Sastry, 1983). Generally, peaks of higher breeding activity may be associated with variations of temperature, salinity, oxygen, food availability, photoperiod, rainfall, among others (Litulo, 2004).

At present, S. serrata culture in Bangladesh is still dependent upon crab juveniles caught from the wild. Hence, any commercial development in this direction needs to be considered as overexploitation of mature females and may aggravate the shortage of seed supplies from the natural habitat.

The breeding period is defined as: the time interval during which ovigerous females may be found in a population (Cobo, 2002). The reproductive characteristics of a species or population are a result of the interactions between various exogenous and endogenous factors. It is generally thought that in the tropical region, brachyuran species reproduction occurs year-round due to stable environmental parameters. The present research provides information on the breeding periodicity of S. serrata in the part of Bay of Bengal at Satkhira range Sundarban mangrove forest. Based on the monthly frequency variation of ovigerous and nonovigerous females, an evaluation of the association between the breeding intensity and environmental parameters of temperature, photoperiod, salinity and rainfall was conducted.

S. serrata is distributed throughout the coastal districts of Cox's Bazar, Chittagong, Noakhali, Bhola, Barisal, Potuakhali, Bagerhat, Khulna, Paikgacha and Satkhira (Ahmed, 1992). It is very delicious, used as gourmet in high class restaurant and is highly price both in local as well as international market. Crab meat contains high protein level with all the essential amino acids recommended by FAO/WHO (1973) and (Nandi and Paramanik, 1994). The waste material consisting of gills, intestines and shell are good raw materials for the preparation of fish meal and high quality chitin and chitosan (Azam et al., 1994; Pervin, 2000). There is flourishing international trade in live mud crab and the market is highly demanding.

The mud crab is mainly caught from mangrove areas as high tide especially when the crab moves with the tidal water in search of food. Intensive and indiscriminate fishing of mud crabs have resulted in drastic declined in fisheries and there is an urgent need for promotion of crab culture. In recent years the higher demand for mud crabs in international markets has expanded the interest of crab family in coastal region of Bangladesh. The mud crab is a very good alternative to shrimp in aquaculture and is a suitable species in the diversification of brackish water aquaculture activities. Inadequate supply of stackable size crabs has been a great constraint towards the expansion of fattening and culture of mud crab. So that, sustainable mud crab fishery must be ensured for further development in fattening, culture and harvesting.

## 2. MATERIALS AND METHODS

Several field surveys were made from different parts of the coastal belt of Bangladesh, especially some part of Sundarbans like Satkhira, Khulna and Bagerhat ranges. A number of crab fishing villages was also surveyed especially at Tala. Kaligonge, Piakgacha, Koira and Dumuria areas. The different kinds of gears and techniques used by crab fishers specially for fishing S. serrata in this region were observed. The main fishing site was Piakgacha region of Khulna district. Especially several surveys were made at Bangladesh fisheries research institute, Brackish water centre, Piakgacha, Khulna.

Crabs for the present study were obtained during my field trip at different study area from March 2009 to February 2010. Basically we used traditional crab net for catching crabs.

In the laboratory, crabs were sexed and carapace length and width were measured. Besides I also noted the abdomen length and width. The weight of crabs was recorded using an electronic balance. Pleopods and vulva of the crabs were examined to determine if mating of eggs had taken place. Presence of eggs or egg remnants or their absence on pleopods, color of egg mass and condition of vulva were noted.

The morphology of reproductive tract was studied by dissecting mature crabs. The stages of maturation were determined by macroscopic examination of the size, color and turgidity of ovaries after incision of the carapace.

Measurements of whole female reproductive organs were made by using six female mud crabs. The ovaries were dissected just after catch and preserved on board. After taking photographs ovaries of six females were presented in 4% formaldehyde for analyses of size and number of oocytes. We took the note of ovary weight and length, width; first, second, third and fourth gonopod by length and width for measurement of female reproductive organs.

From the 30 eggs examined each day for egg diameter an index of embryonic development wad developed, which would aid in predicting the expected date of hatch. The following criteria were used to develop the index: egg size, egg colour, stages of embryonic development and movement within egg. It is a well-established fact that the development rates of eggs increase in proportion to temperature. For every batch of eggs that was incubated temperature was measured daily throughout development. To establish the relationship between temperature and incubation period, the average water temperature was calculated and plotted against period for each batch of eggs.

Measurements of the whole male reproductive organs were made by using 4 male mud crabs. After dissecting, we took the testis weight and length and width. Besides first and second gonopod length and width were also measured. In addition, detailed measurement of body parts were also obtained for relative growth analyses of secondary sexual characteristics.

Sampling, Collection and analysis

Monthly samplings were conducted March 2009 to February 2010, during low tide conditions. Specimens were collected by hand during the day- time by two people over a period of approximately 1h over the same area of about 500 $m^2$. Crabs from different parts of the coastal belt of Bangladesh, especially some part of Sundarban like Satkhira, Khulna and Bagerhat ranges

The breeding season duration was determined through the record of the monthly frequency of ovigerous females in relation to the adult females in the population during the study period. All collected crabs were placed in a pastic bag, labeled and stored in 70% ethanol until further analysis. In the laboratory, crabs were identified, sexed and checked for eggs on the pleopods of females. The carapace length (CL) was measured using a vernier caliper (± 0.05mm accuracy). Only crabs larger than 81.0 mm (CW), the size of the smallest egg bearing female recorded, were used to define mature female. Using this classification, the ovigerous female frequency was calculated. The local meteorological station Satkhira provided the monthly average values of temperature, photoperiod, salinity, pH and rainfall. The degree of association among the ovigerous females with environmental factors was assessed using Pearson's correlation (Statistical software, SPSS version 11). The significance level for the correlation test was adjusted using a Bonferroni correlation ($\alpha$ = 0.01). We also checked the status of oocyte during months when the spawning was completely stopped.

## 3. RESULT

### 3.1. Male reproductive system

The male reproductive system of S. serrata consists of symmetric penis and testes with Vas deferentia connecting to paired gonopores located on the ventral side of the coxae of the fifth pereiopods (Fig 1). Each of the testes is situated in the cephalothoracic region, dorso lateral to the gut and ventral to the heart, surrounded by lobes of the hepatopancreas. The posterior part of each of the testes merges into the vas deferens.

The male reproductive system consists of the following reproductive organs:

### 3.1.1. Testis

The testes are located in the anterior cephalothoracic region. They form wide tubules, surrounded by a basilar membrane. After dissecting four male mud crabs, the average weight of testis is 1.379gm and average testis length and width is 116.67mm and 6.33mm respectively. The correlation between body weight and tests weight of four crabs is positive. It results that testes weight gradually increase for the increasing of body weight. The correlation between testes weight and carapace width is also positive. In most of the cases when carapace width increase then it occurs the increasing of testes.

### 3.1.2. Vas deferences

The vas deferens is divisible into four parts. 1. A proximal parts of narrow, closely packed coils with small diameter, extending posteriorly for a short distance. 2. An intermediate, irregularly, and strongly twisted tube with a larger diameter than that of the proximal part, forming irregular descending and ascending coils. 3. The distal part of the vas deferens forming a long straight tube merging into a muscular terminal ampulla and 4. The ejaculatory ductor, ampulla that commences shortly in front of the coxa of the fifth pleopod. Within the vas deferens different degrees of spermatophonre formation can be distinguished.

### 3.1.3. Spermatophore

The spermatophores are pedunculate, with an oblong, capacious, sperm-filled ampulla elevated on a short thick stalk, which is attached to a gelatinous base. The spermatophores consist of spermatozoae and secrete it to female crab.

### 3.1.4. Male gonopods

The first and second gonopods consists of three segments and the first is distinctly larger than the second one. The average length and width of first and second gonopods is 35.38 mm and 6 mm and 14.88 and 2.87 respectively. It is noticeable that there is existing a close positive relation between gonopod width and length with body weight.

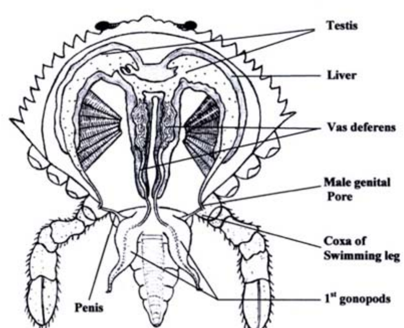


**Fig 1: The male Reproductive System.**

### 3.2. The female reproductive system

The female reproductive system comprises of a pair of ovaries, a pair of spermatheca or seminal receptacle, and a pair of vagina.

### 3.2.1. Ovary

The entire ovary is bounded by fibrous connective tissue which is bounded organ from the surrounding hemocoel. The ovary is "H" shaped and located dorsally just beneath the carapace. The horn of the ovary extend antero-lateally from either side of the gastric mill and lie dorsally to the hepatopancreas. At the postero-lateral border of the gastric mill, near the origin of the posterior mandibular muscle bundles, the anterior horns are joined by a commissure. Two posterior horn, which lie ventral to the heart, extend posteriorly on either side of the intestine (Plate 2). The average ovray weight of six dissected female crab is 1.032 and length and width is 95mm 20.05 mm respectively.

### 3.2.2. Spermatheca, vagina and female gonopod

The spermatheca arises from the midlateral border of the posterior horns. Each seminal receptacle leads into a narrow vaginal tube which further opens outside through a small circular gonopors (vulvae) situated on the south thoracic sternite. The length and width of first, second, third and fourth gonopod legs are noted. The length is larger than width.

**Plate 2: Photographic plate of ovary of mud crab.**

### 3.3. Mating and copulation

The mating and copulation of S. serrata was closely observed. Mating occurs while the female is in a soft-shelled state just after moulting. The male crab finds a receptive female that is ready to moult and clasps her with his walking legs and carries her beneath him. This position is termed the pre-copulatory embrace and continues until the female is ready to moult. In S. serrata, the pre-copulatory embrace lasts for approximately 3-4 days before moulting.

During copulation, the male turns the female so that the ventral surfaces of both the sexes are apposed to each other. The abdomens become unfolded with the males on the inside and ultimately the second pair of abdominal appendages of the male is inserted inside the first, and both together acting as a penis are thrust into the female genital. Copulation may last as long as three to ten hours.

### 3.4. Spawning

S. serrata females migrate out of estuaries in to the marine environment to spawn, where they remain until the eggs hatch. This has made the collection of data on spawning behavior and egg production very difficult. It is for this reason that this investigation did not cover all aspects about spawning of S. Serrata. Several parameters have been identified that may affect the reproductive performance of crustaceans. These include fecundity, egg size, incubation period, egg dropping and hatch success. . In this report, date is collected from root level crab farmers on spawning.

### 3.5. Egg and egg mass

In this experiment 1,100 females were closely observed. Among them 312 were berred or ovigerous. The range of weigth of ovigerous female is 168 to 380g. After extrusion of eggs during oviposition, the eggs attach to the setae present on the endpod of the pleopods. The amount of eggs is variable in number depending upon the weight or size of mother mud crab. The eggs when deposited are bright orange or yellowish orange, but they become yellow, brown and the dark known, or black before hatching. The colour change is caused by absorption of the yellow yolk and development of dark pigment in the eggs. Brownish oval eggs enclosed within gelatinous matrix are together termed as egg masses or egg capsules. The egg masses look as translucent, jellylike and some what flattened and broader at the centre and gradually tapering at the end.

Individual egg mass ranged between 16.2 micro grams and 31.8 micro grams with an average mass of 22.4 micro grams. Egg diameter at extrusion varied between crabs, ranging from 0.28 to 0.32mm.

In S. serrata there is a linear relationship between the number of eggs per brood and the size of the female. The 312 ovigerous females were used to observe the fecundity of S. serrata. Individual fecundity range from 6,000 to 1,20,000. We measured the fecundity range measuring the egg mass of barred females. Mean relative fecundity in this study is 10654 (number of eggs/g female) and mean total fecundity (millions) is 5.79. Relation between body weight and ovary weight have been evaluated and the relation is positive(r= 0.832162).

### 3.6 External factors determining the breeding season of S. Serrata

A total of 1100 females were obtained. Among them 788 were nonovigerous and 312 ovigerous during the study period. The mean carapace length (CL), (Mean) of all egg-bearing females was 64.83 mm ranging from 55.0 to 79.0 mm. The monthly percentage of ovigerous and nonovigerous matured females during the study period is plotted in Fig 2. S. serrata showed a seasonal pattern reproduction. Breeding began in early March and ended at the October. The peak breeding season of this species was from July to August, when the percentages of ovigerous females were higher. The non- breeding season of S. serrata was from November to February.

Photoperiod was negatively correlated with the relative frequency of ovigerous females (Pearson's correlation coefficient, $r^2 = -.80$) (Fig 3**)**. In addition, Fig 4 represents the monthly variation of ovigerous females and temperature. The relative frequency of ovigerous females tends to increase with increasing of temperature (Pearson's correlation coefficient, $r^2 = 0.57$). However, Rainfall and salinity also positively correlation with the relative frequency of ovigerous females (Fig 5).

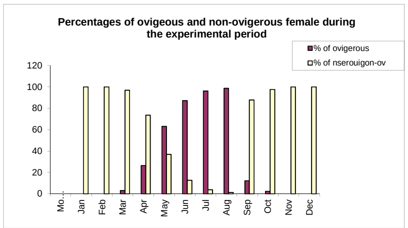


Fig 2: Percentages of ovigeous and non-ovigerous female during the experimental Period

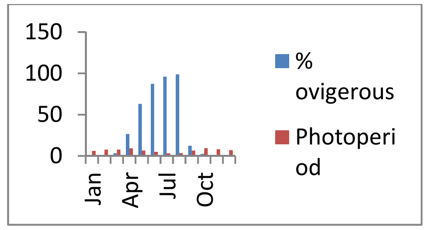


Fig 3: Monthly frequency distribution of ovigerous female and photoperid.

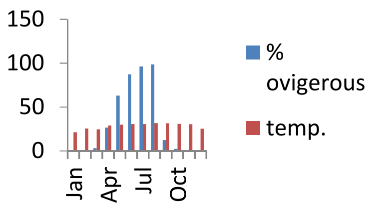


Fig 4 Monthly frequency distribution of ovigerous female and temperature.

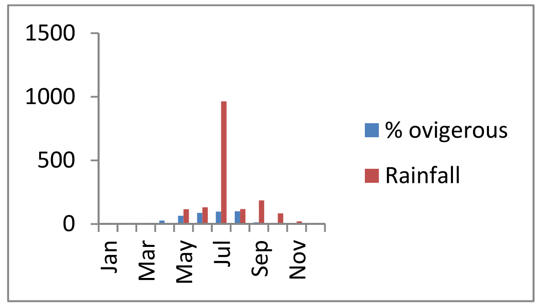


Fig 5: Monthly frequency distribution of ovigerous female and rainfall.

A detailed survey of the crab fisher's population of Paikigacha Upazila comprising of Paikgacha Pourosava and ten Union Parisads viz.,Horidhali, Kopilmuni, Lata, Delhuti, Saladana, Laskere,Godaipur, Ranuli, Chadkhali and Goroikhat. It may also be remarked that there are 222 wards and vallages and the total population engaged in crab fishery is 1,79,250.

Monthly catchment including fattened of muds crab landing of the Piakgacha Upazila in March 2009-February 2010 were evaluated and estimated. Total estimated mud crabs was 3,60,000 kg (three lacks sixty thousands kilograms) during the experiments. It is interesting to note that maximum female crabs were caught during the November to April than the male crabs. Whereas maximum male crabs were caught in the month of May to October than the female crabs

## 4. DISCUSSION

Scylla serrata, like most crustaceans, are dioceious and copulate in order to reproduce. General morphology of reproductive system of some male crabs are observed or described by Tudge and Jamiesor (1996) and Subramonian (1993). These are more or less similar with the present observation. In female reproductive system, Estampador (1949) in Scylla genus observed that the posterior prolongations of the ovary are connected at the posterior and. It is similar condition with the present observation of S. serrata

Maturation and spawning of Scylla species, both in the wild and captivity, has been observed to occur all year round (Mann et al., 1999). Second peaks in spawning actively do occur but differ according to climate and latitude (Heasman et al., 1985). In this study the peak spawning period in wild is May to August.

In S. serrata there is a linear relationship between the number of eggs per brood and the size of the female. This has also been observed for the velvet swimming crab Necora puber (Norman and Jones, 1992). Parsed and Neelakatan (1989) showed a similar direct relationship between size and fecundity in S.serrata up to a size of 140 mm carapace width. In this study the relation between body weight and ovary weight is more or less similar with Parsed and Neelakatan (1989). According to Litulo (2004), rain-fall was also an important environmental factor controlling the breeding of Uca annulipes in the tropical region. In contrast, rain-fall had no direct effects on the breeding of P. bidens and also in the present observation.

In near past, mud crab was the unexplored marine resource in Bangladesh. A particular group of people, namely the Hindus, Buddhist and Tribal were used to exploits crab from the wild for their consumption. By the time, it entered into the local market for sale and gradually fetched demand. However, the prices were far lower than any other fisheries item. Now-a-days crabs are eaten by the Muslim and other groups of people who are free from traditional customs. Extensive commercial exploitation of mud crab has been started from 1977 after introduction of its living condition export by air (Azam et al., 1994).

## 5. CONCLUSION

Scylla serrata is a dioceous crab. S. serrata started reproduction early March to late October and peak of spawning was during summer season and completely absent of spawning during winter season. We may conserve such natural resources only control the catchments of the crab during peak breeding season. The number of crab fishers of ten Union Porisad and one Pourosava of Piakgacha is 1,79,250.Among them male, female and children are 89,625;21700 and 17,925 respectively. Estimated landing of mud crab in Piakgacha is 3,60,000 kg. in the study period.

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# MOLLUSC RESOURCES HARVESTED FROM THE SUNDARBANS OF BANGLADESH

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## ABSTRACT

The Sundarbans provides a valuable physical habitat for a variety of important coastal species including molluscs. Among molluscs, *Telescopium telescopium* is the most abundant, heavy shelled largest gastropod mainly harvested from the swamps of the Sundarbans for lime industries. Few bivalves and oyster including *Meretrix meretrix, Polymesoda bengalensis, Anadara granosa* and *Crassostrea gryphoides* are also utilized in lime and shell industries but their contribution is very limited. The study reveals that the average annual landing, average annual calcination and average annual harvesting (according to the DoF) of molluscs in the study area are 1166.09 mt, 1678.08 mt and 2355.72 mt respectively. The average amount of collected revenue per year is Tk 79,685.00. This important molluscan shellfish of the Sundarbans is under tremendous threat due to overexploitation. Now, it urgently needs the proper management for conservation for the future progeny.
Key Words: The Sundarbans, Molluscs, Harvesting, Calcination, Conservation

## 1. INTRODUCTION

Bangladesh is one of the most populated countries in the world. Huge demand of food and unemployment are the most important barriers for its development. But the country is uniquely endowed with a wide variety of natural resources including the Sundarbans, the world single largest mangrove forest. It encompasses an area of 6017 sq. km. It provides a resilient buffer for the lives and assets of the 3.5 million people who live in the immediate vicinity [5]. The Sundarbans is indeed a treasure-trove of biodiversity because of its wide spectrum of flora and fauna. It provides a valuable physical habitat for a variety of important coastal species including molluscs. At least 42 species of molluscs are present in Sundarbans of Bangladesh [4]. Among them, few are highly economically important either for their food value or for the shells, essential for lime and shell industries. The animal serves in converting huge organic matter into utilizable biomass from mangrove ecosystem. It also play significant role for the maintenance of balanced ecosystem of the Sundarbans, which is a prerequisite for conservation of the world heritage.

Asia has immensely valuable marine molluscan resources which have been utilized for food and for various other purposes since ancient time [8]. The molluscs constitute a significant part of the world fishery today. In some developed and developing countries like Japan, USA, Canada, United Kingdom, China, Korea, Philippines and India large quantities of edible

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molluscs are exploited and harvested from natural beds. In some countries these are also cultured [10]. The people of Southeast Asia, Indonesia, Malaysia and Philippines are known to use molluscs for food [2]**,** [7]. On the South-eastern coast of India, molluscs are eaten by man [11]. Though the general peoples of Bangladesh do not consume the meat of molluscs but the shells are being used for producing edible lime for all kinds of people from time immemorial. The lime from the molluscs shell is also used for building materials and recently it is being utilized in all type of aquaculture to secure the water qualities. Like Bangladesh it is also harvested in India for its shell, which is used in the lime industry [6].

The Sundarbans Forest Authorities earned a large amount of money as revenue on molluscan shells in every year (Fig: 1). The local community who collect shells from the Sundarbans is locally called *Jongrakhota* (mollusc fishers) and who produce lime from the shells is called *Chunary* (lime-burners and traders). The people of the community of *Jongrakhota* and *Chunary* are live in the Sundarbans surrounding villages and every old village respectively in Bangladesh. Thousands of people of both the communities are involved in this profession since hundreds of years. Therefore, the role of these molluscs in regulation of the socio-economic status of the country can not be ignored completely.

In spite of its role in national economy it is therefore surprising that no detailed work on these important animals has been done yet in Bangladesh. Unfortunately the lacks of scientific knowledge for the proper management of this commercially important renewable natural resource are under threat due to overexploitation. Profitable constant exploitation of such renewable resource for economic upliftment demand proper management. Now it is an urgent need the scientific management for conservation of the species to ensure the constant and sufficient supply for the future progeny.

Exploring of the status of harvest and utilization of mollusc resources is essential in the sense that it provides information of exploitation and economic status and clues for a tactful and skilful utilization of this resource. Hence the present study**.**

## 2. MATERIALS AND METHODS

This study was carried out from July 2007 to June 2009 at Satkhira and Khulna districts including the Sundarbans in the south western corner of Bangladesh. Surveys were made fortnightly to assess the total landing of molluscs during the study period at the market of the eight villages namely Vetkhali, Harinagar, Gabura, Bangshipur of Shyamnagar upazila, Mathureshur of Kaliganj upazila under Satkhira district and Madinabad of Koyra upazila, Chandkhali of Paikgacha upazila and Nalian of Dacope upazila under Khulna district, where the main snail landing centre and shell lime industries are established. For estimate the amount of total harvesting and collected revenue from the molluscan fishermen, the concerned data are also gathered from the Department of Forest (DoF) of the Sundarbans. Survey on the *Chunarys* live in this area and the estimation of their average annual calcination was also done. The landing and calcination information used in this paper are derived only for the species, *Telescopium telescopium.*

## 3. RESULTS

### 3.1. Important Species

Among the molluscs *Telescopium telescopium* is the most abundant, heavy shelled largest gastropod mainly collected from the swamps of the Sundarbans constitute 95% of the total harvest. Few bivalves and oyster including *Meretrix meretrix, Polymesoda bengalensis, Anadara granosa* and *Crassostrea gryphoides* are also utilized in lime and shell industries but their contribution is very limited.

### 3.2. Fishing Season, Method and Gears

Fishing of molluscs in the Sundarbans and polder areas are almost continuous throughout the year. The peak supply period of the shellfish in the market was September to December (Fig: 2 & 3). The shellfish, *T. telescopium* is collected from the open mudflat, mangrove swamp, river and creek bank and polder area by only handpicking method in low tide. No gear is used to collect the mangrove snails, although *jhuri* (bamboo made basket), small bag and *dingi* (small boat) are used in harvesting site to transport the snail (Photograph 1).

### 3.3. Harvest Record from the Sundarbans Authority

The records of the amount of collected molluscs shell from the Sundarbans by legally permitted *Jongrakhota* and their given revenue of previous 25 years are shown in the Fig: 1. The figure represents that the legal harvest from the Sundarbans is gradually declining. The highest and lowest amounts of shell harvesting are 4360.00 mt, and 309.84 mt in the year 1993-1994 and 2002-2003 respectively. The average amount of harvesting per year is 2355.72 mt; according to the survey if we deduct 20% for other molluscan shell from this, then the amount will be approximately 1888.58 mt.

The highest and lowest amounts of collected revenue are Tk 1,61,535.00 and Tk 20,500.00 in the year 2005-2006 and 1997-1998 respectively. The average amount of collected revenue per year is Tk 79,685.00.

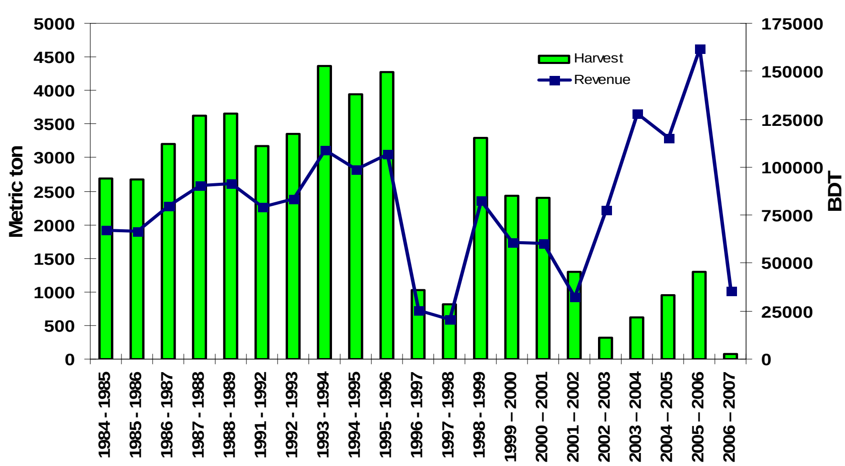


Fig 1: 25 years records of harvest and revenue collection on *T. telescopium* by Department of Forest, Bangladesh Government.

### 3.4. Landing

Monthwise landing in different landing stations of *T. telescopium* from July 2007 to May 2009 are presented in Fig: 2 & 3.

During the two years of study average annual landing of *T. telescopium* were 117.73±4.47 mt, 66.31±12.41 mt, 53.21±6.09 mt, 154.07±7.85 mt, 132.86±5.18 mt, 103.66±5.77 mt, 381.75±8.72 mt and 156.47±0.64 mt in the eight selected landing stations Vetkhali, Harinagar, Gabura, Bangshipur, Mathureshur, Madinabad, Chandkhali and Nalian respectively.

In this time monthwise average landing of the eight landing stations were 86.12±2.76 mt, 122.66±6.08 mt, 174.39±7.82 mt, 188.28±13.11 mt, 161.67±11.86 mt, 127.51±2.48 mt, 82.39±7.51 mt, 60.01±9.92 mt, 43.25±9.83 mt, 40.11±10.15 mt, 46.27±3.01 mt and 66.80 mt in the month of July, August, September, October, November, December, January, February, March, April, May and June respectively.

In the year 2007-’08, total landing of Satkhira and Khulna district were 488.18 mt and 626.75 mt respectively. The total landing of the year in the two districts was 1114.93 mt. In the year 2008-’09, total landing of Satkhira and Khulna district are 560.21 mt and 657.03 mt respectively. The total landing of this year in the two districts is 1217.24 mt.

The average total landing of the two years in the study area is 1166.09 mt.

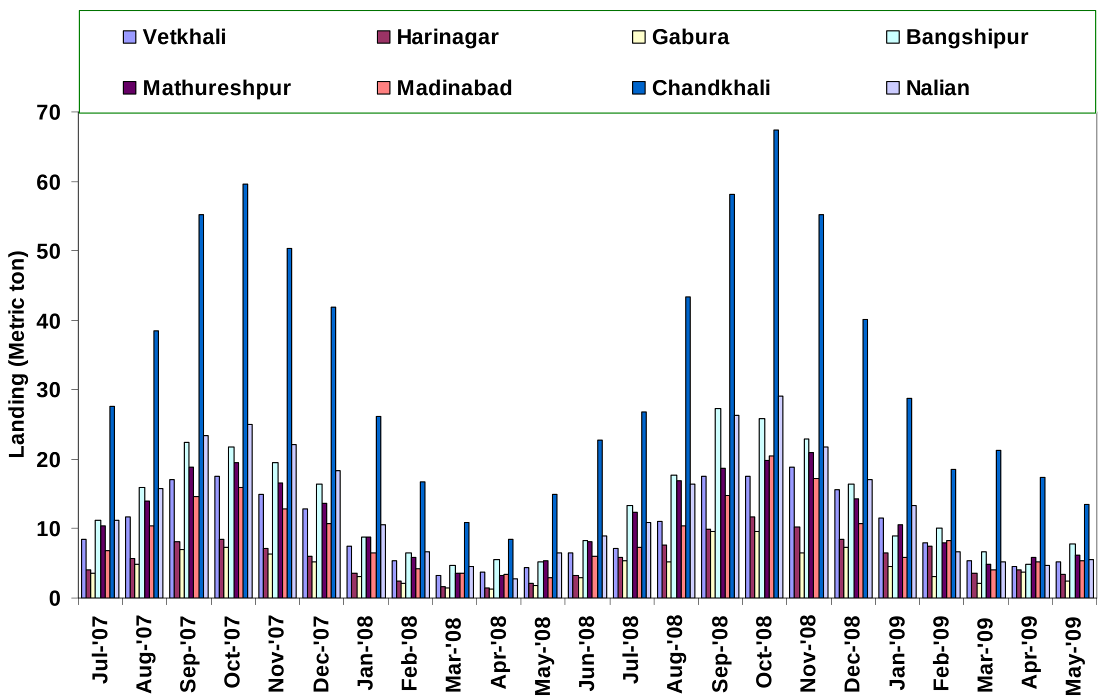


Fig 2: Landing of *T. telescopium* in different landing stations during the period of 23 months (July ’07 to May ’09).

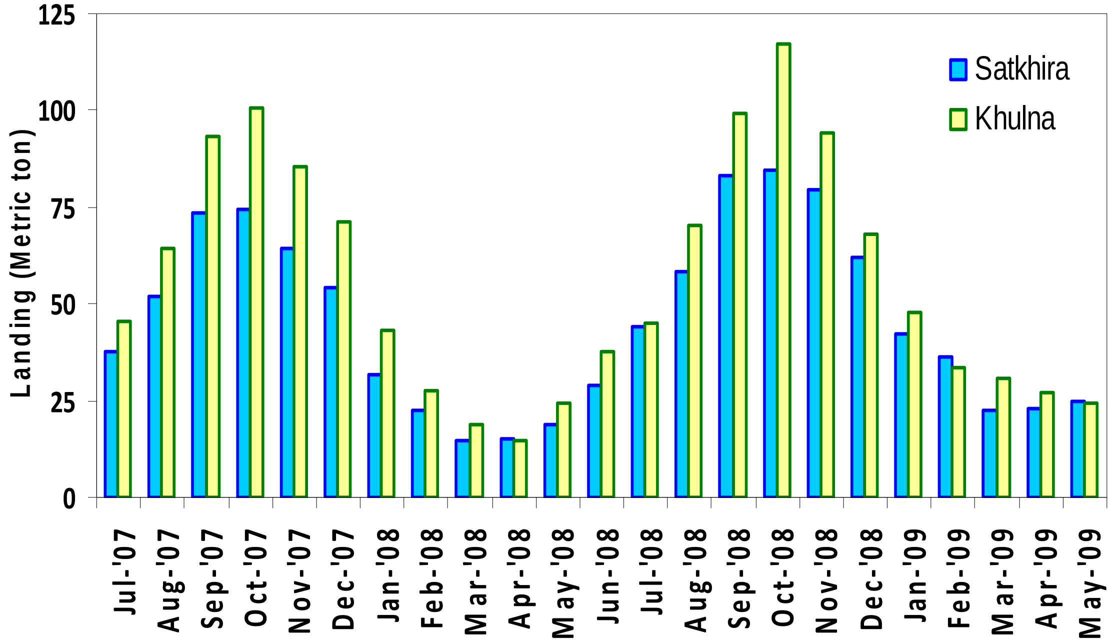


Fig 3: Landing of *T. telescopium* during the period of 23 months (July '07 to May '09) in Satkhira and Khulna districts.

### 3.5. Meat Consumption

In the study area generally the Munda tribe consumes the meat of the snail to meet up their protein demand. The meat of molluscs also is used as food for prawn, catfish and poultry culture, and for crab fattening and fish bait in the study area. The consumption of only the Munda people is estimated below. The average monthly consumption of *T. telescopium* (kg/family) and total amount of consumptions per year by the Munda people is shown in Table 1(Photograph 2).

Table 1: Consumption of *T. telescopium* meat by the Munda of Satkhira and Khulna district.

| Monthly consumption (kg) | Percentage of families | Monthly mean consumption (kg) | District | No. of families | Annual consumption of meat (mt) | Annual use of live snail (meat×10) |
|---|---|---|---|---|---|---|
| 01 – 05 | 65 | 4.85 | Satkhira | 438 | 25.492 | 254.92 |
| 06 – 10 | 33 | | Khulna | 226 | 13.153 | 131.53 |
| 11 – 15 | 02 | | Total | 664 | 38.645 | 386.45 |

The calculation revealed that annual approximate amount of consumption by the Munda in Satkhira and Khulna districts are 254.92 mt and 131.53 mt. The total amount of consumption by the Munda people in the study area is approximately 386.45 mt per year.

### 3.6. Calcination

A total of 76 *Chunary* families out of which 35 in Satkhira and 41 in Khulna district were found in course of the study. Monthly average amount of calcination (mt/family) and yearly total average amount of calcination are shown in Table 2 (Photograph 3)**.**

Table 2: Cacination of *T. telescopium* shell in limekilns of Satkhira and Khulna district.

| Ranges of calcination capacity (mt/month) | Percentage of families | Mean calcination (mt/family) | District | No. of families | Monthly calcination (mt) | Yearly calcination (mt) |
|---|---|---|---|---|---|---|
| 0 | 08 | 1.84 | Satkhira | 35 | 64.40 | 772.80 |
| 0.1 – 2.0 | 55 | | | | | |
| 2.1 – 4.0 | 30 | | Khulna | 41 | 75.44 | 905.28 |
| 4.1 – 6.0 | 05 | | | | | |
| 6.1 – 8.0 | 02 | | Total | 76 | 139.84 | 1678.08 |

The study reveals that a *Chunary* family calcine average 1.84 mt shell of *T. telescopium* in a month. It is estimated that annual approximate amount of calcination in Satkhira and Khulna districts are 772.80 mt and 905.28 mt. The total amount of calcination in the study area is approximately 1678.08 mt per year.

Photograph 1. Harvested *Telescopium telescopium* in boat in the Sundarbans.

Photograph 2. Calcination of molluscs shell at Harinagar in Satkhira.

Photograph 3. Munda women are extracting the meat from boiled shell of *T. telescopium* for cooking.

## 4. DISCUSSION

A great variety of mollusc species are of commercial importance throughout the world. Apart from molluscs harvested from nature, a large number is cultured. Total world landings, both capture and culture has increased from 3,603,426 mt in 1980 to 4,524,929 mt in1986 with an average annual growth rate of about 3.95% [9].

The present study clearly indicates that molluscan shellfish is very much involved with the tradition and economy of Bangladesh. The use of the lime from the shell as edible lime, agricultural lime and building material in Bangladesh has become usual practice. According the study the average amount of annual landing is 1,166.09 mt and the average amount of annual calcinations of molluscan shell is 1678.08 mt (Table 2). The average amount of annual calcination is little higher than harvesting data; probably it is because of huge illegal harvesting from the Sundarbans and hiding the harvest until calcination. Islam (1992) reported that the annual production of shells of the Sundarbans is approximately 3,330 mt [3]. Probably this data was derived from one or two year record of DoF and it resembles to this study (Fig 1). The recorded amount of harvest of DoF is comparatively higher because all the harvest from the parts of the Sundarbans of the study area did not land in the surrounding study area. Although all the records of exploitation is very far less than the real harvesting from the Sundarbans; because maximum harvest of mollusc has not occurred openly to avoid the regulation and revenue of DoF.

## 5. CONCLUSION

In our national economy the molluscan shellfish plays a vital role from the time immemorial. A marketing channel of molluscs for lime producing and prawn farming has been developed in the country. The molluscs from the Sundarbans has been serving as the source of edible and agricultural lime from time immemorable. Presently, the meats of the molluscs are used as supplementary prawn and crab feed in brackish water areas of Bangladesh [1], [12]. The molluscs play significant role for the maintenance of balanced ecosystem to keep the steady state of mangrove ecosystem of the Sundarbans. The mangrove molluscs are consumed as protein rich food by the people of the coastal tribe, Munda in Bangladesh. The coastal people especially the occupational community *Chunary*, *Jongrakhota* and the tribal people Munda more or less depends on the molluscan shellfish for their livelihood. More specific information on the molluscs of the Sundarbans is urgently needed for the conservation and proper utilization of this resource.

## 6. ACKNOWLEDGEMENT

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# FIRST RECORD OF LAND MOLLUSCS *SESARA DIPLODON* AND SIVELLA CASTRA AND (MOLLUSCA: STYLOMMATOPHORA: HELICARIONIDAE ) FROM BANGLADESH

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## ABSTRACT

A total of 2 terrestrial molluscs species under the family Helicarionidae, Order - Stylommatophora were collected. Which are new records from Bangladesh. The information on the distribution and ecology, population density and seasonal variation of *Sesara diplodon* and *Sivella castra* were provided in this paper. Population density was measured. Pearson correlation among meteorological factors of season (air temperature, rainfall and humidity) and molluscs population density were calculated. Morphometric parameters were measured. Moreover, economic importance and economic role were observed.

**Key Words:** Molluscs, Stylommatophora, *Sesara diplodon, Sivella castra*

## 1. INTRODUCTION

The total World fauna of land molluscs is estimated at between 30,000 to 40,000 the minimum (Solem,1984, Abbott,1989), though a more conservative estimated puts the number of valid described species at around 10,000. Some mollusks are excellent indicators of environmental conditions. Some terrestrial moluscs are vectors of human and livestock disease and others have greatly to our understanding of genetics and the process of evolution. Snails are eaten as food in many parts of the world. worked on the systematic, abundance, breeding biology, ecology and parasitological importance of some molluscs species from Bangladesh , India and other parts of the world. [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15] worked on the Diversity, Ecology systematic, abundance, breeding biology, and parasitological importance of some molluscs species from Bangladesh , India and other parts of the world.

## 2. MATERIALS AND METHODS

### Description of Study Area

The Northeastern region includes the present districts of Brahmanbaria, Comilla, Habiganj, Moulvibazar, Sylhet and Sunamganj. This region covers a land area of 13,938.65 sq. is situated between 23°. 2 to 25°. 2´ N latitude and longitude 91°.7´ to 92°.41´E. Reserve forest, hills, haors, and beels are also included in this region.

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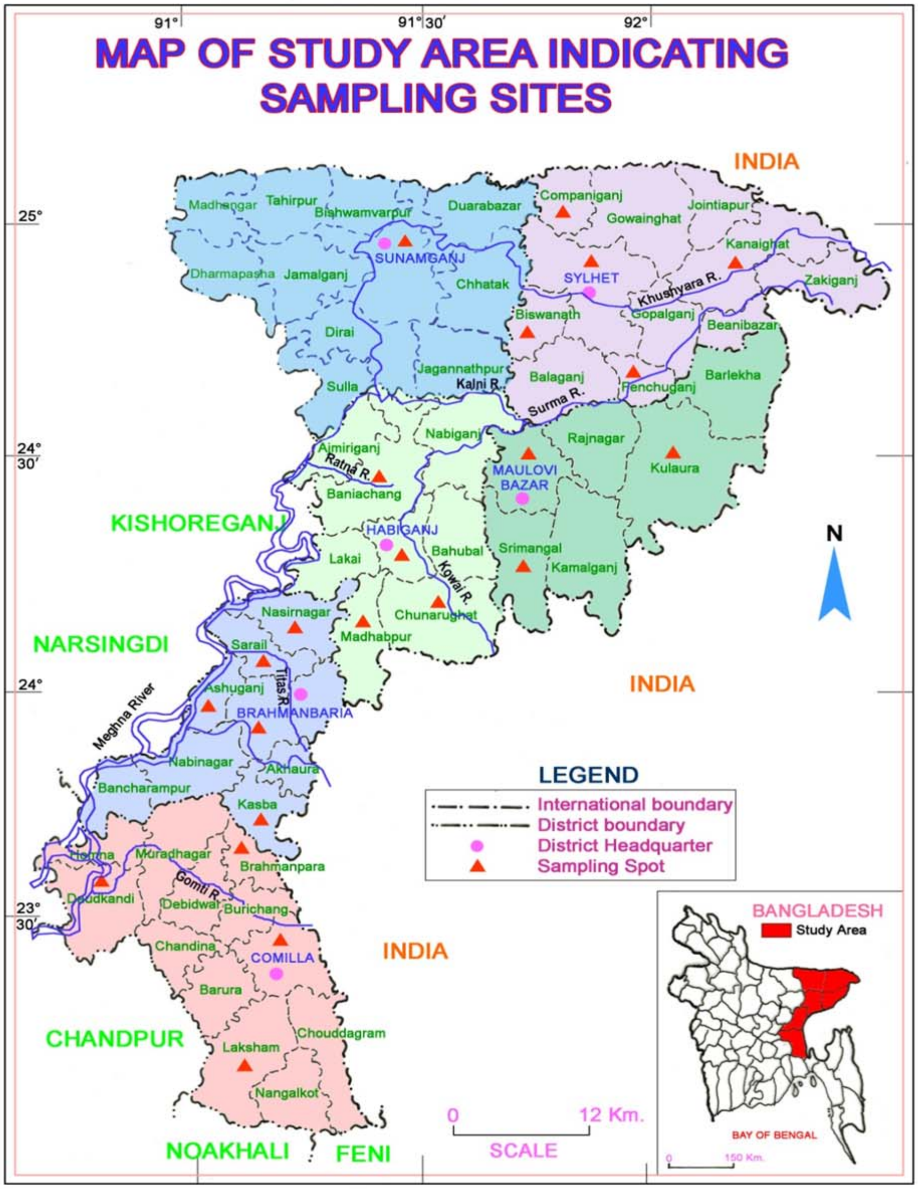


Map of the study area- Study area and the sampling localities are shown in map

**Methodology for faunal study:** Determination of population densities and seasonal variations of mollusc species in respect of climatic factors, soil parameters and water qualities of the North-eastern region of Bangladesh in course of two years (2005-2007) intensive surveys the following materials and method were considered.

Considering the limitations of time, resources and logistic supports, three localities were selected in the study area for determination of population density and seasonal variation of terrestrial mollusc. From each of the localities three spots of 10 $m^2$ quadrate area each were taken in respect of Summer, Monsoon and Winter season. A total of 54 quadrats were taken in two years. The selected localities were ‘BARD’ annex forest of Comilla District, Lawachara National park of Maulvibazar District and Malnichara Tea garden annex forest of Sylhet District. Each locality was chosen to represent a typical part of the surrounding vegetations avoiding edges or transitions. The collected snails were preserved in the 70% ethyl alcohol and then identified following [16] and confirmed from the Molllusca Division of the Zoological Survey of India, Kolkata. A sample of 200 adult of each species were randomly collected from the natural habitats of the North-eastern region of Bangladesh and their various morphometric measurements were taken with the help of a divider, scale and slide calipers.

## 3. RESULTS

Two terrestrial molluscs species belonging to the two genera of Halicarionidae family, Stylomamatophora order under class Gastropoda were recorded. The species were *Sesara diplodon* and *Sivella castra.* It was found for the first time in the Bangladesh. Pearson correlation’s among the climatic factors of different Seasons and Molluscs species population densities are presented in the table 1 and 2.

Table1: Pearson's correlation among the climatic factors of different seasons and Molluscs species population densities of Malnichara, Lawachara and BARD forest in the study area.

| Species | *S. diplodon* | | | *S. castra* | | |
|---|---|---|---|---|---|---|
| Seasons / Habitats | Summer | Monsoon | Winter | Summer | Monsoon | Winter |
| M.chara | - | - | - | - | - | - |
| L.chara | 0.950 | 0.974 | -0.644 | 0.964 | 0.984 | -0.605 |
| BARD | - | - | - | - | - | - |

Table 2: Population densities of *S. diplodon* and *S. castra* are presented in the following table.

| Species | *S. diplodon* | | | *S. castra* | | |
|---|---|---|---|---|---|---|
| Seasons / Habitats | Summer | Monsoon | Winter | Summer | Monsoon | Winter |
| M.chara | - | - | - | - | - | - |
| L.chara | 0.66±0.33 | 7.16±1.83 | 0.16±0.16 | 0.49±0.16 | 12.66±2.00 | 0.33±0.33 |
| BARD | - | - | - | - | - | - |

In Lawachara National forest, *S. diplodon* and *S. castra* were positively correlated with climatic factors of Summer and Monsoon seasons but not significant at 0.05% and 0.01% level. Highest population density of *S. diplodon* (7.17±1.83), *S. castra* (12.66±2.00) were found during the monsoon and lowest (0.16±0.16), (0.33±0.33) were estimated during the winter in L. chara respectively.

**Description of Species**

**Species name: 1.** ***Sesara diplodon***

Fig. 1a: Abapertual view *of Sesara diplodon*

Fig. 1b: Apertual view of *Sesara diplodon*

**Synonym:**

1859. *Helix diplodon Benson, Ann. Mag. nat. Hist*., (3) 3 :187.

1908. *Seasara diplodon* : Blanford & Godwin-Austen, *Fauna of British India. Mollusca*. (Testacellidae & Zonitidac) p. 247.

**Habits :** They are scavenger, living on dead or live plant matters.

**Description**

Shell small, trochiform, flattened at base, minutely perforate, pale whitish, very finely decussately sculptured both above and below, spire conodily raised (varying in height) apex blunt, suture marginate; whorls 7, convex, the last sharply keeled at the periphery, flattened below, slightly impressed around the perforation, longitudinally compressed behind the peristome producing a small hollow ridge ; aperture oblique, trapezoid, peristome thin, sharply angulate at the keel and arcuate at the basal ridge, columella minutely thickened and reflected above. Two teeth in the aperture on small conical inside the columellar edge, another larger, curvedly entering inside the basal margin.

**Size:** Average length of shell width aperture length and width 5.6±.27, 8.72±0.88 3.06±0.51 and 1.12±0.25 mm. respectively.

**Distribution:** Maulvibazar Distract

**Economic importance:** It is a minor pest of crops. Feeds on soft twigs and floral buds of plants.

**Ecological role:** The snail plays an important role in the terrestrial ecosystem as a scavenger; and also contributes to the recycling the plants nutrients.

**Species 2: *Sivella castra***

Fig. 2.a. Abapertual view of *S. castra*

Fig. 2.b *S. castra* (Live)

Fig. 2.c Apertual view of *S. castra*

**Habits:** They are scavenger, living on dead or live plant matters.

**Habitat:** Ground, among low vegetation, evergreen forest, leaf litters, under stones or logs and crevice of trees. During the study period the snails was seen attached to Loha, Raktan, and Mango trees.

**Population density:** *S. castra* highest (12.66/10 $m^2$) during Monsoon in Lawachra forest, Maulvibazar and minimum (0.16/10 $m^2$) Summer in the same forest.

**Description:**
Shell moderately large, thin, depressedly conoid, openly umbilicate, pale whitish to light brown, conspicuously obliquely striate above, deccussately sculptured below ; spire raised, apex obtuse; suture marginate ; whorls 5-6, the last sharply keeled at periphery, slightly convex below ; aperture oblique, subquadrate, peristome thin; columellar margin oblique, simple.

**Synonym:**
1852. *Helix* castra Benson, Ann. Mag. nat. Hist., (2) 10: 349. 1914. *Trochomorpha (Sivella) castra* : Gude, *Fauna of British India, Moll*usca, 2 : 3.

**Size:** Average length of shell width aperture length and width 5±0.70, 11±0.40 , 3.75±0.64 and 1.87±0.25. respectively.

**Distribution:** Maulvibazar District.

**Economic importance:** It is a minor pest of crops. Feeds on soft twigs and floral buds of plants.

**Ecological role:** The snail plays an important role in the terrestrial ecosystem as a scavenger; and also contributes to the recycling the plants nutrients.

## 4. DISCUSSION

Bangladesh, a land of rivers, numerous natural and artificial water reservoirs, and tropical evergreen rainforest with grasslands offer suitable habitats for the land and freshwater dwelling moluscs. But nevertheless, the comprehensive account of the malacofauna of Bangladesh is lacking. In [4] reported 23 (13 terrestrial and 10 fresh water) gastropod species belonging to 19 genera, 14 families and 4 orders were recorded from different localities of Bangladeah. Later on [7] reported sixteen molluscs species from Rajshahi university campus, Bangladesh of which 14 species were also reported previously by [4]. Thus [4] and his associate workers (2003) recorded the presence of 14 species of land molluscs from the territory of Bangladesh for the first time after a long time of publication of the Fauna of British India. The species were viz. *Cyclophorus auranticus* var. *pernobilis, C.aurora, Pterocyclus parvus*, (Cyclophoridae), *Achatina fulica* (Achatinidae), *Macrochlamys sequax*, *M.opiparus*, *M.indica*, *Girasia burtii* (Ariophantidae), *Glessula gemma* (Glessulidae), *Opeas gracile* (Subulinidae), *Rachis bengalensis* (Enidae), *Incillaria monticula* (Philomycidae), *Indosuccinea semiserica* (Succinidae), *Semperula birmanica* (Veronicellidae).

[17] included a total of 479 (20 land, 22 fresh water and 437 marine and brackish water) molluscs species belonged to 210 genera, 105 families, and 23 orders under 4 classes recorded by different workers from Bangladesh. The molluscs *M. lubrica, G. hookeri, Euaustenia cassida* and *Sitala attegia* (Ariophandae) were recorded during the present study for the first time from Bangladesh.

In the present study 26 terrestrial mollusc species were recorded from the different localities of the study area. Out of these 26 land molluscs *M. lubrica, G. hookeri, Girasia.crocea, Euaustenia cassida*, *Sitala attegia* (Ariophandae) *G. notigena* (Subulinidae), *G. gemma*, *S. diplodon*, *S. castra* (Helicarionidae), *C. delibrata* (Camaenidae), *I. plicata*, *Succinea daucina* (Succinidae), *Austenia gigas P. (E.) plectosoma* (Plectopilidae), *Pterocyclus parvus, Streptaxis pfeifferi* (Streptaxidae) *F. alte* (Veronicellidae), *C. theobaldinus*, *C.pearsoni, Chamalycaeus crenatus*, (Cyclophoridae), *A.fulica fulica*, *R.bengalensis*,, *Lamellaxis (Allopeas) gracile* molluscs species were reported previously from the same area [4,16,17,18]. But the present paper, molluscs *S. diplodon* and *S. castra* (Helicarionidae) were recorded during the this study for the first time from Bangladesh.

The Fauna of British India reported a total of 54 terrestrial and freshwater molluscs species from present Bangladesh territory [4,16,17].

Though the presence of *M. hardwickii*, *Clausilia loxostoma*, *Alycaeus sylheticus, Amphidromus sinensis* , *Tiara (Melanoides*) *terebra* and *T.(Mellanella) zonata* were reported in Fauna of British India from the study area but did not encounter during the present study. More over, *C. auranticus* and *C. aurora* and *I. monticola* were reported by [4] but could not find during the present study.

Most of the land snails are nocturnal. The shell of several terrestrial and aquatic molluscs are extremely so alike that the eye fails to differentiate them externally. This might be one of the causes of such missing. Moreover to find out the snails in their natural habitats throughout the country requires very extensive survey. Besides, these natural habitats are degrading day by day due to deforestation and development activities on land. Pollution from industries, agriculture and erosion has seriously threatened Gastropod and Mussel populations. As well as river siltation, impoundment and agriculture activities in haors, baors are also destructing the natural habitats for the malacofauna. Thus it can be assumed that species previously reported are not found presently and they may be extinct.

It is inevitable that the molluscan biodiversity of any habitat play various roles for the maintenance of sustainable ecosystem, food chain and soil fertility. Accordingly, the molluscan biodiversity of Bangladesh deserves proper management. Management of biodiversity is the basis for its states in a given region, can disclose the position of biodiversity indicating the ongoing trend of sustainability of local flora and fauna. It also helps us to gain and understand sufficient knowledge of interdependences of species within ecosystem, economic, aesthetic, health and culture impacts of the decrease or extinction one species to others. Finally, it must be emphasized that extensive survey should be made throughout the country to explore and register the total malacofauna of Bangladesh with their interrelationships to existing ecosystem components and underlying causes of their population reduction, so that the appropriate measures can be taken to keep sustainable molluscan biodiversity for the benefit of the country.

## 4. CONCLUSIONS

Management of biodiversity is the basis for its states in a given region, can disclose the position of biodiversity indicating the ongoing trend of sustainability of local flora and fauna. It also helps us to gain and understand sufficient knowledge of interdependences of species within ecosystem, economic, aesthetic, health and culture impacts of the decrease or extinction one species to others. Finally, it must be emphasized that extensive survey should be made throughout the country to explore and register the total malacofauna of Bangladesh with their interrelationships to existing ecosystem components and underlying causes of their population reduction, so that the appropriate measures can be taken to keep sustainable molluscan biodiversity for the benefit of the country.

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# HUMAN SAFETY MANAGEMENT PRACTICES IN CONSTRUCTION INDUSTRY

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## ABSTRACT

T Construction industry is considered to be one of the most significant industries in terms of contributing to GDP and its impact on health and safety of the working population. Construction industry is economically and socially important. However, the construction industry is also recognized to be the most hazardous sector. In developed countries, recent advancement has contributed positively to industry productivity, but has created a more challenging and unsafe working environment. Accidents and associated damages caused to the employees, properties, equipments and morale have generated negative effects on profitability and productivity. Responding to this increased safety requirement generated by technology advancement, construction industry in developed countries has incorporated safety as an integral part in the regulatory framework.

In most developing countries, there is no proper safety management for raising consciousness among stakeholders. This study investigates safety management system in construction industry, awareness to safety, accident patterns and requirements for increasing productivity. Construction industry in Bangladesh is more labor intensive than that in the developed countries. Most large firms do have a safety policy, on paper, but employees in general are not aware of its existence. Major construction companies have established various safety procedures. However, maximizing profit is the prime concern. Unsafe conditions exist on many sites and laborers are subjected to numerous hazards. In most cases employees are required to learn from their own mistakes or experiences. In addition, lack of medical facilities, shanty housing and substandard sanitation exist at remote projects.

Common problems in construction site are found as accidents due to cave-ins often occur while excavating in deep trenches, concreting without using gloves and boots, weak scaffolding, absence of personal protection equipments, long time exposure to extreme temperature, bad house keeping. The top ten safety non-performance practices found on sites are no ear defender, protective footwear, face mask, safety helmet, gloves, eye protector, missing guardrails at scaffold platform, uncovered openings, timber with nails and tools or small machineries not stored properly. The major injuries faced are fall injuries, struck-by injuries, injuries by wastage and raw material, heat stroke, head injuries, eye injuries and burning.

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According to OSHA construction industry has to give emphasis on identifying and involving key members, effective communication, managing contractors and identifying and quantifying hazards. Three aspects need to be included in site layout planning as proper temporary facilities, proper safety zones and optimum placement of facilities. Management should avoid long time worker, child worker, non- hygienic working environment and explosive chemical. There should be some strategies such as job study/ observation, preventing accumulation of hazardous material, reducing energy accumulation, separating individuals from energy, raising injury threshold, acclimatization to working condition change, controlling behavior. Some ergonomic safety principles should be followed such as safe way of doing job, remove unwanted event, comfort ness of worker, component failure should not cause property damage, material handling procedure, lighting and safety symbols. There should be smoke detector, heat detector, flame detector and as well as fixed automatic sprinklers and portable fire extinguishers, fire escape stairs, smoke proof tower, emergency lighting and exits, fire alarm and smoke venting system.
Key Words: Construction industry, Health, Safety.

## 1. INTRODUCTION

The number of fatalities at work in the construction sector remains a matter of serious concern for the Government, employers and employees alike (HSA, 1999). Statistics on fatalities generally places the construction sector as the second highest industry, only surpassed by the garments sector (in recent years). Among the most common sources of fatalities in construction, falls from heights is the category that accounts for the highest proportion of deaths. A brief comment of some statistics will be given below. Some international figures regarding fatality rates will also be reported in the literature. The chance of an average worker sustaining a fatal work injury is slim – there were just 3.9 fatal occupational injuries per 100,000 workers in the United States in 2006, according to the most recent figures from the U.S. Department of Labor's Bureau of Labor Statistics (BLS). There were 5,703 overall work-related fatalities in 2006.

One major goal of safety research is to support interventions that can demonstrably improve safety. However, thorough empirical studies are rare and they normally focus on changing individual behavior. Duff et al. (1993) and Robertson et al. (1999) carried out a two – phased study on the effectiveness of different intervention strategies. Specifically, they looked at the effects of feedback, goal setting and training, on safety performance. They found that the techniques used produced marked improvements in site safety, participative goal-setting being the more effective of the three. However, a continuous and consistent intervention along the lifecycle of the site was recommended to achieve the maximum benefit. The results also highlighted the vital role of management commitment in the effectiveness of the intervention methods used. Lingard and Rowlinson (1998) used a similar design to Duff et al. (1993) in the Hong Kong construction industry. They reported highly significant improvements in housekeeping with their intervention. However, in general, the intervention did not result in significant improvements in the areas of access to heights or bamboo scaffolding. Again, the main reason was the management commitment towards those two areas of activity. They concluded in relation to that in "behavior-based safety management programs... safe behavior can only be achieved where a basic safety infrastructure is already in place". Other variables of interest, such as attitudes and safety climate, have received little attention in the literature. For example, Langford et al. (2000) carried out a research on safety attitudes in construction workers. This identified some variables that influenced the attitude of construction workers towards safe behavior: organizing for safety supervision and equipment management, industry norms and culture, attitudes to risk taking, and management behavior. However, there are no data available for the influence of attitudes on behavioral or site performance. In her degree project, **Curran (2000)** researched safety attitudes and the safety climate on one construction site. However, the results cannot be generalized. To our knowledge, this is the only research on safety climate in the construction industry.

For workers in industries like mining, construction and agriculture, the odds weren't quite as good – agriculture workers saw 29.6 fatalities per 100,000 workers in 2006, while miners saw 27.8 fatalities per 100,000. Additionally, construction and extraction occupations and transportation and material moving occupations accounted for nearly half (48 percent) of all fatal work injuries in 2006.

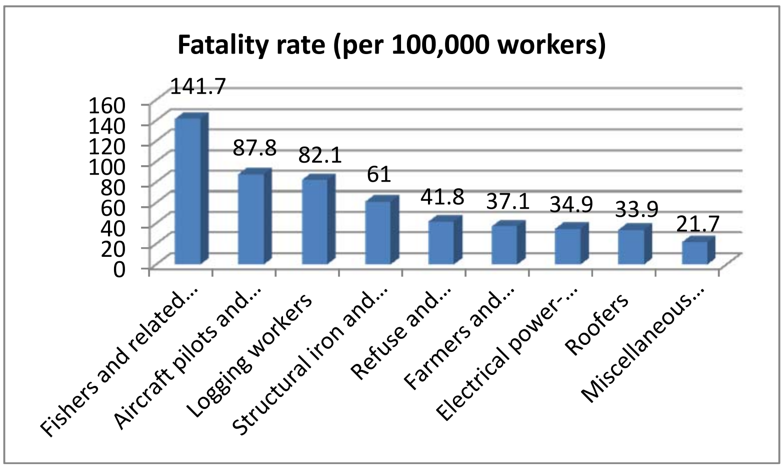


**Fig 1:** Fatality rate versus different job types (BLS USA)

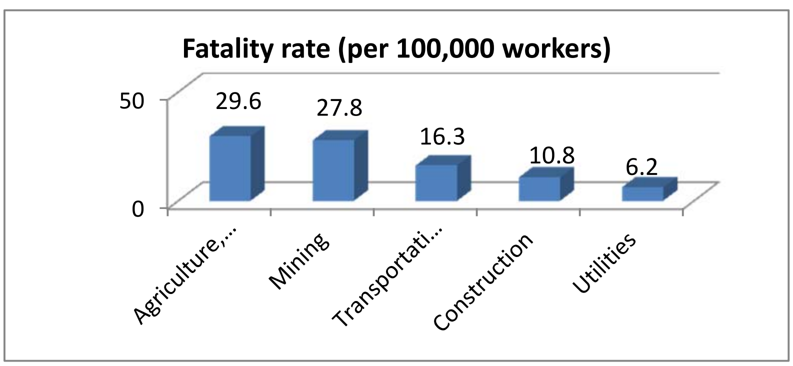


**Fig 2:** Fatality rate versus different industries (BLS USA)

## 2. RESEARCH METHODOLOGY

To identify major areas which are mostly vulnerable for accidents and fatalities that have occurred in the construction industry, data were collected from the Workplace safety report 2006 by Bangladesh Institute of Labor Studies (BILS). The number of injured persons, accident type, and accident description, type of project and injury results were collected from each accident document. Also, another set of data was collected from U.S. Department of Labor's Bureau of Labor Statistics (BLS) containing the highest fatality rates for 2006 in USA. To compare injuries and fatalities that have occurred in the construction industry with those in all other industries, visits were conducted. Accident results were presented according to economic activity in fiscal year 2006. Finally, to understand the extent of safety problems and to evaluate the current procedures in controlling safety performance adopted at construction sites, a number of interviews were conducted with laborers, safety engineers and top managers in government sectors and private firms. These interviews were guided via a simple questionnaire covering areas such as safety records, accidents statistics, accident costs and safety policy which are given in the attached appendix.

## 3. CASE STUDY

### 3.1 Construction Safety Performance in Bangladesh

Construction in developing countries, such as Bangladesh, is more labor intensive than that in the developed areas of the globe. In Bangladesh, there is a significant difference between large and small contractors. Most large firms do have a safety policy, on paper, but employees in general are not aware of its existence. Nevertheless, a number of major constructors exhibit a concern for safety and have established various safety procedures. They also provide training for workers and maintain safety on the jobsite. For the majority of contractors, however, maximizing profit is the prime concern. Unsafe conditions exist on many sites, both large and small, and laborers are subjected to numerous hazards. On many sites, no training programs for the staff and workers exist; therefore, no orientation for new staff or workers is conducted, hazards are not pointed out, and no safety meetings are held. Employees are required to learn from their own mistakes or experience. In addition, lack of medical facilities, shanty housing, and substandard sanitation tend to exist on remote projects. Injuries generally are unreported; however, if necessary, a laborer might receive first aid or preliminary medical care. In most cases, specialized medical treatment or compensation is unavailable. Workers themselves consider accidents as due to their own negligence, and accept that construction is a dangerous occupation. Nevertheless, major accidents involving the death of a worker may be reported due to the financial expenses and litigation that could be involved. Maintenance and inspection schedules often are not followed, and only after a breakdown is equipment repaired. This approach leads to loss of time, idle workers, and project delays. It may also cause damage to property. Breakdown of concrete mixers, vibrators, water pumps, and tractors are common. Electrocution is also a major hazard, due to use of substandard electrical equipment and underground cables. Workers, especially young ones, take chances, and often do not follow safety norms or use personal protective equipment. Also laborers and staff are sometimes are under the influence of alcohol and drugs. Workers are not checked for drugs and alcohol before the start of and doing work.

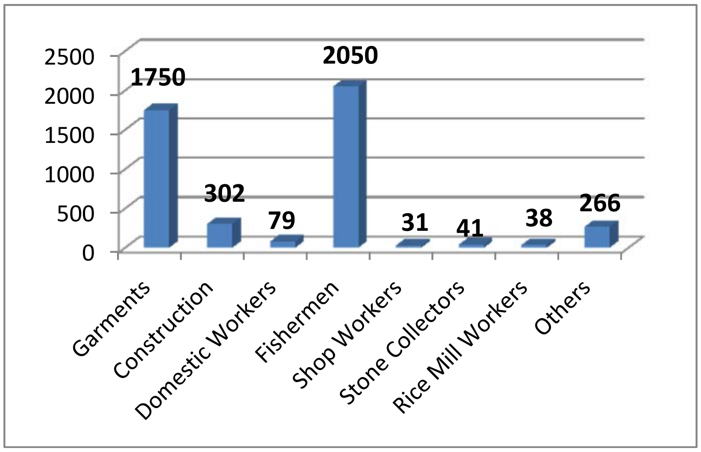


**Fig 3:** Total accidents versus different sectors (Bangladesh Institute of Labor Studies)

### 3.2 Causes of Accidents

There are different type reasons for occurring accidents in construction sites. One of the reasons, workers non performance activity of safety is most important. The top ten safety non-performance practices found on sites are as follows:

- Ear defenders not worn (while using noisy equipment).
- Protective footwear not worn.
- Face masks not worn (in dusty conditions).
- Guardrails are missing on working scaffold platforms.
- Safety helmets not worn.
- Gloves not worn (while handling materials which have sharp edges, hot or could cause skin problems).
- Openings left uncovered or unguarded.
- Goggles or other items of eye protectors not worn (when using motorized cutting equipment, welding and cartridge operated tools).
- Timbers left lying around, have nails left in.
- Tools or small machinery not placed or stored properly.

### 3.3 Common Problems at Construction Site

Workers undertake a risk while at work and the following problem areas are common:

- While excavating in deep trenches (with no proper shoring or bracing), accidents due to cave-ins often occur.
- Concreting is done mainly by laborers, and cements burns due to the unavailability of protective gloves and boots are common.
- Workers fall from heights due to weak scaffolding and the unavailability of safety belts.
- Workers sustain injuries on the head, fingers, eyes, feet, and face due to absence of personal protection equipment.

- Workers sustain temperature extremes.
- Workers also face electric shock or electrocution.
- There is improper house keeping.

### 3.4 Major Injuries

The major injuries faced by construction firms in Bangladesh on their project sites are given in Table 1.

Table 1: The major injuries faced by construction firms in Bangladesh (BILS 2006)

| Causes | Killed | Injured |
|---|---|---|
| Landslide/ collapse | 69 | 245 |
| Fire Accidents | 85 | 829 |
| Electrocution | 33 | 11 |
| Road Accidents | 82 | 170 |
| Boiler or cylinder blasts | 10 | 118 |
| Slipping from the roof | 16 | 34 |
| Gas Suffocation | 14 | -- |
| Rolling with ribbon of machine | 3 | -- |
| Thunderbolt | 12 | 45 |
| Trawler Capsize | 502 | 1500 |
| Others | 15 | 204 |

## 4. RECOMMENDATIONS FOR MAXIMUM SAFETY

### 4.1 Defining Temporary Facilities

The temporary facilities are needed to support construction operations and to provide services for the workers on site. Good facilities can have a positive benefit on health and well being and can help prevent dermatitis. Necessary temporary facilities and services range from access roads, lay down areas, warehouses, and batch plant, to first aid office, toilet on site, and labor rest area. Construction workers need adequate toilet and washing facilities, a place to warm up and eat their food, and somewhere to store their clothing. The size and number of these facilities should reflect the site size, nature of the work, and numbers of people who will use them. If a large number of people are working on site or the work being carried out is particularly dirty or involves a health risk (e.g. pouring concrete), more washing facilities are needed. Important facilities and services are listed below.

#### 4.1.1 Site Access

Easy site accessibility will keep the morale of the equipment and vehicle drivers high, minimize the chance of accidents, and save time in maneuvering to access and leave the project. In large projects, proper planning is required for the roads leading to the nearest highway, internal roads, and parking lots (if enough space is available).

#### 4.1.2 Site Offices

Site offices should be close together, close to the construction space, and in a safe area. Their location should provide a good view with less noise from construction operations. In addition to the job office, offices should be provided for the general contractor, sub-contractors, and consultants.

### 4.1.3 Welfare Facilities

Minimum welfare facilities should be provided on construction sites to comply with the construction health and safety regulations. Welfare facilities may include: toilets, washing, changing, personal storage, and rest areas. Such facilities (more than one of each type if necessary) should be easily accessible and have adequate heating, lighting, and ventilation.

### 4.1.4 First Aid

First aid services and provisions for medical care shall be made available.

### 4.1.5 House Keeping

During the course of construction, formwork and scrap lumber with protruding nails, and all other debris, shall be kept cleared from work areas, passageways, stairs, buildings, or other structures. Debris shall be removed at regular intervals during the course of construction with safe means. Containers shall be provided for the collection and separation of waste, trash, oil, and other refuse.

### 4.1.6 Workshops

Workshops are used where materials and equipment are fabricated on site. This includes electrical, mechanical, carpentry, and paint shops. Also, testing shops used to house the necessary testing equipment and personnel.

### 4.1.7 Material Storage And Handling

It is necessary to plan and reserve storage areas for materials so that multiple movement of material is avoided. Lay down areas, staging areas, and warehouses are used for material storage and they are generally located as close to work as possible. One third or more of all construction operations can be classified as material handling. The use of proper equipment for material handling, and advanced planning for minimizing multiple handling will result in direct cost and time savings.

As described earlier, falls represent the major cause of accidents in construction site (33% of the construction fatalities). In order to reduce accidents, proper safety zones around construction areas should be provided to prevent harm from falling objects. Some of the regulations were described by the uniform building code (UBC 1985), including: at least 10 feet clearance from buildings or structures shall be kept clear from using, driveways between and around open yard storage shall be at least 15 feet wide and free from accumulation of rubbish, and materials stored inside buildings under construction shall not be placed within 6 feet of any hoist way or inside floor opening.

Accordingly, a proper site layout planning model should allow the use of safety zones around construction areas, hoists, cranes, and lay down (storage) areas.

## 4.2 Strategies For Controlling Accidents

Some strategies are very much important for controlling accidents. They are:

- Job study/Observation.
- Preventing accumulation of hazardous material.
- Reducing the amount of energy accumulation.
- Preventing or modifying release of energy.
- Separating individuals from energy by place & time.
- Raising the injury threshold. Example: Joint mobility, muscle-strong etc.
- Acclimatization: Bodies gradual adjustment to a change in climate or working condition.
- Controlling behavior. Example: horse play at abnormal workers, drug , alcohol etc.

**4.3 Ergonomics For Accident Control**

There are some ergonomic safety principles:

- Safe way of doing thing.
- Remove unforeseen or unwanted event.
- Comfortable position of worker.
- Failure of a product should not cause property damage.
- Worker should be taught about how to the use of handling devise.
- Proper lighting.
- Use of safety symbols such as red light for danger, green light for safe.

**4.4 Fire Protection & Control In Plants And Factories**

The Life Safety Code (NFPA 101-1981) gives the following criteria for the fire escape stair design:

- Fire escape stairs ideally extend to the street or ground level. When sidewalks would be obstructed by permanent stairs, swinging stair section (designed to the swing down with the weight of a person) may be sued for the lowest flight of the fire escape stair.
- Smoke proof tower are safest from of stairs enclosure recommended by the Life Safety Code. Access to the stair tower is only by balconies open to the outside air, vented shafts, so that smoke and fire will not readily spread into the tower even if the doors are accidently left open.
- Well-designed emergency lightings provide the necessary illumination automatically. The necessary exit floor illumination will be automatically maintained in the event of failure of the normal lighting of the building.
- These must have exits wide enough to handle occupants from upper floors as well as occupants from the various public section of the building. Two exits are the minimum required for hotel occupants.
- If there is only one means of agree, caution must be taken to ensure that occupants cannot be trapped by the construction or design of a tower. Fire alarm system must be needed.
- These present special life safety risks because of the difficulty of venting combustion products. They must have complete automatic sprinkler protection and automatic smoke venting system. Outside access panels are required for windowless buildings.

- For avoiding fire and controlling fire immediately following notice board must be placed inside the industry or at every production floor.

When placing portable fire extinguishers, select locations that will

- Provide uniform distribution.
- Provide easy access and be relatively free from temporary blockage.
- Be near normal paths of travel.
- Be near exits and entrances.
- Be free from the potential of physical damage.
- Be readily available.

## 5. CONCLUSION

In terms of occupational safety and health, there are volumes of materials, information and aids available to anyone. There are now more safety practitioners, advisors and consultants. The fast face at which Malaysia is advancing technologically means that information and guidance on any safety and health issues can easily be accessed. Even the government is trying their level best to curb the astounding accident statistics and every effort is being made to make the work site more conducive. Unfortunately the work sites are far from perfect and are still unsatisfactory. This is mainly due to the attitude of those involved in the industry, in short apathy. This greatest fallacy of all is the old cliché: "nothing *serious has so far happened, so perhaps we have got it under control. there is really no need to do anything more about it, and anyway, nasty things always happen to other people. they will not happen to us"*. The only tool to fight apathy is education. This issue has rightfully been codified in the OSH Act 1994,15 (s)(c) which requires the provision of information, instruction, training and supervision. A proper safety system should identify the four fundamental issues of involving key members, effective communication, managing contractors and risk identification. This will in turn ensure the construction site is a safer and comfortable place to work.

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# STUDY ON PARTICULATE MATTER IN AIR OF GAZIPUR AND DHAKA CITY

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## ABSTRACT

Particulate matter (PM) is the term for particles found in the air, including dust, dirt, soot, smoke and liquid droplets. Particulate matter (PM) was analyzed by PM analyzer in two locations in Gazipur (Chawrasta, Shibbari) and two locations in Dhaka (Mohakhali, Farmgate). For PM, $PM_{10}$ and $PM_{2.5}$ was analyzed. Positive relation obtained with $PM_{2.5}$ and traffic volume in almost all stations. That indicates the possible source of $PM_{2.5}$ is traffic, especially diesel operated vehicles. $PM_{10}$ Concentration was found to be high with day time passing and become low in afternoon and has no distinct relation with traffic volume. That indicates possible source of $PM_{10}$ are unpaved road shoulder and construction activity beside the road. Roads in Dhaka and Gazipur should be paved and planted should be done in median lane and/or shoulder. Vehicles should be added with catalytic converter or other device to refrain the emission of $PM_{2.5}$.

**Key Words:** Air, Dhaka, Gazipur, Particulate Matter, $PM_{10}$, $PM_{2.5}$, Traffic

## 1. INTRODUCTION

Particulate matter (PM) is the term for particles found in the air, including dust, dirt, soot, smoke and liquid droplets. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that they can be detected individually only with specialized microscopes [1]. Particles are directly emitted into the air from a variety of sources, such as vehicles, factories, construction sites, farming, unpaved roads, burning wood, and blowing sand and dust in desert environments. Others particles may be formed in the air when gases from burning fuels chemically react with sunlight and water vapor. These can result from fuel combustion in motor vehicles, at oil fields and refiners, at power plants, and in other industrial processes [2].

Small particulate matter that is less than 10- micrometers in diameter can be breathed in (inhaled) into respiratory tract. A 10- micrometer particle is roughly one- sixth the width of a human hair. This is called (PM-10) size range. In some areas, particulate matter can be very heavy because of high levels of industrial activity or natural environmental conditions (e.g., dry, dusty climates). In these types of environments, large amount of PM can be inhaled. Particulate matter air pollution can cause a variety of health problems [3, 4, 5, 6]. Particle pollution is made up of different substances, including carbon, sulphur and nitrogen compounds metals, and soil or dust particles. These particles come in different shapes and sizes and can be either solid or liquid particles. Particle size is usually measured in units of one millionth of a metre – a micron. PM10 refers to particles that are 10 micrometers or

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smaller in diameter. This is about one-eighth the diameter of a human hair. PM10 includes coarse particles that range in size from 2.5-10 micrometers in diameter. Fine particles, which have diameters less than 2.5 micrometers (PM2.5) are most closely linked to serious health effects [1]. Fine particles can be inhaled more deeply into the lungs, where they are slow to clear. Dust is an irritant that bothers some people more than others. Symptoms such as coughing, sneezing, sinus congestion, sinus drainage (drip), and sore throat are common during peak periods. People with asthma or allergies may feel worse or need more medicine than usual. These effects usually go away quickly after the local weather improves, and permanent health effects are uncommon [7].

Long term health effects of PM in the atmosphere have been conducted by organizations, including the American Cancer Society, Harvard University, and the Health Effects Institute (a non profit organization jointly funded by the U.S. Environmental Protection Agency) [1] and industry). In general these studies suggest that PM does effect long-term lung function, especially in the young and elderly, although this generally occurs only after very long periods (years) of exposure.

In addition, research indicates that potential health effects may be related to the type of particles, as well as to the concentration. For instance, particulates generated from combustion and industries have a different chemical nature than sand. However, because current PM studies are inconclusive or inconsistent in their findings the U.S. EPA is continuing to try to resolve this issue [1].

Particulate matters (PM) are so common in Southwest Asia; the office of the special Assistant for Gulf War Illnesses conducted a study on the health effects of PM. This study examined the potential for adverse health effects from long-term exposure to silica and soot (the main components of PM in Southwest Asia) [4,5,6]. The study found that, at high concentration in an occupational environment, and under conditions of extent exposure, high levels of inhaled PM can lead to changes in lung function, damage to lung tissue, and altered respiratory defense mechanisms (e.g. an impaired ability to naturally eject or cough up foreign matter via exhalation). However, limiting outdoor activity during periods of high PM will help reduce exposure that might lead to these conditions. In an study PM collected from different locations of Dhaka city and it has been found that about 30 - 50% of the PM10 mass (depending on location) is fine particles with aerodynamic diameter less than 2.5 μm which are mainly of anthropogenic origin and predominately from range transport during the winter time, the PM concentrations remain much higher than the Bangladesh transport related sources. Another study found $PM_{10}$ concentration in Dhaka city exceeds 68 $\mu g/m^3$, which is much higher than the DOE standard [9]. Major part of this PM is contributed by construction site. Objective of this study is to determine the concentration of particulate matter in air in Dhaka and Gazipur city at different locations and to identify possible source of particulate matter. A health survey was conducted along the road side to evaluate impact of PM on health of road side people.

## 2. METHODOLOGY

Particulate matter (PM) was analyzed by PM analyzer in two locations in Gazipur (Chawrasta, Shibbari) and two locations in Dhaka (Mohakhali, Farmgate) as per methods described earlier [5, 6]. For PM, $PM_{10}$ and $PM_{2.5}$ was analyzed. Traffic Survey was conducted along with PM analysis in same hours. In addition health survey was conducted in the same place in order to evaluate the impact of PM in health of road side people.

## PM Concentration Analysis

### $PM_{10}$

$PM_{10}$ was analyzed by Fine Particulate Matter Sampler of Envirotech, India. $PM_{10}$ was analysis for 1 hour air sample placing the instrument beside the road in each location. The data was taken for 3 times (10:30am-11:30am, 12:30pm-01:30pm, 02:30pm-03:30pm) throughout the day. In $PM_{10,}$ particles less than 10µm were arrested in filter.

### $PM_{2.5}$

$PM_{2.5}$ was analyzed by the same sampler. $PM_{2.5}$ was analyzed for 1 hour air sample placing the instrument beside the road each locations. The data was also taken for 3 times (11:30am-12:30am, 01:30pm-02:30pm, 03:30pm-04:30pm) throughout the day.
For $PM_{2.5}$ an additional Attachment was added to screen and the particles in between $PM_{10}$-$PM_{2.5}$, then particles less then 2.5micrometer were arrested in the filter.

### Traffic Survey

Traffic volume was conducted for same hour as PM concentration analysis was done. Hourly volume was taken as per the standard method of traffic survey. Different number of vehicles was counted throughout the hour in both directions.

### Health survey

For health survey we have collected the various information from the road side people in the same location by using questionnaire

## 3. RESULTS AND DISCUSSION

Particulate matter (PM) was analyzed by PM analyzer in two locations in Gazipur (Chawrasta, Shibbari) and two locations in Dhaka (Mohakhali, Farmgate). For PM, $PM_{10}$ and $PM_{2.5}$ was analyzed. Traffic Survey was conducted along with PM analysis in same hours. In addition health survey was conducted in the same place in order to evaluate the impact of PM in health of road side people. $PM_{10}$ and $PM_{2.5}$ were observed high in all locations. Between the two stations in Gazipur, PM was found to be high in Chawrasta. $PM_{10}$ and $PM_{2.5}$ were found as 898.2 µg/m$^3$ and 710.66 µg/m$^3$ respectively (Fig. 1). Between the two stations in Dhaka, PM was found to be high in Farmgate. PM10 and PM 2.5 were found as 556.59 µg/m$^3$ and 397.22 µg/m$^3$ (Fig. 2) respectively.

Positive relation is obtained with $PM_{2.5}$ and traffic volume in almost all stations. That indicates the possible source of $PM_{2.5}$ is traffic, especially diesel operated vehicles (Fig. 3). $PM_{2.5}$ is found to be high in Chawrasta even with low traffic than Mohakhali because in expected that most of these particles

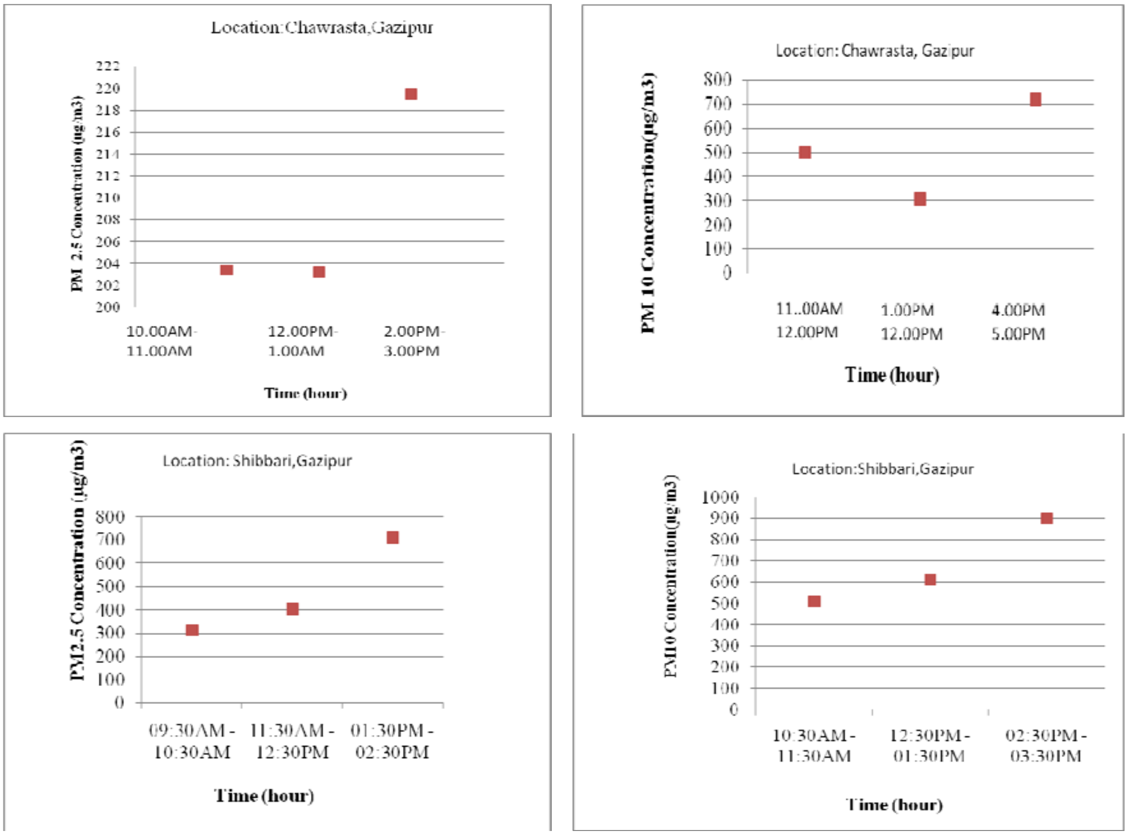


Fig 1: $PM_{2.5}$ and $PM_{10}$ at Chawrasta and Shibbari, Gazipur at different time of the day.

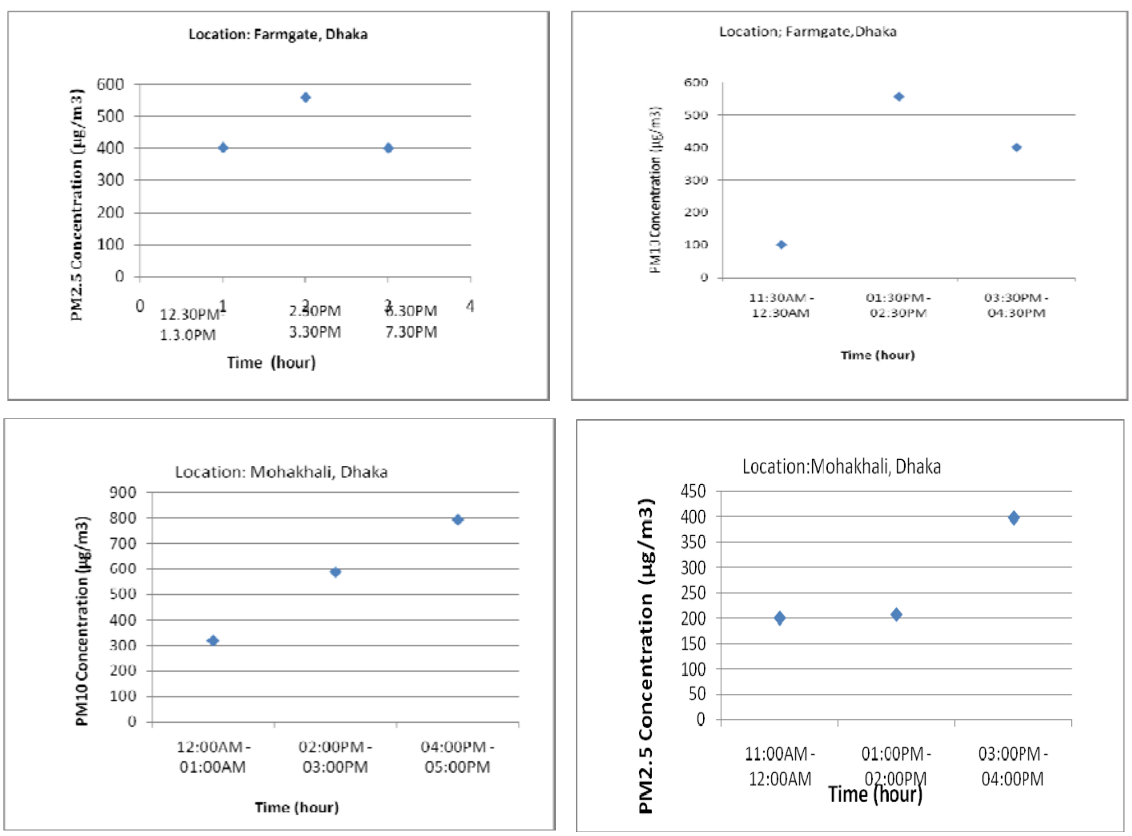


Fig 2: $PM_{2.5}$ and $PM_{10}$ at Farmgate and Mohakhali, Dhaka at different time of the day.

Chawrasta more traffic is diesel operated. Particulate matter emissions from road transport arise as direct emissions from vehicle exhausts, tyre and brake wear and re- suspension of road dust. In urban areas, emissions from road transport are thought to be the major source of PM10. In general, diesel engine vehicles emit a greater mass of fine particulate matter, per vehicle, than petrol engines Diesel emissions are mainly composed of soot particles, volatile hydrocarbons and some sulphate from the fuel sulphur. When hydrocarbons and sulphates are released by the car exhaust they condense on airborne particles, mainly on the freshly emitted carbon. The size distribution of these particles tends to be bimodal, with particles of 0.01 to 0.05 µm in the nucleation mode in the case of freshly emitted soot particles and, of some 0.05 to 2.5 µm in the accumulation mode in the case of older coagulated soot particles [7, 8,10]. The movement of vehicles on the street also results in re suspension of road dust. Emissions also occur as a result of tyre wear and brake lining wear. Although there is a lack of data, it is will be in the size range (3 to 30) µm. The chemical composition of these particles may the road dust deposit available for re- suspension comes from mechanical wear of, and dirt on, vehicles (tyre and brake lining wear), debris from loads on vehicles, influx of soil material etc. In some parts of Europe, notably in Scandinavia, the widespread use of studded tyres on vehicles wears off the road surface (asphalt, concrete) to such an extent that the resulting particle deposit on the road becomes the totally dominating source of re suspension particles. This source is active during dry winter situations on snow/ice-free roads and causes substantially increased PM10 concentrations.

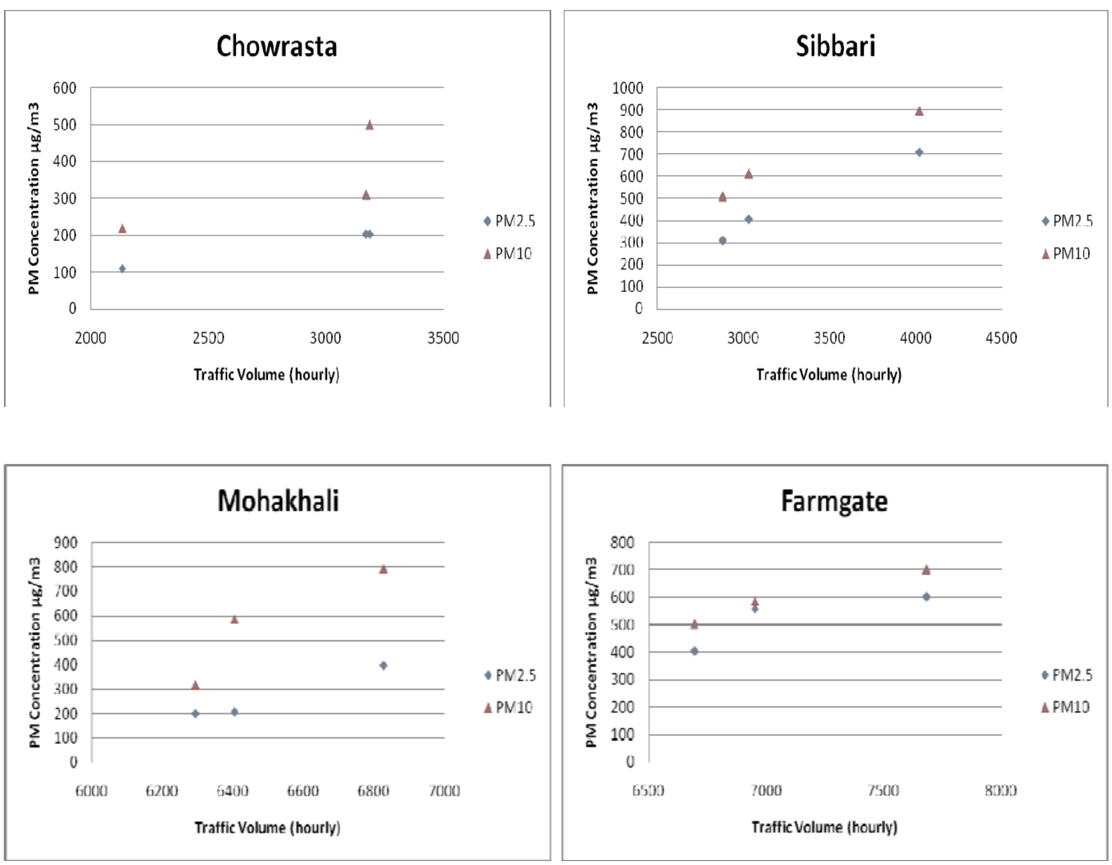


Fig 3: Correlation with PM and traffic volume

Due to rapid and unplanned urbanization, the total number of vehicles has increased enormously. Most of the cars, jeeps, auto-rickshaws, motorcycles, etc., ply in the cities. This has really led to a deterioration of air quality, particularly in Dhaka [5, 6, 10]. The blackening of the city air and reduced visibility are observed in some areas, especially during dry seasons, even with unaided eyes. Episodes of choking smells and irritating eyes are common. With rising population growth, the urbanization in Bangladesh is also taking place at a quick pace. The current population of the country stands at 140.5 million out of which 12.7 million people live in the capital, Dhaka. One estimate says by 2050, 57% of people will be living in cities, compared to 26% in 1990. By 2015, Dhaka may become one of the densest cities of the world. The unplanned urban development coupled with urban population growth will result in increased demands for transport, energy and other infrastructure that in turn will result in high emission levels [6,10]. The vehicles in Dhaka City are increasing rapidly. The vehicles growth in Dhaka is shown in Fig. 4. in recent year. The largest polluters are trucks and buses, although they are only 10% of the total automotive vehicles in Dhaka. These cause about 44% of the $PM_{10}$ pollution. The automobiles on the roads are often very old, overloaded, and poorly maintained. Other old vehicles, including 40-year old trucks and dilapidated mini-buses, are also plying on the city streets emitting smokes and gases. According to an assessment made by DOE, a large cross-section of the vehicles that ply on the streets of Dhaka daily are faulty, and emit smoke far exceeding the prescribed limit. Black smoke which is primarily unburned fine carbon particles is emitted by diesel vehicles. $PM_{10}$ Concentration was found to be high with day time passing and become low in afternoon and has no distinct relation with traffic volume. That indicates possible source of $PM_{10}$ are unpaved road shoulder and construction activity beside the road. As the sunshine increase with day time passing more $PM_{10}$ occurs in air that indicates this relation. $PM_{10}$ and $PM_{2.5}$ is found to be high as much higher than ambient air quality standard for urban area of Bangladesh and WHO ambient air quality guidelines (Fig. 5).

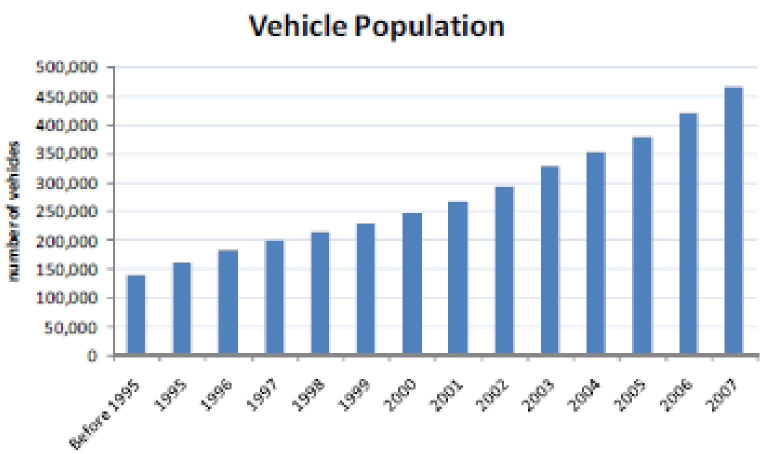


Fig 4. Vehicle growth in Dhaka city between 1995 and2007 (Source BRTA)

Most of the people from health survey responded that the reason of their cough, cold, asthma, headache, eye irritation is the dust in air. People are anxious about the dust in air in Dhaka and Gazipur. They are willing to get rid of this problem. Both PM10 (big) and PM2.5 (small) particles can cause health problems; specifically respiratory health (that's the lungs and airway). Because the PM2.5 travels deeper into the lungs and because the PM2.5 is made up things that are more toxic (like heavy metals and cancer causing organic compounds), PM2.5 can have worse health effects than the bigger PM10.

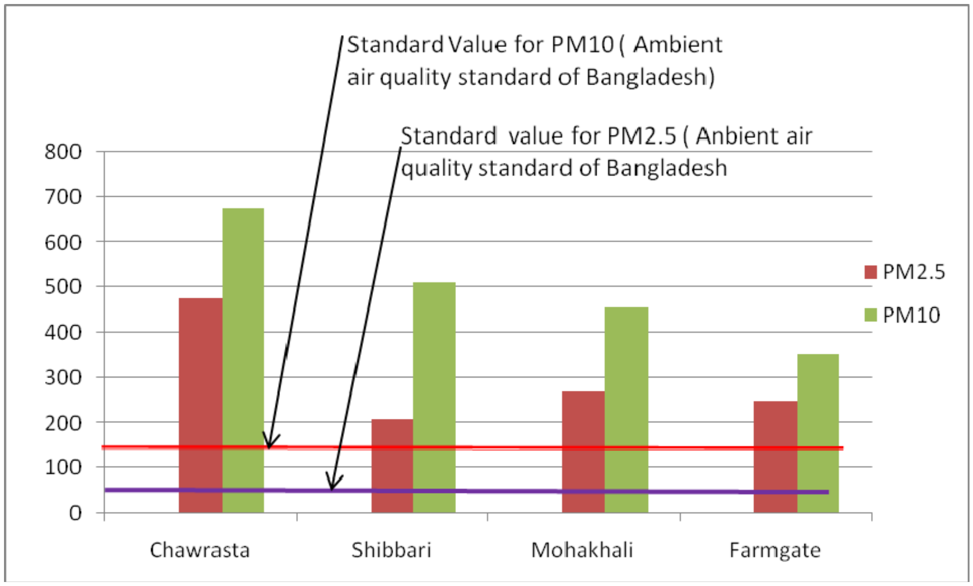


Fig 5: Comparison of PM with ambient air quality standard

Exposure to particulate matter leads to increased use of medication and more visits to the doctor or emergency room. Health effects include the following:

- Coughing, wheezing, shortness of breath
- Aggravated asthma
- Lung damage (including decreased lung function and lifelong respiratory disease)
- Premature death in individuals with existing heart or lung diseases

## 6. CONCLUSIONS

The Strategic Framework note several challenges in Dhaka city relating to policies and regulatory issues, magnitude of air pollution, emissions inventories and source apportionment. Challenges for air quality management policies in Dhaka include among others:

- Low government commitment
- Limited co-ordination and sectoral integration
- Limited collaboration between different agencies
- Poor institutional capacity
- Absence of appropriate review mechanisms
- Regional differences in regulation of emission sources
- Deficiencies in setting air quality standards
- Lack of
    - Stakeholder participation;
    - Up-to-date emission standards;
    - Monitoring and quantitative data on air quality and its impact on human health and the environment.

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Challenges regarding law enforcement and implementation of an integrated air quality management system in Asia include among others:

- Conflicts through duplicated responsibilities
- In appropriate technical equipment and ignorance about its usability
- Prevalence of ad hoc awareness raising with a focus on raising alarm
- Poor information on public participation
- Deficiencies in information dissemination
- High cost of awareness raising programs.
- Design and implementation of AQM strategies often based on incomplete knowledge
- Potential of misinterpretation of air quality reporting and information
- Insufficiency of adequate communication strategies among stakeholders
- Inadequate regulatory, planning, technical, social, institutional, and financial capacity for (AQM).
- Lack of
    - Reporting to upper management in agencies
    - Inter-Agency communication.

In addition to take measures to above challenges, roads in Dhaka and Gazipur should be paved and planted should be done in median lane and/or shoulder. Vehicles should added with catalytic converter or other device to refrain the emission of $PM_{2.5}$.The construction site should be well covered in all urban areas. Some regulators and laws should be introduced and enforced.

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# VETIVER GRASS AS A SUSTAINABLE LOW COST SLOPE PROTECTION MEASURE IN BANGLADESH

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## ABSTRACT

Embankment and river bank failure is a common phenomenon in the history of Bangladesh. From field surveys, it is found that erosion due to rain splash, wave action, overtopping of storm surge, poor maintenance practice, overturning or uprooting of trees are general reasons of embankment and river bank failure. It is found that the traditional practice for protection of such structures are to use cement concrete blocks, stone or wood revetments, geobags, geotextile and plantation etc. These are expensive and not so effective to protect the embankments, river bank and slopes for the designed life. On the other hand, protection of slopes using vegetation is being used efficiently in many parts of the world. This paper presents the effectiveness of vetiver grass as a sustainable low-cost solution to protect slopes and embankments against natural disasters such as cyclonic storm surge and flood. Shear strength of vetiver rooted soil is 90% higher than that of soil without root. It is estimated that vetiver rooted soil matrix is able to increase the factor of safety of slopes by 1.8 to 2.1 times. Cost of vetiver grass protection is significantly lower than that of other common methods used for slope and embankment protection. It means that vetiver grass might be a sustainable low cost solution to protect slopes against natural disasters such as cyclone and flood in Bangladesh.

**Keywords:** low cost, natural disaster, slope protection, shear strength, sustainable, vetiver.

## 1 INTRODUCTION

Bangladesh is a reverie country and she also has a very long coast. About 4000 km of coastal embankments have been constructed to safeguard against inundation, intrusion of saline water and devastation. During the years from 1797 to 2010, Bangladesh has been hit by more than 60 severe cyclones. Flood is a common disaster and during the monsoon (June to October) 30 to 50% of the entire country becomes flooded. As the embankments, river bank and other hydraulic structures are the first defense against the storm surge and flood, they received the most severe injury. Over the last few decades, nearly 13000 km of flood and river embankments have been repaired in Bangladesh. Traditional practice for protection of such embankments is to use cement concrete (CC) blocks, stone or wood revetments, geotextile and geobags, etc. These are expensive and in many cases not effective

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to protect them during their designed lives [1]. Though tree plantation is also a cost effective methods but during cyclone and storm surge, it cut-off the transportation systems of affected areas by uprooting and enhance the sufferings of affected peoples.

On the contrary, our State budget is never sufficient which confines rigid structural protection measures to the most acute sections, never to the full length of the river bank or coastline and embankment. This bandage approach compounds the problem. On the other hand, hard engineering structure makes the scenic environment unpleasant and helps only to transfer the problem from one place to another place, to the opposite site or downstream, which aggravates the problem rather than reducing. Establishment of vegetation as a soft bioengineering technique to rigid or hard structures has been accepted all over the world due to its low-cost, longevity and environment friendliness [2].

Many researchers have been conducted to know the performance of vetiver grass against climatic change, slope protection, coastal embankment protection and so on. Hengchaovanich [3] analyzed slope stability based on vetiver root strength. Ke et al. [4] tested vetiver as a bank protection measure on several test sites in Australia, China, Philippines and Vietnam. Their tests showed promising results for the use of vetiver grass as a bank protection measure. Verhagen et al. [5] conducted different laboratory and model tests on vetiver grass to realize the use of it in coastal engineering and showed that vetiver grass is able to establish a full-stop of bank erosion caused by rapid draw down.

Dudai et al. [6] studied the growth management of vetiver grass under Mediterranean condition. They found that the plant height and the number of sprout per plant in clay soil under long day conditions were significantly higher than under short day. They also found that the heights of irrigated vetiver plant in open fields were higher than those of rain-fed plants. They suggested that in order to obtain fast growth of vetiver and to increase the possibility of using the rainwater for their growth, the plants should be planted during winter (i.e., February to March). But unfortunately, a very few researches have been conducted in local level in Bangladesh for the protection of embankment against natural disasters such as cyclone and flood using vegetation such as vetiver grass.

Islam [7] studied the performance of vetiver grass on eighteen coastal polders over eighty- seven kilometers of earthen coastal embankment of Bangladesh during the period from September 2000 October 2001. He observed that the main problem in maintaining those earthen embankments is water borne erosion either through surface run-off or from wave action or both. He provided some guidelines on vetiver application which is helpful for better performance. He achieved successful cases where initial protection and watering could be ensured.

Moula et al. [8] studied on the nursery performance of vetiver grass during the period from June 2000 to June 2001 with different number of tillers. He investigated the optimum number of tillers per clump for the proper propagation of vetiver grass. According to their observation, it is revealed that propagation of vetiver clump with double tillers is better than single or triple tillers.

This paper investigates the prospect and performance of vetiver grass as a low cost slope protection measures against natural disasters. This paper also investigates the availability and sustainability of vetiver grass in the cyclone and flood affected regions of Bangladesh and estimates the stability of slopes with vetiver grass. Finally, the cost of vetiver grass for embankment protection has been compared with that of other conventional methods for embankment protection.

## 2 FIELD SURVEY AND TEST PROGRAM

### 2.1 Survey for Vetiver Availability in Bangladesh

Field survey was conducted to know the vetiver availability and their types in Bangladesh. Sustainability of vetiver grass in the climatic and soil condition of Bangladesh was also studied.

## 2.2 Laboratory and Field Tests

Sub-soil investigation was carried out at some selected locations of the coastal regions of Bangladesh. Figure 1 shows the location of study areas on Bangladesh map. Tests were conducted on the collected samples in the Geotechnical Engineering Laboratory of Bangladesh University of Engineering and Technology. Field block samples were collected to determine the in-situ density of the soils. A detailed laboratory investigation was carried out on 24 soil samples collected from coastal zone of Bangladesh. All the tests were conducted according to ASTM standards [9].

Tests were conducted to determine the in-situ shear strength and failure strain of vetiver rooted soil and bare soil at coastal zone of Bangladesh. Soil samples were collected in polythene bags during the field tests for laboratory investigations. In-situ shear strength test was conducted in the field on twenty four block samples. Schematic diagram of the test set-up is shown in Figure 2. Tests were conducted under different normal stresses at different depths. Normal stresses were arbitrarily selected

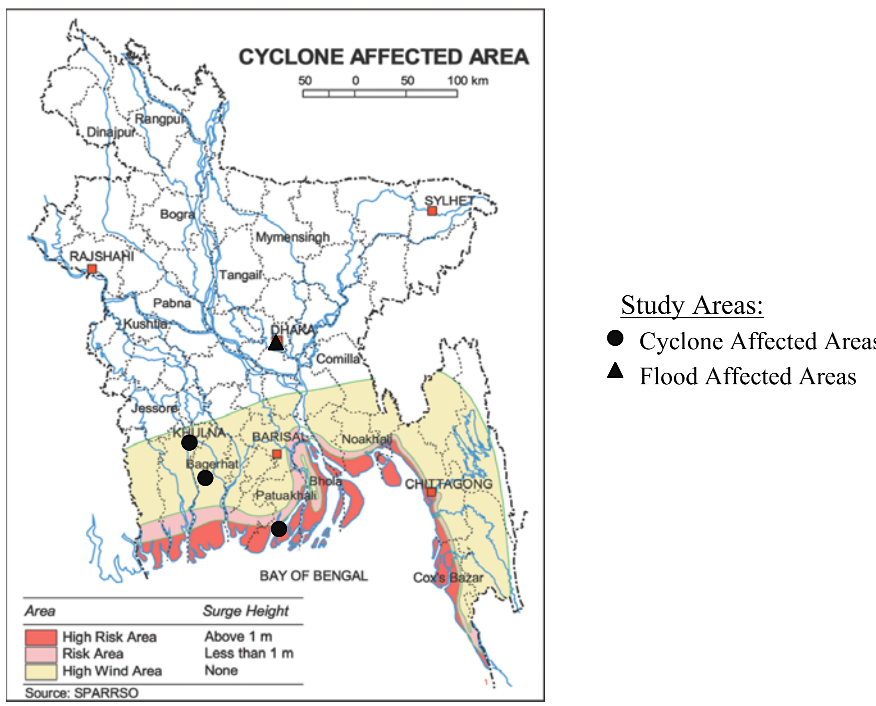



Fig. 1 Location of study areas on Bangladesh map.

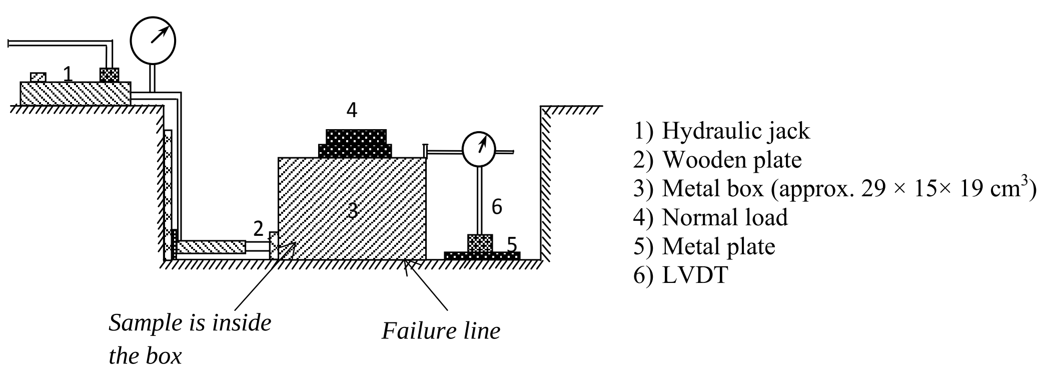



Fig. 2 Schematic diagram of the test set-up for in situ-shear strength determination.

in the range between 10.96 kPa and 19.98 kPa. More details about the sample preparation, experimental set-up and test method are available in Islam et al. [10].

## 3 STABILITY OF EMBANKMENTS

The factor of safety of embankment slope is estimated using the mass procedure of slope stability analysis [11]. For this method of analysis, it is considered that the soil is homogeneous. Figure 3 shows the stability analysis mechanism of slope by mass procedure [11]. Here, β is slope angle, φ is angle of internal friction, c is cohesion, H is height of slope, $c_d$ is developed cohesion at failure plane and defined by Equation 1. α and θ are shown in Fig. 3.

$$c_d = \gamma H[f(\alpha, \beta, \theta, \varphi)] \quad (1)$$

For critical equilibrium— that is, $F_c = F_\varphi = F_s = 1$— it can substituted $H = H_{cr}$ and $c_d = c$

Then, $$\frac{c}{\gamma H_{cr}} = [f\,(\alpha, \beta, \theta, \varphi)] = m \quad (2)$$

where, γ is unit weight, m is stability number, $H_{cr}$ is critical height, $F_c$ is factor of safety with respect to cohesion and $F_\varphi$ is factor of safety with respect to friction angle. The value of stability number (m) can be obtained from $F_c$ versus $F_\varphi$ graph [11].

Again, $F_c = \frac{c}{c_d}$ and $F_\phi = \frac{\tan\phi}{\tan\phi_d}$

where, $\varphi_d$ = developed angle of internal friction at failure plane.

Then the $F_c$ versus $F_\varphi$ is plotted in a plain graph. From the $F_c$ versus $F_\varphi$ graph the factor of safety $F_s$ is estimated.

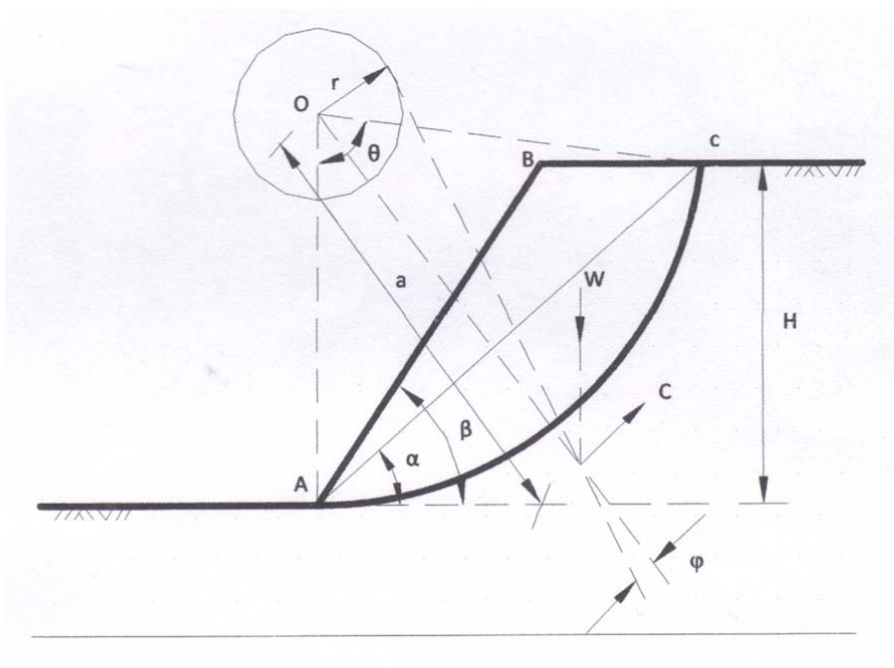



Fig. 3 Stability analysis of slope in homogeneous soil (φ > 0) using mass procedure [11].

# 4 RESULTS AND DISCUSSIONS

## 4.1 Field Survey

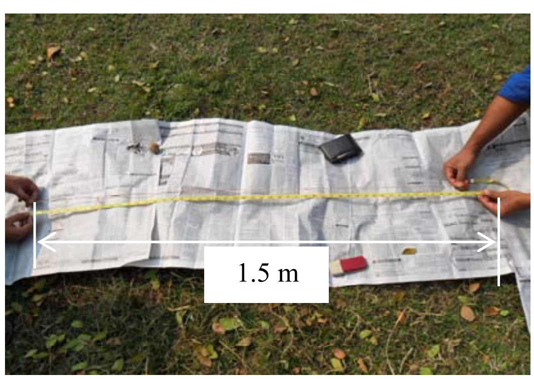
### *4.1.1 Availability of Vetiver in Bangladesh*

Field survey was carried out to know the availability and types of vetiver grass in different parts of Bangladesh. It is found that vetiver is available in most parts of Bangladesh with vernacular names. Five types of vetiver grass like Bennashoba (*vetiver*), KhusKhus (*Vetiveria zizanioides*), Gondhabena (*vetiver*), Ecorban (*vetiver*), Vetiveria zizanioides (*dwarf ecotype*) are available in Bangladesh [12].

It is found that vetiver is very common in the division of Chittagong, Dhaka and Rajshahi which is about 40% of the total land area of Bangladesh. Vetiver is common in the Khulna, Sylhet division and other parts of Bangladesh which is about 45% of the total land of Bangladesh. There are some other districts of Bangladesh like Barguna, Bagerhat, Bhola, Jamalpur, Pirojpur and Shatkhira where vetiver is rarely found which is about 15% of the total area of Bangladesh [13]. It is observed that vetiver is commonly available in the coastal regions of Bangladesh. During field survey at Kuakata naturally grown vetiver was found.

Survey was also carried out at Pubail, Gazipur district to find the availability of vetiver grass. It was found that vetiver grass is available in that area. The massive root system and depth of roots of vetiver grass found in this area are presented in Figure 4a and 4b, respectively. It is observed that vetiver has strong root system and root length of a one year old vetiver grass is found to be more than 1.5 m (Fig. 4b).

**(a)**




**(b)**

Fig. 4 (a) Massive root system of vetiver and (b) length of vetiver root found in Pubail, Gazipur.

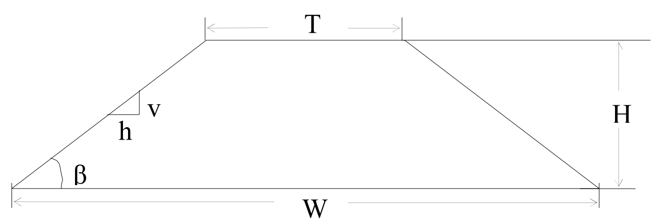
Table 1: Tolerance of vetiver grass in abrupt climatic condition and climatic condition of coastal regions of Bangladesh

| Parameters | Tolerable limit of vetiver grass | Coastal climatic condition | Remarks |
|---|---|---|---|
| Temperature (˚C) | -15~50 | 15~41 | In the tolerable range |
| Annual rain fall (mm) | 200~5000 | 1500~2750 | In the tolerable range |
| Salinity ($dSm^{-1}$) | < 20 | 2~10 | In the tolerable range |
| pH | 3.0~10.5 | 6.0~8.4 | In the tolerable range |

Survey was also carried out to know the survivability of vetiver grass in the coastal regions of Bangladesh. Table 1 shows the comparison between the tolerances of vetiver grass in the abrupt climatic condition of the coastal regions of Bangladesh. From the Table, it is seen that the climatic and soil condition of the coast of Bangladesh is between the tolerable limit of vetiver grass. It means that vetiver can grow in the coastal regions of Bangladesh.

### *4.1.2 Causes of Embankment Failure at Coast*

Figure 5a shows a typical embankment section at the coast of Bangladesh. Embankments are constructed at the coast of Bangladesh with slopes in the ratio of 2:1 to 3:1 (horizontal, h and vertical, v) direction. Height (H) of embankments varies from 2.2 m to 4.0 m. Width of embankment surface (T) varies from 3.0 m to 4.5 m and width of the base of embankment (W) varies from 15.0 m to 22.5 m.




**(a)**

**(b)**

Fig. 5 (a) Typical embankment section (h = horizontal; v= vertical; T= top width; w= base width; H= height of the embankment; β= slope angle) and (b) eroded embankment section due to wave action.

The main causes of embankment failure are: erosion due to rain splash, wave action, overtopping of storm surge, overturning or uprooting of trees during cyclone, inaccurate construction of side slope of embankment and poor maintenance practice. Among these main causes of embankment failure to rain splash and wave action is most vulnerable for coastal embankment.

Photograph of Figure 5b shows an eroded embankment section due to wave action. From the Figure, it is clear that due to wave action soil particles from embankment are washed away and the slope of embankment becomes steeper. Therefore, it reduces the cross section and also the factor of safety of the embankment.

## 4.2 Sub-Soil Characteristics of Coastal Zone

### *4.2.1 Physical and Index Properties*

The physical and index properties as well as grain size of the samples are presented in Table 2. Specific gravity ($G_s$) of the soil sample varies from 2.62 to 2.70. Dry unit weight and moisture content of the clayey silt, silty clay or silty sand samples varies from 10.8 to 14.7 kN/m$^3$ and 30 to 54%, respectively. The mean grain size ($D_{50}$) and fines content ($F_c$) of the silty clay or clayey silt soil varies from 0.007 to 0.02 mm and 90 to 98%, respectively. The mean grain size ($D_{50}$) and fines content ($F_c$) of dense sand varies from 0.08 to 0.30 mm and 7.3 to 36.5%, respectively. Liquid limit (LL), plastic limit (PL) and plasticity index (PI) of clayey silt or silty clay layer varies from 35 to 50%, 25 to 28% and 9 to 25%, respectively. Using the results of grain size analysis, soil samples have been classified according to the ASTM D 2487 [9]. It has been found that the soil samples are silty sand (SM), silty clay (CL-ML) or clayey silt. Figure 6 shows some typical borelogs of coastal regions (Bagerhat district, Patuakhali district and Khulna district) of Bangladesh.

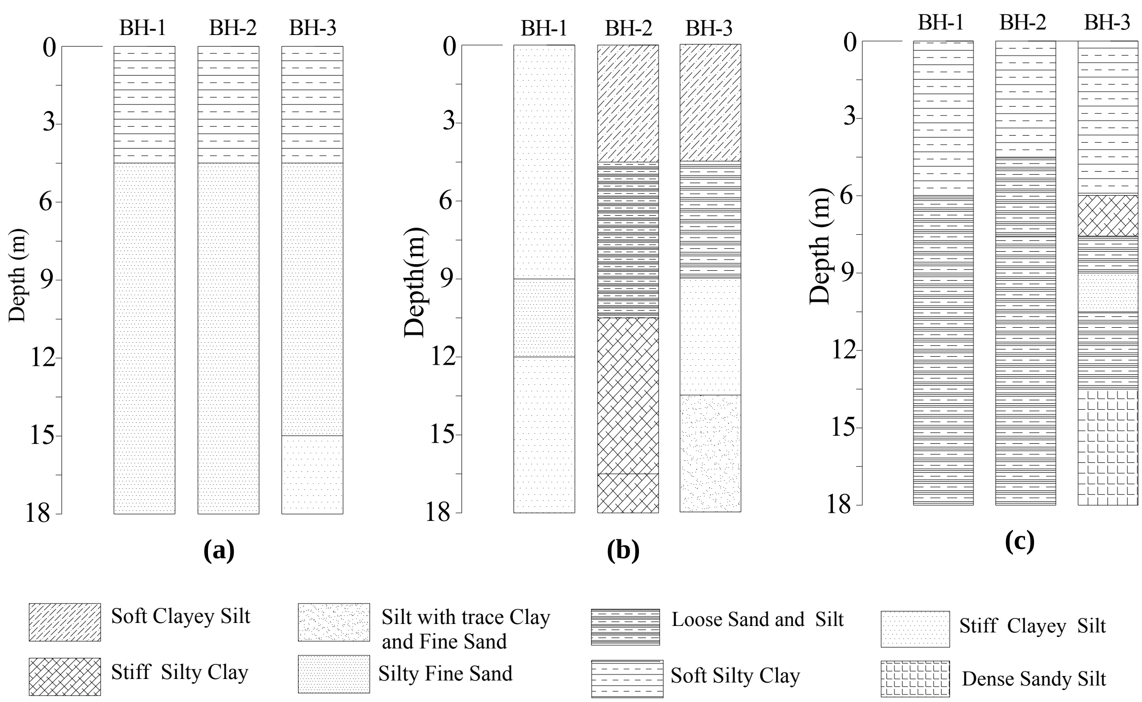



Fig. 6: Typical borelogs at coastal regions of Bangladesh at: (a) Bagerhat district; (b) Patuakhali district and (c) Khulna district.

Table 2: Physical properties and shear strength characteristics of soil samples collected for coastal regions

| Soil type | $G_s$ | $w_n$ (%) | $\gamma_d$ ($kN/m^3$) | $D_{50}$ (mm) | $F_c$ (%) | PI | c (kPa) | φ (˚) |
|---|---|---|---|---|---|---|---|---|
| Silty sand | 2.65~2.70 | 30~40 | 12.7~14.7 | 0.080~0.30 | 11~40 | NP | − | 25~28 |
| Silty clay | 2.63~2.68 | 35~49 | 11.3~11.7 | 0.010~0.02 | 80~89 | 11~17 | 8~9 | − |
| Cayey silt | 2.62~2.68 | 42~54 | 10.8~11.6 | 0.007~0.02 | 80~98 | 09~25 | 8~9 | − |

Note: $G_s$ = specific gravity; $\gamma_d$ = dry unit weight; $w_n$ = natural moisture content; $D_{50}$ = mean grain size; $F_c$ = fines content; PI = plasticity index; c = cohesion; φ = angle of internal friction and NP = non-plastic

#### *4.2.2 Shear Strength Characteristics*

Direct shear tests were carried out on ten silty sand soil samples according to ASTM D 3080. The cohesion and angle of internal friction of the soil samples vary in the range from 8 to 9 kPa and 25˚ to 28˚, respectively. Here cohesion is very low and it is reasonable, because the tested soil samples were silty sand and the percentage of clay was 5%. The shear strength properties are presented in Table 2.

### 4.3 In-situ Shear Strength Properties

A total of 24 block samples were tested in the field under different normal stress (i.e., 10.96 kPa, 15.47 kPa and 19.98 kPa) at different depths (200 mm and 400 mm) from the Existing Ground Level (EGL). Out of 24 samples, 12 samples were vetiver rooted soil and 12 samples were soil without root.

Two tests were conducted for each case to check the repeatability of the test results. It is found that for a particular normal stresses the strength of vetiver rooted soil is 90% higher than that of soil without root. Again, the cohesion and angle of internal friction of vetiver rooted soil matrix and soil without root at 200 mm depth from EGL is 15 kPa and 8 kPa and 35˚ and 18˚, respectively. It means that, vetiver grass able to increase the cohesion and angle of internal friction of vetiver rooted soil and therefore, increase the shear strength of vetiver rooted soil. So, it is clear that vetiver rooted soil matrix increases the factor of safety of slopes against natural disasters.

### 4.4 Stability of Slopes

Stability of slopes for different heights and different slope angles are estimated by using mass procedure of slope stability analysis (Section 3). For this analysis it is considered that the density of sol is 18 $kN/m^3$. The cohesion and angle of internal friction of vetiver rooted soil and soil without root is considered 15 kPa and 9 kPa and 35˚ and 18˚, respectively. It is found that for a particular soil the factor of safety of vetiver rooted soil slope is 1.8 to 2.1 times higher than that of the slope without root. The results are presented in the Table 4.

### 4.5 Cost of Different Slope Protection Measures

The common practices for protection of embankments in our country is to use cement concrete (CC) blocks, geotextiles, sand bags and wood revetment. Recently, in some slope protection works vetiver is also used in Bangladesh. According to the rate schedule of Local Government Engineering Department, LGED (July, 2009), the cost of vetiver application per square meter is 22 taka including labour and placement cost. Again, according to the work schedules of Water Development Board of Bangladesh, WDB (Dhaka Division Rate Schedule, 2009-2010) the cost of geotextiles and cement concrete blocks including labour and placement cost per square meter are 151 taka and 5843 taka, respectively.

Table 3: Comparison of factor of safety of embankment slope

| Height of embankment, H (m) | Side slope (h : v) | Factor of safety of embankment slopes without protection, $F_{sb}$ | Factor of safety of embankment slopes with vetiver grass protection, $F_{sv}$ | Ratio $= \frac{F_{sv}}{F_{sb}}$ |
|---|---|---|---|---|
| 2 | 2:1 | 2.7 | 5.4 | 2.00 |
| 3 | 2:1 | 2.4 | 4.3 | 1.79 |
| 3 | 1:1 | 1.6 | 3.0 | 1.88 |
| 4 | 2:1 | 1.8 | 3.8 | 2.11 |
| 4 | 1:1 | 1.2 | 2.5 | 2.10 |

Table 4: Comparison between costs of different slope protective measures

| Slope Protective Measures | Cost Per Sq. Meter (USD) | Height (m) | Length (m) | Width (m) | Area ($m^2$) | Cost (USD) |
|---|---|---|---|---|---|---|
| Vetiver Grass | 0.314 | 3.0 | 1000 | 6.71 | 6710 | 2109 |
| Geotextiles | 2.157 | 3.0 | 1000 | 6.71 | 6710 | 14475 |
| CC block | 83.471 | 3.0 | 1000 | 6.71 | 6710 | 560093 |

According to the rate schedule, the cost of one kilometer embankment section is estimated. It is considered that embankment having slope two horizontal to one vertical and embankment height is 3 m. Table 4 shows the cost estimation of the different slope protective measures. From the Table 4, it is seen that the cost of slope protection for one kilometer of embankment by vetiver grass is 2109 US $, by geotextiles is14475 US $ and by CC blocks is 560093 US $. Therefore, it is seen that the cost of slope protection by vetiver grass is significantly lower than the others method of slope protection measures.

## 5 CONCLUSIONS

Bangladesh has 32% coastal area (47,211 $km^2$). Unfortunately, this part of Bangladesh is most vulnerable to different natural disasters. About 4000 km of coastal embankments has been constructed to safeguard against inundation, intrusion of saline water and devastation.

The common practice for protection of such embankments is to use cement concrete (CC) blocks, stone or wood revetments, geotextile, geobags and plantation etc. These are expensive and in many cases not effective to protect them during their designed lives.

It is found that five types of vetiver are available at the coastal regions of Bangladesh. It is also found that vetiver is very common in the division of Chittagong, Dhaka and Rajshahi which is 40% of the total land area of Bangladesh. Vetiver is common in Khulna and Sylhet division and other parts of Bangladesh which is about 45% of the total land area of Bangladesh.

The coastal soil of the study area is predominantly silty sand. It means that slope made of such soil is vulnerable to tidal surge and flood. From the field test results, it is observed that for a particular normal stress the strength of vetiver rooted soil is about 90% higher than that of the soil without root.

For a particular soil the factor of safety of vetiver rooted soil slope is 1.8 to 2.1 times higher than that of the slopes constructed with soil without vetiver root.

Again, slope protection by vetiver grass is significantly cheaper than the other current practices. It means that vetiver grass might be a sustainable low cost solution for the protection of slopes against natural disasters such as cyclone and flood in Bangladesh.

Further researches are being conducted at BUET to elucidate growth parameters and establishment of vetiver under different climatic and soil conditions of Bangladesh. Management practices for growing vetiver in the climatic and soil conditions of Bangladesh is also under investigation at BUET.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# AN ASSESSMENT OF GREENER HOMES BY CODING AND RATING SYSTEM

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## ABSTRACT

The design, construction, and maintenance of buildings have a tremendous impact on the environment and natural resources. Building contributes almost 40 percent of $CO_2$ emissions and is a major contributor to the Green House Gas Emissions (GHG). Making our homes greener requires optimization of environmental impacts through efficient use of energy, water and building materials and proper disposal of waste. The study is an attempt to address the issues of greener homes by introducing codes leading to a rating system to minimize the environmental damage during its life span and to revolutionize the design of new buildings for healthy and more sustainable lifestyles. The code has been proposed based on six criteria covering energy, water, materials, waste, ecology, health and wellbeing. Each criterion is assessed and weighted based on its relative importance and a total score is obtained after assessing all the criteria. The buildings are rated with in a scale of 1-5 indicating how green the buildings are. It also recommended that all buildings should be certified or coded by a licensed and accredited code assessor to ensure that the rating is independent and trustworthy.

**Keywords:** Building materials, greener homes, sustainable construction.

## 1. INTRODUCTION

The concept of sustainability in building and construction has evolved over many years. In fact, the United Nations Centre for Human Settlements [1] acknowledges that housing is now universally recognized as a human right and that effort to implement this right must be strengthened and accelerated. Furthermore, the success and progress of human society depends on physical infrastructure, and a nation's economic strength is reflected in its infrastructure assets [2]. With almost 60 percent of world population expected to be living in urban areas by the year 2030 [3], massive construction activity is taking place globally.

Sustainable construction is a way for the building industry to move towards achieving sustainable development, taking into account the environmental, socio-economic and cultural issues. Specifically, it involves issues such as design and management of buildings, materials and building performance, energy and resource consumption - within the larger orbit of urban development and management [4]. Building greener homes requires optimization of environmental impacts such as water use, energy flow and waste output in addition to $CO_2$

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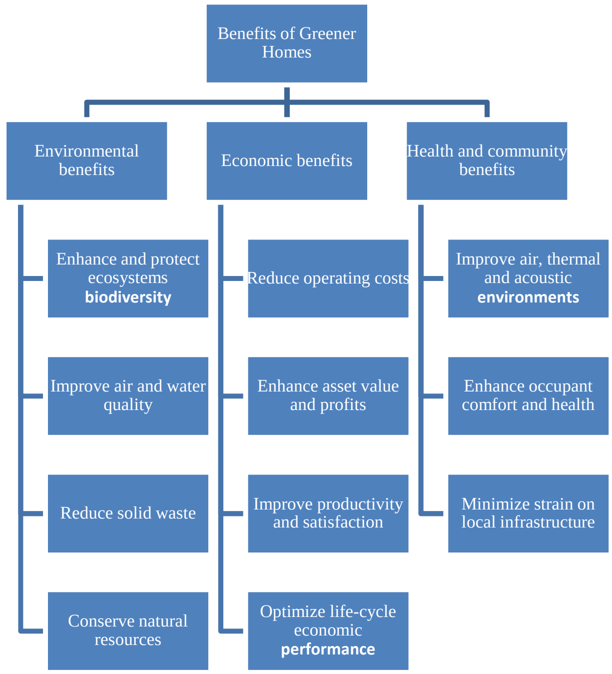
emissions from the building. Bangladesh is recognized worldwide as one of the countries potentially most vulnerable to the impacts of global warming and climate change [5] [6] [7] [8] [9] [10]. This is due to its unique geographic location, dominance of floodplains, low elevation from the sea, high population density, high levels of poverty, and overwhelming dependence on nature, its resources and services. Global warming has caused fundamental changes to our climate. According to the IPCC (2001) [8], a 45 cm sea-level rise could cause a potential land loss of 10.9 percent and a one meter sea-level rise a loss of 20.7 percent. The UNDP (2007) [11] predicts that 11 percent of the population will be directly threatened by a one meter sea-level rise. The fast growing mega city like Dhaka is more exposed due to its unplanned urbanization, rapid population growth and massive boom in construction sectors, improper management and planning. The wetland has been filled up for constructing houses, agricultural land around Dhaka city is decreasing very rapidly. Therefore, the study is an attempt to address the issues of greener homes by introducing a rating system indicating scale of 1-5 based on six criteria covering energy, water, materials, waste, ecology, health and wellbeing. Homes are coded to encourage their owners to live a more sustainable lifestyle and build homes in a more efficient way using materials from sustainable and locally available sources. This creates less waste with lower running costs.

## 2. CONCEPTS OF GREENER HOMES

Green buildings or homes practices offer an opportunity to create environmentally-sound and resource-efficient buildings or homes by using an integrated approach to design. Green homes or sustainable homes are the process of producing a constructed facility that encompasses ultimate energy efficiency, forward-thinking resources management, and general sustainable construction [12]. Achieving green building, however, requires an integrated team; combining a wide range of different specialists through in-depth collaboration so that the complexity of trade-offs between architectural features, value and cost, building services and other factors can be reached [13]. The characteristics of greener homes include:

- resource conservation, including energy efficiency, renewable energy, and water conservation features;
- consideration of environmental impacts and waste minimization;
- creation of a healthy and comfortable environment;
- reduce operation and maintenance costs and use of environment friendly construction materials;
- Contribute to overall quality of life.

The USGBC (2004) [14] identifies that the greener homes have following advantages:




In US, LEED™ (Leadership in Energy & Environmental Design) provides Green Building Rating System, provides a complete framework for assessing building performance and meeting sustainability goals [15]. UK introduced the Code for Sustainable Homes in April 2007 (Department for Communities and Local Government, 2007) after consultation with environmental groups and the home building and construction industries. The code is a voluntary standard designed to improve the overall sustainability of new homes based on nine criteria such as energy and $CO_2$ emissions, pollution, water, health and well-being, materials, management, surface water run-off, ecology and waste. The code is set in a single framework within which the home building industry can design and construct homes to higher environmental standards and offers a tool for developers to differentiate themselves within the market. Where it is used the code also gives new homebuyers better information about the environmental impact of their new home and its potential running costs.

## 3. IMPORTANCE OF RATING AND CODING SYSTEM

The developing city like Dhaka is having an annual growth of 12% in construction sector which contributes 3.7% of GDP [16] and employs 1.6 million people. Today, real estate and construction industry is the biggest of all the locally run industries and contributing 14.50 billion BDT (US$ 231 million) [17] annually. As per the Town Improvement Act 1953 (TI Act 1953) Rajdhani Unnayan Kartipakkhya (RAJUK: Capital Development Authority) is the legitimate authority to prepare land use plan and take care of plan implementation, control the development and manage the growth of Dhaka city. But it has failed to implement and control the planned development growth resulting Dhaka into an overcrowded and polluted mega city. Inappropriate planning permission process and corruption in the whole system are hindering the planned development of Dhaka city. The existing one or two stories buildings are demolished to construct multi-storied building by the real estate developers which create a significant stress on water, energy and waste management. If present trend of unsustainable unplanned growth of construction goes on it will not be far away when the city might turn into a deserted city due to lack of basic utilities such as water supply, gas and electricity. Therefore, a rating and coding system is required to for existing and new homes to influence the design and construction approach leading to a sustainable and healthy environment.

## 4. CODING AND RATING SYSTEM

The code for Greener Homes (CGH) is an environmental assessment rating method for existing and new homes which assesses environmental performance in a two stage process (Design stage for new homes and Post-construction for existing homes) using objective criteria and verification. The results of the code assessment are recorded on a certificate assigned to the dwelling. The code has been proposed based on six criteria covering energy, water, materials, waste, ecology, health and wellbeing. Each criterion is given a weight based on their relative importance over one another as shown in the Table 1 below. The weighting factors used in the Code have been derived from extensive studies involving a wide range of stakeholders who were asked to rank (in order of importance) a range of environmental impacts. Stakeholders including experts, architects, engineers, dwellers were involved during the weighting and assessment process.

Table 1: Showing the relative importance of each criterion in the coding assessment.

| Criteria | Weight | Credits | Reason |
|---|---|---|---|
| Energy | 0.3 | 30 | It is the most important criteria and the city like Dhaka is facing severe energy crisis and so it is three times more important than the use of materials |
| Water | 0.2 | 20 | Twice as important as the use of materials |
| Materials | 0.1 | 10 | Less important as compared to other criteria |
| Waste | 0.2 | 20 | Twice as important as the use of materials |
| Ecology | 0.1 | 10 | Ecology is directly or indirectly related with water uses and waste disposal and given half importance as compared to water or waste. |
| Health and Wellbeing | 0.1 | 10 | Health and Wellbeing is as important as ecology |

### 4.1 Energy

Energy is one of the most important criteria which need to be assessed based on use of renewable energy such as solar energy, energy from biomass. Proper management and wise use of energy can cut down emissions. Therefore, optimum and use of renewable energy is a major criterion for greener homes and it has been highly weighted with 30 credits. The Table 2 below shows the importance of each factor.

Table 2: Factors affecting energy uses and their relative importance.

| Sub-criteria for energy | Weight | Credits | Reason |
|---|---|---|---|
| Solar Energy | 0.5 | 15 | In a country like Bangladesh there is a tremendous potential in use of solar energy and emphasis has been given for using solar energy in every houses, particularly in high rising buildings. It can promote use of renewable energy and save significant energy. |
| Biogas | 0.5 | 15 | Biodegradable waste from the houses or large dwelling places can be used to trap biogas and use it for cooking, generating electricity. |

**4.2 Water**

Adequate water supply with necessary drainage facility for disposal of waste water is an important criterion and therefore it has been given 20 credits. Ecology, health and wellbeing are directly or indirectly influenced by the availability of water and its proper management. Provisions for Rain Water Harvesting (RWH), giving priority on uses of surface water over ground water, necessary water storage facilities with emphasis on ground water recharge and disposal of waste water through connected sewer lines can be an important factor and they have been weighted accordingly as shown in the Table 3 below. The dwellers are encouraged to use water saving technologies through aerated and self-closing faucets.

Table 3: Factors affecting water uses and storage and their relative importance

| Sub-criteria | Weight | Credits | Reason |
|---|---|---|---|
| RWH | 0.5 | 10 | In Bangladesh the average rainfall is good enough for RWH and hence the homes are encouraged to incorporate RWH in their design. |
| Water storage facilities using ground water recharge | 0.2 | 4 | Ground water in many cities are declining rapidly in Bangladesh and therefore emphasis is given on recharge of ground water |
| Proper disposal of waste water connected to sewer line and protection against flooding | 0.3 | 6 | Proper disposal of waste water is needed to ensure healthy environment and indiscriminate disposal leading to environmental pollution, water logging and flooding problem. |

### 4.3 Materials

Use of materials is one of the criteria used in code assessment and given 10 credits. Use of locally available materials are encouraged and emphasis has been given on use of materials which can recycled as shown in Table 4 with relative importance. The materials for construction have a significant impact on the embodied energy and embodied $CO_2$ of a building. Therefore, selection of materials can significantly reduce embodied energy and $CO_2$ which play an important role in reducing the impact of climate change resulting from emission.

Table 4: Factors affecting materials use and their relative importance.

| Sub-criteria | Weight | Credits | Reason |
|---|---|---|---|
| Use of locally available materials over 80 % | 0.7 | 7 | Use of locally available materials will ensure sustainability and generate local jobs and save money. |
| Use of materials that can be recycled | 0.3 | 3 | Using recycles materials can decrease ecological footprint. |

### 4.4 Waste

The disposal of waste and its efficient management can reduce environmental impact, cut down water, air and soil pollution and given a total of 20 credits. Waste can be viewed as a resources and the concept of greener homes based on management of waste is another important criteria in code assessment. It can directly or indirectly improve surrounding ecological set up and ensure safe health and promote wellbeing. Table 5 below shows the factors affecting waste disposal.

Table 5: Factors affecting waste disposal and their relative importance

| Sub-criteria | Weight | Credits | Reason |
|---|---|---|---|
| Community based waste management and disposal using composting | 0.6 | 12 | Waste should be managed locally with emphasis on provision for composting. Emphasis should be given on energy recovery if possible using through bio-gas plant. |
| Segregation and collection of materials for recycling | 0.4 | 8 | Door to door collection ensure better waste management Ground water in many cities are declining rapidly in Bangladesh and therefore emphasis is given on recharge of ground water |

### 4.5 Ecology

Ecology is always under threat when homes are built up by clearing of land resulting into destruction of natural habitat. Therefore, one should keep in mind that homes should be constructed with minimum loss of habitat. Necessary vegetation can contribute healthy environment by keeping requirement for energy for cooling to minimum. Rooftop garden can supplement for the green space lost for constructed homes. Table 6 shows the factors affecting ecological value.

Table-6: Factors affecting ecological value and their relative importance

| Sub-criteria | Weight | Credits | Reason |
|---|---|---|---|
| Vegetation between 5-10% area | 0.1 | 1 | Vegetation such as plants, trees around the homes can keep the environment green and assist in keeping the temperature inside and surrounding homes less thereby reducing the necessity of using cooling though fan/AC. |
| Vegetation between 11-25% area | 0.2 | 2 | More vegetation means less required energy for cooling. |
| Vegetation over 25% area | 0.3 | 3 | Better cooling and more saving in energy. |
| Rooftop garden | 0.4 | 4 | Very effective way of keeping green space and leading to a healthy environment. Since construction of homes destroys the green space therefore using rooftop as garden can regain the lost ecological values. |

### 4.6 Health and wellbeing

Health and wellbeing is directly or indirectly dependent on water, waste disposal and ecology. The greener homes should ensure sound health for its dwellers with adequate ventilation and provision for natural sunlight as shown in Table 7 below. The construction of greener homes should emphasis on efficient lighting and day lighting.

Table 7: Factors affecting health and wellbeing and their relative importance

| Sub-criteria | Weight | Credits | Reason |
|---|---|---|---|
| Adequate ventilation (80% of indoor area covered with ventilation) | 0.4 | 4 | Necessary ventilation is required for maintaining indoors of house free from any odours and keeping air fresh. |
| Adequate natural sunlight (over 80% indoor area has access to natural sunlight) | 0.6 | 6 | The houses constructed should ensure enough natural sunlight and keeping the indoor free from from dampness and thereby reducing the growth of germs and bacteria harmful for health. |

Based on the above criteria it has been recommended that homes will be rated based on the following Table 8.

Table 8: Showing ratings of homes based on the obtained credits or scores.

| Credits | Rating |
|---|---|
| Less than 20 | 1 |
| Between 20-40 | 2 |
| Between 41-60 | 3 |
| Between 61-80 | 4 |
| Over 80 | 5 |

## 5. IMPLICATIONS FOR DEVELOPING CITIES

Developing cities are at present faced with the need to increase their energy production to accelerate development and raise the living standards of their populations, while at the same time reducing energy production costs and energy-related pollution. Increasing the efficiency of energy use to reduce its polluting effects and to promote the use of renewable energies must be a priority in any action taken to protect the urban environment [1]. Habitat highlight the following figures illustrate the magnitude of the urbanization trend [1]:

- Currently, 40% of the population of developing countries already lives in cities,
- By 2020, 52% of the population of developing countries will be in cities and towns;

- Currently, three-quarters of global population growth occurs and is expected to continue to occur in the urban areas of developing countries, causing hypergrowth in the cities.

The greatest challenge will be in Africa and Asia as Latin America and the Caribbean already have 75% city dwellers, while in contrast, only one-third of the population of Africa and Asia live in urban areas [1]. Cities in the developing world thus provide great opportunities for introducing rating and coding system leading towards sustainable greener homes. It is therefore imperative that developing countries develop and operationalize a system of sustainable homes indicators, with the aim of making them part and parcel of the design and construction process.

## 6. CONCLUSION

Developing countries are experiencing rapid growth, with the associated need for their infrastructure to support that growth. Countries with mature economies are in the position of being able to devote greater attention to creating more sustainable buildings by upgrading the existing building stock through the application of new developments or the invention and use of innovative technologies for energy and material savings during design of buildings. While in developing countries, technologies should be developed to meet the social, economic, and environmental needs and its transfer should be based on the process which is adaptable and sustainable in the context of that particular country. The refurbishment works for high-rise building could be adapted to the cities where there is a demand for high-rise buildings with emphasis on reducing energy bills and water consumption through use of appliances that consume less water, use of materials which has greater recycling values. A green building should incorporate as many sustainable, local materials as possible into its construction - to support local economies, to avoid the high energy and financial costs of long-distance transportation, and to fit in with local aesthetics. It also recommended that there should be an authority in the developing countries to certify the buildings in terms of sustainability. All buildings should be certified or coded by a licensed and accredited code assessor to ensure that the rating is independent and trustworthy. The code will minimize the environmental damage from the construction process and will offer an opportunity to revolutionise the design of new homes so that the housing market encourages people to live more sustainable lifestyles. The fast growing cities like Dhaka needs immediate attention so that buildings are designed for maximum efficiency with optimum use of resources and lesser impact on environment. Energy efficient buildings, while limiting the growth of $CO_2$ emissions, can also improve indoor and outdoor air quality, improve social welfare and enhance energy security. It is also recommended that the real estate developers working with construction industries needs to be assessed and ranked annually based on the concept of greener buildings or energy savings in comparison to the conventional approach of construction method. Following steps are recommended for the greener homes.

- Establish and strengthen indigenous building materials industry based on inputs of locally available natural resources;
- Formulate programmes to enhance the utilization of local resources including energy, water, waste disposal to be managed by the local community.
- Promote the increased use of energy-efficient designs and technologies and sustainable utilization of natural resources.

- Provide financial incentives to promote recycling of energy-intensive materials in the construction industry.
- The use of construction materials and products that create pollution during their life cycle should be discouraged such as imposing pollution tax.

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# THE ROLE OF PHYSICS IN THE SUSTAINABLE AGGREGATE DEVELOPMENT IN BANGLADESH

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## ABSTRACT

Sustainable development is deeply rooted in physics. The aim of the article is to show the role of physics in sustainable development in Bangladesh. Physics provides the theoretical foundation for essentially all of the technologies and processes involved from resource exploration and extraction, conversion, transmission and distribution to providing the energy services demanded by our societies. Materials are taken by the energy system from and then returned to the environment. Climate change, air quality, regional acidification, etc. and the role of physics in understanding the energy-environment nexus plus what physics can do for abatement and mitigation of the adverse environmental effects. The fundamental laws of physics tell us that there is no technology without wastes, risks and interaction with the environment. Again, physics has been instrumental in our understanding of the adverse impacts of energy production and use ranging from climate change, the interaction of the atmosphere and the oceans to the abatement of pollutants in flue gases. Understanding and assisting in putting to use the laws of nature for the transition towards a sustainable energy system is the fundamental challenge of today's and tomorrow's physicists. One of the greatest challenges ahead is to connect the 1.6 billion people in developing countries like Bangladesh currently without access to modern energy services in an environmentally kind manner. Clearly, without a proactive contribution of physics and physicists working along with engineers, economists, sociologists, etc, this challenge cannot be met. The health of a population is a fundamental element contributing to progressive sustainable development in all regions of the world. Throughout the course of medical history, physics has been one of the fundamental medical sciences. First, it was applied to understand the functions of the human body. There is a long and rich history of applying physical principles and the development of many types of technology for both the diagnosis of disease and injury and for a variety of therapeutic purposes. In Bangladesh physics education is not getting enough importance. The physics education in the secondary and higher secondary is not strong. There is also lack of good teachers' even good books. There are even no government programs to popularize physics among the children and school going students. In the engineering

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universities the physics curriculum is not adequate. In the medical school it is not even included, whereas the doctors should have a sound knowledge in physics. Now it is suggested that physics courses should get more importance in the secondary and higher secondary schools, in the undergraduate courses it should get more importance, and in the undergraduate medical curriculum it should be introduced. It will play a great role in the sustainable aggregate development in Bangladesh.

**Key words:** Physics, sustainable development, healthcare, medical science, engineering economics, education.

## INTRODUCTION

Sustainable development is deeply rooted in physics. Technology, industry, healthcare, economy all are connected with physics. Since physics deals with all general laws of nature so for sustainable development physics plays a key role. Physics provides the theoretical foundation for essentially all of the technologies and processes involved from resource exploration and extraction, conversion, transmission and distribution to providing the energy services demanded by our societies. Materials are taken by the energy system from and then returned to the environment. Climate change, air quality, regional acidification, etc. and the role of physics in understanding the energy-environment nexus plus what physics can do for abatement and mitigation of the adverse environmental effects. The fundamental laws of physics tell us that there is no technology without wastes, risks and interaction with the environment. The ongoing urbanization in Bangladesh and electrification throughout the country creating higher and higher energy demand densities, increasing demand for mobility, and additional energy needs for new processes such as industrialization, use of electricity in agricultural sector, etc. Clearly, without a proactive contribution of physics and physicists working along with engineers, economists, sociologists, etc, this challenge cannot be met. Unfortunately physics is not well taught in developing countries [1].

## ENERGY TECHNOLOGY

Energy technologies are deeply rooted in physics. Without thermodynamics there would be no heat engines that from the mainstay of the world’s current electricity generation or transportation systems; without the laws of classical mechanics, classical electro-magnetics or relativity theory, there would be no nuclear fission, photovoltaics or fuel cells. Again, physics has been instrumental in our understanding of the adverse impacts of energy production and use ranging from climate change, the interaction of the atmosphere and the oceans to the abatement of pollutants in flue gases.

Understanding and assisting in putting to use the laws of nature for the transition towards a sustainable energy system is the fundamental challenge of today's and tomorrow's physicists. One of the greatest challenges ahead is to connect the 1.6 billion people in developing countries currently without access to modern energy services in an environmentally kind manner.

We need to identify areas of concrete action– research, development, demonstration, transfer, commercialization - suitable for physicist working in the applied fields of energy-environment modeling, energy planning, engineering, technology development and diffusion, and education/training. Partnerships between technology development laboratories in the industrialized countries and physicists and associated institutions in Bangladesh will be sought for know-how and technology transfer [2].

Finding better ways to meet the energy needs of our people is critically important. Here physics plays a key role.

**Power to the people: a decentralized generation "off the grid" overview**

A new paradigm for approaching energy generation is unfolding, but what is it and how does it work? Here we explain why decentralized generation is increasingly important in today's environment, especially in a developing world context. Decentralized generation (DG) is an umbrella term for a wide range of technologies, so it's important to know what this spectrum encompasses. To help survey the field we will focus on six DG areas: turbines, fuel cells, solar, wind, biomass, and other renewable energies. We'll learn about what these technologies are, what new needs and demands they meet, under what conditions and geographies they work best in, what physics can do for their commercialization and market penetration and identify RD&D requirements.

**Fueling the Big Cities – A continued need for centralized energy production**

Providing affordable and clean energy services to the "unconnected" in rural areas is a prerequisite to poverty alleviation. In rural areas, energy densities of decentralized technology often match demand densities, a situation which is distinctly different from the situation in the big cities of the world. In Bangladesh, about 30% of total population is living in the town areas. Centralized conventional fossil, hydro power and nuclear technologies will continue to supply the bulk of the energy needs. Here we present and investigate the technology options for the decades ahead, how these can comply with ever more rigorous environmental constraints and sustainable energy requirements, and identify key areas for action within the physics community.

**Capacity building and human resources development**

Education and training constitutes a key issue for use and application of the different energy forms. No sustainable use of energy systems can be made without local competencies capable to design, implement and maintain the energy systems. Special focus could be made on decentralized energy generation (renewable energies) were there is need to a specific knowledge to use and maintain the systems by local communities.

## PHYSICS & HEALTHCARE

The health of a population is a fundamental element contributing to progressive sustainable development in all regions of the world. The physics has wide application to medicine. Physics is changing the way medicine is practiced. While a doctor will still use a stethoscope, a diagnosis now often requires devices that make use of sophisticated physics. As a consequence of technological evolution of medical science, doctors are more and more recognizing the influence of physics to medicine. The history of the application of physics to medicine started in the Islamic Golden Age. De Gradibus an Arabic book published by Muslim physician Al-Kindi (801-873 CE) was the first attempt at serious quantification in medicine. Al-Kindi also developed a system based on the phases of the moon, that would allow a doctor to determine in advance the most critical days of a patient's illness [3]. Ibn Sina the father of modern medicine in his famous book *The Canon of Medicine* (1025 C.E.) [4], (the first book dealing with evidence based medicine) established a set of rules, one of them is "The quality of drug must correspond the strength of the disease. For example there are some drugs whose heat is less than the coldness of certain diseases, so that they would have no effect on them."The law is directly related to the heat and thermodynamics chapter of physics. The contribution of famous Muslim physicist Ibn Al-Haytham (Al-Hazen) to anatomy and physiology include many improvements in our understanding of the process of visual perception in his *Book of Optics* [5], published in 1021. Much later in Europe Leonardo da Vinci, showed profound interest in the mechanics of human locomotion. The subsequent gradual development in physical tools contributed to advances in the medical sciences. One outstanding example is the microscope by Leeuwenhoek during the 17$^{th}$ century. The development of electromagnetism in the 19$^{th}$ century enabled physicists to make contributions to medical treatment and diagnosis. D'Arsonval, a French physicist, pioneered the therapeutic use of high-frequency electric currents and pointed the way towards development of critical measuring instruments. Thus electrocardiography and electroencephalography was developed. The discoveries of X-rays and radioactivity by the physicist Roetgen in 1895 and Becquerel in 1896 were rapidly followed by the application of ionizing radiations to the diagnosis and treatment of disease. This actively has been primarily responsible for bringing physicists directly into the sphere of hospital. Bio-systems are based on the same laws as physical systems. Medical physics is an applied branch of physics concerned with the application of the concepts and methods of physics to the diagnosis, management and treatment of human disease. Some vital areas of application are ionizing radiation, imaging with X-rays, ultrasound and MRI, nuclear medicine, electroencephalography, electrocardiography, thermography, hyperthermia, optical imaging, and RF and laser surgery. Considering the profound relation of physics with medical science highly developed countries like USA, Russia, Germany, England, France, Italy, Ukraine, etc. included the physics education in their medical schools.

Physics education is included in the medical schools of different highly developed countries. Some may raise question, since physics is taught in the secondary schools, is it really meaningful to teach it in undergraduate courses? However, the course taught in the secondary school level is very much general. For the better understanding of the subject and its correlation with future professional activities is necessary to study physics at advanced level. The physical concepts should be medically oriented with the intention of relating physics to the students' future professional lives. Each topic should start with a medical case related with medical diagnosis and treatment. It is well known that vital areas of application of physics in medicine are ionizing radiation, imaging with X-rays, ultrasound and MRI, nuclear medicine, electroencephalography, electrocardiography, thermography, cardiac pacemakers, hyperthermia, optical imaging, and RF, laser surgery. Once the equipment is accepted, the doctors should have sound knowledge on all those machines, so that the equipment can be used clinically. The doctors also should have knowledge on equipments' physical concept and their effect on human body.

We should enhance healthcare in Bangladesh by organizing variety of resource projects that support applications of medical physics, biomedical engineering and medical technology, the rapid development of medical technology and its increased availability in the developing countries; the expanding need for medical physicists and biomedical engineers educated and trained to provide professional support for the effective utilization of medical technology; the availability of digital technology, including the internet that will be the foundation of innovative projects for the continuing development and support of the physics and engineering professions.

A significant contribution to quality healthcare within any region is the education and training of a wide spectrum of medical and healthcare professionals to insure that investments in medical technology produce maximum benefits to society. The technology infrastructure of healthcare spans five major applications:
i) *Imaging* used for diagnosis, guidance of therapeutic procedures, and the general management of patient care; ii) *Therapy* using a variety of radiations and energy applications to the human body; iii) *Management* of healthcare functions through information processing and access to medical information on an international basis; iv) *Communication* of medical data, images, consultations, reports, etc., within local clinical networks and internationally in the practice of telemedicine; v) *Education and Training* with extensive web-based and digitally recorded learning resources.

We need to identify specific needs in the developing countries relating to physics and engineering applications to healthcare. We also need to lead potential resource providers in the development and sharing of resources and the formation of partnerships and collaborations in the form of defined *resource projects*. It is also necessary to provide an organizational structure to identify and provide visibility of all available resource projects submitted to the Conference. We should as well provide a *point of access* for medical physicists, biomedical engineers, and other healthcare professionals in Bangladesh to identify and obtain access to appropriate resources.

**ROLE OF PHYSICS IN ECONOMIC DEVELOPMENT**

Physics plays many vital roles in economic development, and its applications are as important in the developing world as in the developed world. It has a major role to play in many key sectors, including information and communications technologies, where the production of consumer devices continues to move from the developed world to lower cost centers of production, thus requiring local expertise; the emerging field of nano-science and its associated nanotechnology, which will have deep impact in all areas of national economies of the developing countries allowing them, for the first time, to break free from traditional raw material-based production infrastructures and move into knowledge-based and modern economic, political and social systems; green eco-friendly energy production, including the local generation of electricity in remote areas by solar, and wind, energy, etc.

Transport is a big problem, where physics provides solutions. Physics also helps in understanding, prediction, modelling and communication of ecological, meteorological and other such events and conditions (including tsunamis and earth quakes) and action to be taken. Physics also covers modern, knowledge-based agriculture and food production and a range of further areas.

Nowadays economic development entails the sustainability because most scarce resources will be vanished at the current consumption rate and over industrialization and urbanization will have serious negative input on environment, citizens' health, and above all will increase the even bigger disparity of income between rich and poor. A thorough economic plan must be formulated which will carry development in a sustained level for decades and physics has a major role to play. For example, water purification to solar energy requires the application of physics.

Basic research may be the field that attracts most publicity, and this does lead to new and important technologies, the role of the physicists in economic development is much more extensive. Many physicists are employed in a range of roles within industry. Advantages of a physics training include the flexibility to tackle a wide range of problems and to be able to move from one discipline to another. It also gives the ability to solve problems from first principles, when standard solutions do not apply and where a range of disciplines needs to be called on. This can be of particular importance in Bangladesh where, for reasons of scale, economics or other local conditions, approaches developed and used elsewhere may be inappropriate.

## CONCLUSION

Unfortunately physics is not one of the subjects that most students are eager to enroll. Besides we are lacking in quality physics teacher at different level of educational institutions. In public universities of Bangladesh the capacity of the physics departments is inadequate. Only in two/three private universities are having fully fledged physics departments. If we want development that is sustained we must acknowledge the importance of physics and its contribution towards sustainable economic development. To achieve it we must build the infrastructure that is teachers who love the subject and who can motivate students by making the subject more interesting and must add physics in all level of higher studies including university level. In the western world governments are giving extra incentives as if more physics teachers are produced [6] and thus trying to maximize the benefit that the subject physics offer to sustain development. By distanting us from physics we are lagging behind more on development especially sustainable development. Physics may not be the answer of all our development problem but it may have the power to devise a plan how to proceed on to solve it in a sustainable manner.

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# ECO-FRIENDLY APPROACH FOR REVIVAL AND SUSTAINABLE FUNCTIONING OF RIVER SYSTEMS IN SOUTH-WEST REGION OF BANGLADESH

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## ABSTRACT

The rivers of the south-west region of Bangladesh are characterized by active deposition of sediment causing significant reduction in their drainage capacity. Besides, construction of costal polders that de-linked the floodplains from the rivers, and diminished upstream flow during the dry season deteriorated the sedimentation problem in this region. Consequently, this area has been experiencing severe environmental disasters such as water-logging, tidal surge, silting-up of rivers and dearth of fresh water due to salinity intrusion, drainage structures made by LGED in unplanned ways since the early eighties causing unimaginable suffering to the people. After being paid no attention from the authority, people themselves took an initiative to solve these long-standing problems by breaching or cutting away polders to allow tidal flows. This eco-technological solution to the water logging problem was formally known as the Tidal River Management (TRM) concept. This paper aims to present the river systems of south-west region in conjunction with the above mentioned problems and environment friendly measures taken up for restoration and proper functioning of the river systems under the context of Khulna-Jessore Drainage Rehabilitation Project (KJDRP). The declared aim of the six-year long project by BWDB was to “mitigate the water-logging problem to increase agricultural production and alleviate poverty of the area through farm-based employment generation”. The Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) studies carried out under KJDRP, proposed and elaborated TRM (which was initially suggested by local community) as an innovative approach for mitigating drainage problem of this region. This paper speaks about how the prevailing drainage congestion was partially mitigated and agricultural, social and economic benefits were achieved after implementation of the project.

**Key words**: River Systems, Water-Logging, Tidal Flow, Tidal River Management, Eco-technology, Siltation, KJDRP

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## 1. INTRODUCTION

The water- logging problem of Jessore, Khulna and Satkhira, the coastal districts of south western region of Bangladesh, is a widely discussed issue in both national and international level. Other environmental disasters such as tidal surge, silting-up of rivers and dearth of fresh water due to salinity intrusion, drainage structures made by LGED in unplanned ways since the early eighties have become common occurrences in this region and are causing unimaginable suffering for the people. The people were pressing hard for the formulation of an environmentally friendly project to mitigate the water-logging problem. But the Bangladesh Water Development Board (BWDB) failed to propose any project which would take proper account of the existing eco-system. The latest project aimed to mitigate water-logging is the Khulna-Jessore Drainage Rehabilitation Project (KJDRP). At the very start in 1993–94, local people expressed their doubts about the effectiveness of the project. This relentless advocacy ultimately convinced the Asian Development Bank (ADB) to critically review the KJDRP and, on the basis of the people’s demand, they agreed, albeit partially, to go for an eco-technological solution to the water logging problem: the Tidal River Management (TRM) concept. This resulted in some alteration of the drainage plans, in the context of specific ecological characteristics of the south-west coastal region. This paper contains a brief account of the phenomenon of water-logging, its causes and effects and TRM concept to for restoration and proper functioning of the river systems under the context of KJDRP.[1,3 and 7]

**Figure 1.1: Water logging in Low lying area** **Figure 1.2 : Water logging in Homestead area**

## 2. HYDRO-MORPHOLOGY OF SOUTHWEST REGION

The river hydro-morphology of the area is characterized by the active deposition of sediments and silts into the area during neap tide of dry season. The volume of tidal inflow is comparatively very less such that there is no erosion and scour during the wet and dry season. This process of sedimentation by the upcoming silt from sea in the river system and less or no upland flow cause drainage congestion within the project area. [1,2 and 6]

In the coastal area, the peripheral land near the tidal river system is generally relatively high. The northwest side of the region is also relatively high area and southeast part is relatively low-lying area, which maintains the natural gradient. Too many channels are interconnected with each other as well as with the above 27 Beels and the following river systems. Major rivers in the project area are: Upper Bhadra, Lower Bhadra, Harihar, Muktessawari, Teka, Sree and Hari which are connected with downstream rivers Pussur, Shibsha and Arpanggasia rivers all of which are mighty tidal rivers. The rivers and khals in the project area form three distinct drainage systems. These are: a) Mukteswari-Teka-Sree-Hari River System, b) Dyar Khal-Hari River System, and c) Harihar-Upper Bhadra-Lower Bhadra River System. Buri-Bhadra River maintains lateral connection in between Kapataksha and Upper Bhadra.[1]

The following table shows union falls under drainage catchments of three River systems:

| Sl.No. | River/Channel System | Union wise Drainage Catchments |
|---|---|---|
| 1 | Dayer Khal- Hari River System | Khanpur, Durbadanga, Manoharpur,Panjia, Sufalkati |
| 2 | Muktessari-Teka- Sree Nadi-Hari Nadi System | Dhakuria, Bhojgati, Haridaskati,Kultia, Payra, Nehalpur, Dhamalia, Rudhagara, Paurashava |
| 3 | Harihar River-Upper Bhadra-Lower Bhadra System | Rohita,Manirampur, Kheda para, Jhanpa, Shyamkur, Chaluhati, Keshabpur, Trimohoni, Majidpur, Mangalkot, Gaurighona, Bidyanandakati |

Table 1: Union wise drainage catchments under the river systems

## 3. WATER LOGGING AND ITS EFFECT

The rivers of the southwestern region in Bangladesh are characterized by active deposition of sediment causing significant reduction in their drainage capacity. [5] Besides, construction of costal polders that de-linked the floodplains from the rivers, and diminished upstream flow during the dry season deteriorated the sedimentation problem in this region. Consequently, this area has been experiencing severe drainage congestion and water logging since the early eighties. In most of the beel areas, the depth of water at the deepest point used to increase significantly causing destruction of houses, disrupted communication and the rhythm of daily life, killed off fruit trees and reduced the number of domestic animals. Many migrated to other areas as life became difficult to support. The pollution caused by the stagnant waters

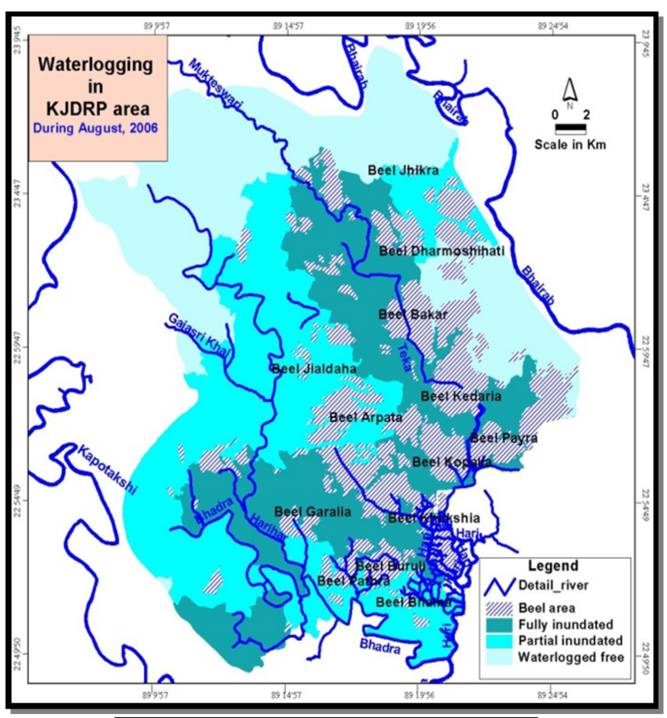


Fig 3.1: Water logging in KJDRP

created epidemics of water-borne diseases. Schools closed and children were deprived of education. Hundreds of thousands lost their occupations and became destitute. The following table shows the union wise water logged area.

| Sl. No | Upazila Name | Union Name | Percentage of water logged area (%) | |
|---|---|---|---|---|
| | | | 2007’August | 2008’March |
| 1 | Abhoynagar | Mahakal | 80 | 40 |
| 2 | | | | |
| 3 | | Noapara | 25 | 5 |
| 4 | | Rajghat | 25 | 5 |
| 5 | | Payra | 40 | 10 |
| 6 | Keshabpur | Keshabpur | 80 | 30 |
| 7 | | Panjia | 85 | 30 |
| 8 | | Trimohini | 40 | 10 |
| 9 | | Sufalakati | 95 | 50 |
| 10 | | Majidpur | 25 | 5 |
| 11 | | Mangalkot | 60 | 30 |
| 12 | | Gaurighona | 25 | 5 |
| 13 | | Sagardari | 25 | 5 |
| 14 | | Bidyanandakati | 40 | 10 |
| 15 | Kotwali | Basundia | 20 | 3 |
| 16 | | Chanchra | 10 | 2 |
| 17 | | Narendrapur | 20 | 5 |
| 18 | Manirampur | Dhakuria | 20 | 5 |
| 19 | | Haridaskati | 80 | 40 |
| 20 | | Manirampur | 10 | 0 |
| 21 | | Kultia | 90 | 50 |
| 22 | | Khanpur | 90 | 45 |
| 23 | | Jhanpa | 10 | 2 |
| 24 | | Shyamkur | 25 | 5 |
| 25 | | Chaluahati | 10 | 2 |
| 26 | | Nehalpur | 90 | 40 |
| 27 | | Durbadanga | 80 | 35 |
| 28 | | Manoharpur | 90 | 40 |

Table 2: Union wise Waterlogged Area
Source: Field Survey, using RRA and PRA technique

## 4. METHODOLOGY: SELECTION OF TRM

In the past few years, both National Water Policy and National Water Management Plan (NWMP) have put emphasis on initiating region specific water resources planning. This vision, however, has hardly been materialized in Bangladesh; the present exercise of Integrated Water Resources Management (IWRM) planning for the Khulna-Jessore Rehabilitation Project is a comprehensive attempt at initiating IWRM planning at a local level. It is also an attempt at building planning capabilities of local and regional level communities through newly formed water management organizations. [1 and 2]

KJDRP was done by two round planning (Regional & Zonal Round) and developed with 'III' approach (integration, interaction & iteration). By this process numerous options were selected to analyze the performance of those criteria. A simplified Multi-criteria Analysis (MCA) evaluation system was performed where Alternatives were first scored based on the physical criteria: from 1 (least favored state) to 4 (most favored state). Then alternatives were scored directly against the decision issues include socio-economic, environmental, fisheries etc. As per the scoring of alternatives the ranking was done and decision was taken to proceed with the highest scored option. TRM was one of the options which was selected through this MCA process.

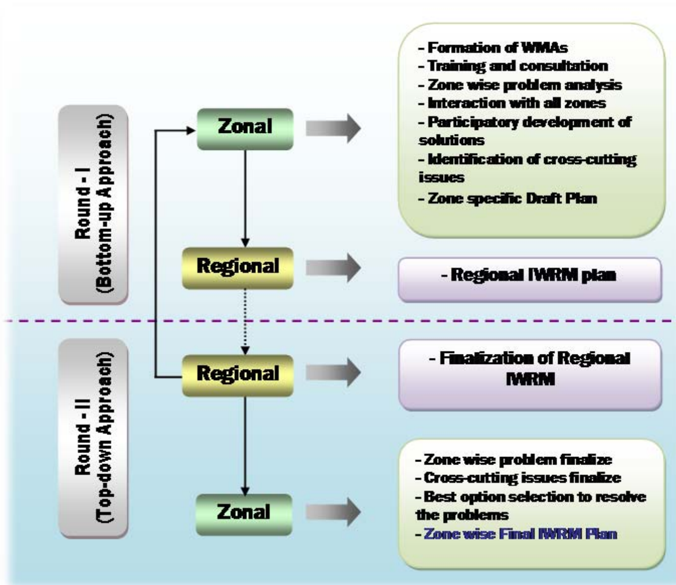


Fig 4.1: Methodology

## 5. TIDAL RIVER MANAGEMENT

Tidal River Management (TRM) means the management of river systems for improved drainage condition and bringing more tidal volume, preventing sedimentation in the rivers and accelerating river scouring for sustaining the river system.[7] The main purpose was to get suspended sediment deposits gradually under a controlled system, going from tidal channels up to the mean high tide level in the waterlogged areas. This planned system means that deposits will be made in a certain site by a specific tidal channel. Later on, deposit sites may be shifted to other sites according to the topography of the area. Breaches may be shifted to ensure uniform silting within a basin.

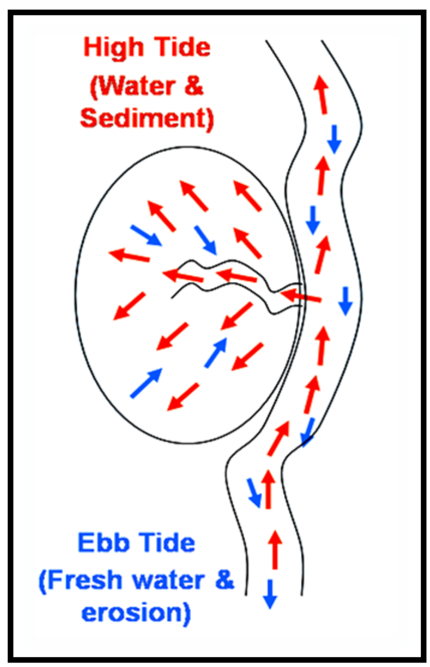


Fig 5: Tidal River Management

### 5.1 Criteria for Environment Friendly Operation of TRM

It is to be mentioned here that to operate smooth environment friendly tidal river management in any beel the following four works are essential: a) De-siltation of the connected main River; b) Selection of new Tidal basin; c) Tidal basin preparation and management and d) Sediment management practice are to be carried out before hand.

### 5.1.1 De-siltation of the Connected Main River

The very first thing required is to improve the channel conveyance capacity up to the design level in case of operation of TRM in any tidal basin. This is needed to let in enough volume of tidal water, which carries huge sediments from the sea. This tidal water with sediments enters into the basin where the sediments settle down and fresh water leaves the basin and erode channel and make the river functional.

### 5.1.2 Selection of New Tidal Basin

A TRM beel with appropriate size based on tidal volume has to be selected before hand through root level planning ensuring the participation of stakeholders. In that case sufficient motivational work has to be carried out before hand. The selection of new basin will be easier if an integrated water resources plan is prepared earlier.

### 5.1.3 Tidal Basin Preparation and management

The tidal basin is to be designed and implemented in such a way that the selected areas are encircled with earthen peripheral embankment and the important draining channels on these peripheries should have controlled drainage outlets. It is to be mentioned here that the construction of new tidal basin and peripherals have to be done simultaneously with the operation of tidal basin in other basin so that immediately after closing of one basin instantaneously the other basin can be opened. Otherwise, severe sedimentation in the existing river system will be resulted, as there is no source of upland flow during dry season. Another important issue is that the starting time and date of TRM in any basin must be selected in such a way when all the upland drainage has been completed. And to get better results of even sedimentation throughout the beel, the sediment management process has to be applied.

### 5.1.4 Sediment Management Practice

Sediment management practice has to be applied to the TRM basin areas to guide the sediment in the tail end first and gradually coming to the off take end successively. This is needed for even deposition of sediments and rising of the land uniformly. Earlier it has been found in the beel Bhaina and beel Kedaria that due to lack of sediment management practice, the sediments were not guided and distributed evenly in the area. Another important issue that during TRM the inflow channel will need to be clear continuously for transporting the sediment flow to the desired locations.

## 6. IMPACT ASSESSMENT OF TRM

### 6.1 Hydro-morphology

### 6.1.1 Water Logging Extent

From the context of KJDRP, the selection of proper TRM in new basins will reduce the water logging to a maximum of 60-65% mostly in the upstream areas and middle reach areas and no water from the low lying areas will be drained out under this situation. However, the improvement scale of water logging situation will be further improved to about 85-90% under future with project situation depending on the scouring and its deepening of the main rivers and its downstream condition.

### 6.1.2 River Erosion and Sedimentation

Before TRM, river erosion and sedimentation status were in worst condition. During operation of beel Bhaina TRM, river scouring has gone upto 10m and even beyond the design drainage level and subsequently the tidal volume has increased significantly. This entry of more volume in each tidal prism has improved the drainage situation of the project and it continued till completion of operation of tidal river management in Beel Bhaina. This situation would more be more improvised if two tidal basins are being operated one after another.

### 6.1.3 TRM beel sedimentation

The environment friendly operation of TRM has the main objective to keep the river functional and make the area free from drainage congestion and water logging. However, the secondary objective is to raise the associated beels through sediment management in the TRM beel areas. One of the main interventions of sediment management is to apply sediment management infrastructure in the TRM beels for guiding the sediment to go to the furthest end and gradually come to the mouth of TRM beel and evenly deposit the sediments in the basin. TRM will be operated in the beel Kapalia and sediments will only be deposited in the beel Kapalia, not in beel Khuksia as it will be closed then. In this case due to operation of TRM in beel Khuksia the river situation will be improved and it is expected that there will be more scouring and more tidal prism will be generated. So immediate operation of TRM in beel Kaplaia after closing TRM in beel Khuksia will further increase the tidal prism, which will bring more sediment flow in the beel Kapalia than in beel Khuksia.

## 6.2 Agriculture

### 6.2.1 Cropping pattern

Under this condition, improved cropping patterns will be introduced. During Kharif-I season, more new areas will come under Aus crop. In some of the areas, during Kharif-II season, high yielding variety of T Aman cropped areas will be increased by replacing local varieties. In Rabi season, about 3% fallow land will come under cultivation.

### 6.2.2 Crop production

The paddy production will be significantly increased, as Aus and T Aman crops will be fully protected against tidal flooding/drainage congestion during the monsoon season.

## 6.3 Fisheries

### 6.3.1 Fish habitat

By the TRM option, it is predicted that there will be a significant change in fish habitat. It is also predictable that more ponds and ditches of the project area will be free from seasonal flooding and water logging.On the other hand, fish and shrimp (both Bagda and Golda) culture practice in Ghers will be expanded in more new areas of the beels due to its high profit margin.

### 6.3.2 Fish production

Fish production from existing rivers and khals will be increased up to 36 and 16 tons respectively as a result of the channel re-excavation and TRM operation.  Capture fisheries production will also be reduced.

## 6.4 Ecosystem

Prior to current drainage problem, the village groves had high concentration of terrestrial plants and were densely populated with wild life. Under the present condition, timber yielding, fruit yielding, bush plants (eg: under growth including climber) and other herbs, which cannot tolerate standing water for more than a month are dying in many places. After implementation of the project interventions the drainage congestion would develop. Most of the lands will be free from water logging and new plant succession will be observed.

## 6.5 Socio-economic

On the basis of people’s perceptions, it was ensured well that the socio-economic condition of the region will be highly developed utilizing the TRM option.

### 6.5.1 Major Occupation and Employment Opportunities

Implementation of the proposed project will ensure the employment opportunities in major occupation like farming, day laboring in the area. Due to water logging condition, occupations like farming, day laborer have been hampered severely. The employment opportunities in farming and day labor sectors will also improve with project situation.

### 6.5.2 Income

Agricultural income will gradually increase with decrease in inundation of land resources with project. In baseline condition, it is estimated that 28% households lie below lower poverty line. But the proposed interventions will create opportunities for intensive cultivation in flood-free land. So, Poverty level will reduce (20% hhs) after completion of the project. In TRM basin area, the income of affected household due to requisition of land in the basin will be reduced severely. So, crop compensation will be required for those affected households.

### 6.5.3 Quality of Life

In baseline situation, 90 schooling days (mid-July to mid October) remain closed due to water logging on average. If the proposed project is not implemented, the closure of schooling days will be further elongated. Well-drained environment will expand pure drinking water availability even from far area. The communication facilities will be improved with project situation. The proposed project will help by allowing people to go for good sanitary latrines and good hygienic behavior for the children, women and men.

## 7. PEOPLE'S SUGGESTIONS FOR OPERATION OF SUCCESSFUL TRM IN ANY BASIN

Local knowledgeable people suggested the following steps to keep KJDRP, its downstream and surrounding areas free from water logging

- ❖ Appropriate and timely selection of Basin for running TRM.
- ❖ Appropriate sizing of TRM basin and correct location of bypass channel.
- ❖ Implementing sediment management arrangement and infrastructures.
- ❖ Development of main river system to its full drainage condition connected with TRM basin.
- ❖ Improvement of downstream river system as because this river system has silted up over the years.
- ❖ Monitoring and measuring the morphological characteristics of main river system and informing the stakeholders.
- ❖ Keeping the provision of free drainage of upstream areas of TRM basin.
- ❖ Exploring the scope of opening more than one TRM basin.
- ❖ The TRM operation must be done through natural canal/river.

## 8. CONCLUDING REMARKS

The environmental study concludes the following, based on the detailed interaction with stakeholders, WMOs, and others

- ❖ Like KJDRP area, all the river systems of the southwestern region are very much vulnerable and gradually dying. The water resources systems are gradually becoming non productive. Therefore, planning any project for this region must be truly participatory and must be well discussed with location specific stakeholders.

- ❖ A long term plan to cover all the river systems by operating TRM one after another starting from the downstream so that conveyance capacity of the river reaches is increased and sustained. Reference is made to the Integrated Water Resources Management Plan (IWRM) prepared by the WMF and the WMAs suggesting which river system and which beel should be taken up for TRM and the sequence to be followed.

- ❖ Proper sediment management practice must be designed and implemented.

- ❖ The study concludes that the TRM infrastructural arrangement for next TRM beel has to be made simultaneously with motivational works and information campaign. This will create the scope that closing of one TRM basin will open the next TRM basin instantaneously. Otherwise, any gap in operation of next TRM will bring back the water logging problem again due to massive river sedimentation within short period of time.

- The KJDRP and TRM solution is a very time sensitive. So, the river and project should be closely monitored and measures have to be taken instantaneously. Sufficient fund has to be allocated for this in each year.

- The project is socially most desirable one, claiming continuous participation of stakeholders in the process of TRM and land development in the basin.

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# INTEGRATED WATER RESOURCE MANAGEMENT PLANNING FOR RESTORING ECOSYSTEM OF CHALAN BEEL

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## ABSTRACT

Chalan beel is an inter-fluvial depression in north-west Bangladesh and one of the largest surface water resources of the country. It is an ecologically rich area due to its diversified physiological foundation. Biologically, the beel offers a vast variety of terrestrial, aquatic and marshy habitats, predominantly used by waterfowl. Reportedly, the Chalan Beel was formerly an important wintering area for ducks, geese and shorebirds, but now that the wetland dries out in early winter, fewer migrant waterfowl visit the area. Wildlife has suffered badly from the ever increasing pressures from human population, destruction of natural wetland habitats in recent decades and conflicts between sectoral water resources systems. Many species of mammals, birds and reptiles have become rare and in some cases extinct in this particular region, and the large concentrations of waterfowl which occurred as recently as thirty years ago have disappeared. Equally the former legendary fish production of this region was vanishing. At that situation, an effective water resources management theme like Integrated Water Resources Management (IWRM) was performed by BWDB for preservation and restoration of eco-hydrologic system at Chalan beel area through integrating several FCD projects which were implemented over the last three decades with the objective of providing flood protection and drainage facilities of agricultural lands in that area. IWRM plan for Chalan beel area was a systematic process for the sustainable development, allocation and monitoring of water resources based on the perception of water as an integral part of the ecosystem, a natural resource and social and economic goods, whose quantity and quality determine the nature of its utilization. This study was proceeding through identification of threats driven by stakeholder concerns and the existing and potential environmental problems they perceive, assessment of cause-effect relationships, development of system solutions for ecosystem conservation and equitable integration of water resource management systems. This study focused mainly an integrated planning approach to address the issues as like conjunctive use of surface and groundwater to save the threaten ecosystem; Preservation of bio-diversity; Promotion of culture fisheries and allowing flood plain fisheries in Chalan beel area.

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**Key words:** Chalan Beel, Eco-hydrology, Ecological threats, Ecosystem restoration, Stakeholder, Participation, Integrated planning

## 1. INTRODUCTION

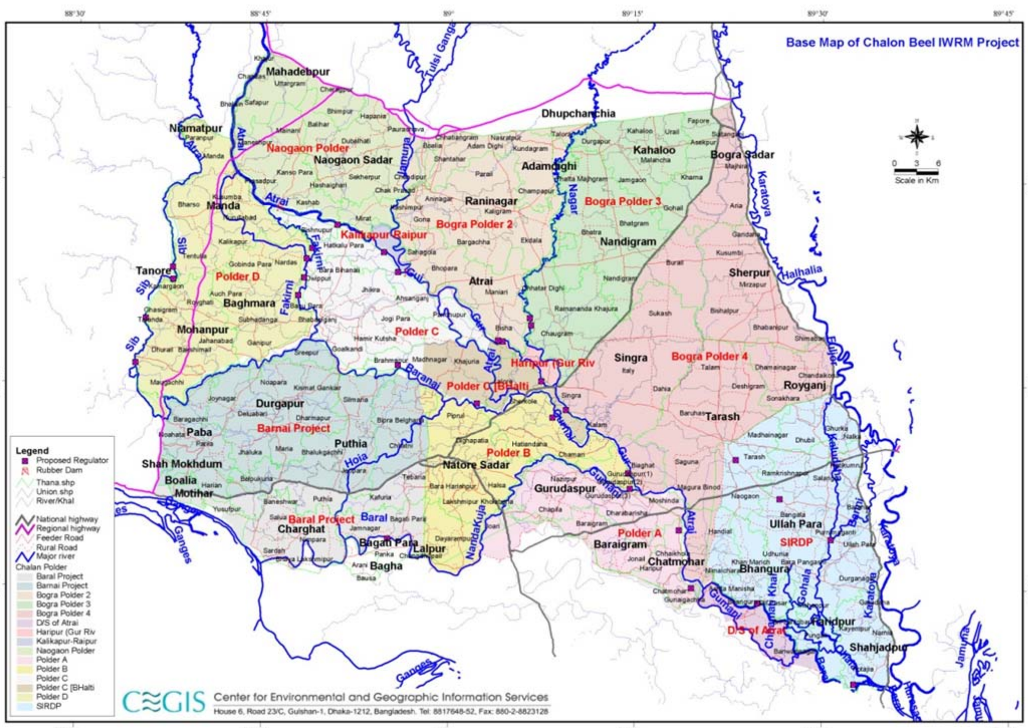
In Bangladesh, Integrated Water Management mainly focuses the issues of flood management and drainage improvement during wet season while it will create the scope of water management for meeting up the dry season irrigation requirement from surface water. But in ecologically reach area it would be a tool for environmental conservation and ecosystem management. Chalan beel is an inter-fluvial depression located in north-west Bangladesh and one of the largest wet land resources of the country. It is an ecologically rich area having a diversified physiological foundation. Biologically, this beel offers a vast variety of terrestrial, aquatic and marshy habitats, predominantly used by waterfowl. The Chalan Beel was formerly an important wintering area for ducks, geese and shorebirds, but now that the wetland dries out in early winter, fewer migrant waterfowl visit the area. Wildlife has suffered badly from the ever increasing pressures from human population, destruction of natural wetland habitats in recent decades and conflicts between sectoral water resources systems (CEGIS, 2007). Many species of mammals, birds and reptiles have become rare and in some cases extinct in this particular region, and the large concentrations of waterfowl which occurred as recently as thirty years ago have disappeared. Equally the former legendary fish production of this region was vanishing. Over the last three decades several FCD projects have been implemented with the objective of providing flood protection and drainage facilities of agricultural lands in that Chalan beel area. BWDB constructed several polder projects for protecting lower ridges. Most of the project caused major ecological changes from wetlands to croplands. Some wetland dependent flora and fauna disappeared from the area. Water retention period over the land have changed and as such productivity (Soil fertility, Ground water recharge, Fish, Birds, Aquatic vegetation, etc.) has started to decline soon after segmentation of the ancient Chalan Beel into several polders. The aim of the polder project was to improve the cropping intensity of agricultural crops, rather than considering the ecosystem settings and its gradual change that may take place during post project situation. As a result, each polder appears as an individual island and the flood dependent ecosystem setting of Chalan Beel area has broken. People think that this has happened because of ignoring the potentiality of flood for sustainable ecosystem in the earlier project planning. Stakeholders want to go back into the traditional ecological condition by integrating all the polders as a single unit and managing the flood flow gradually among the sub-polders.

On the other hand, the earlier studies focused mainly on flood control and drainage leading to engineering solution, but the other issues like environmental and social had not been duly taken care of. The Integrated Water Resources Management in Chalan Beel Area including Beel Halti Development Project would be an integrated approach to address the following issues:

- ◊ Flood protection and drainage management
- ◊ Preservation of bio-diversity
- ◊ Promotion of culture fisheries and allowing flood plain fisheries
- ◊ Mitigating adverse impacts on wet land ecosystem

## 2. STUDY AREA

The Integrated Water Resources Management in Chalan Beel study includes Beel Halti Development Project area extends from the Naogaon-Mohadevpur road and Santahar-Mohimaganj railway line in the north and the Ganges left banks in the south. The western boundary is the west Barind tract whereas the Nagarbari-Bogra highway forms the eastern boundary. The topography in the lower part is relatively low and is more susceptible to flood. Gross area of the project is 6,30,000 ha. This project consists of a cluster of polders and a series of subprojects located in Natore, Rajshahi, Nagoan and Bogra. The polders and sub-projects under this study are: a) Chalan beel polder A, B, C and D, b) Nogaon Polder, Bogura polder 2 which consists of two sub-projects Roktohadoha-Lohachuara project and Nagor sub-project, Bogura Polder 3, Bogra Polder 4, SIRDP and c) Baral and Barnai Sub-project. All these projects are located in the Atrai river basin where Atrai-Gur-Gumani-Hurasagar River is the main artery and Fakirny, Sib-Baranai, Baral-Nandakuja and Nagor are the veins of the main river system. The main artery Atrai-Gur-Gumani- Hurasagar collects water from the above mentioned veins rivers and ultimately discharge into the mighty Brahmaputra River.




Map 1: Location of the Chalan Beel IWRM Project

## 3. METHODOLOGY

Bangladesh Water Development Board (BWDB) initiated the IWRM project in Chalan Beel area. Interventions have been selected under alternative options and proposed to stakeholders for approval. The option has been finalised through stakeholder consultation specially opinion from local people. Environmental and ecological friendliness and social acceptance has been studied by multi-disciplinary Environmental and Social Impact Assessment Team. The EIA/SIA team members collected data from secondary sources before visiting the Integrated Water Resources Management of Chalan Beel area including Beel Halti

Development Project area. Numbers of field visit was made in the project area and later Rapid Rural Appraisals (RRA), Participatory Rural Appraisals (PRA), Focus Group Discussions (FGD) and Key Informant Interviews (KII) were conducted. Recent LANDSAT images of the project area were collected. Aerial photo interpretation was conducted to lay out the traverse lines across the physiographic units of the project area. The traverse lines were placed in such a way that they cut across the maximum number of units within the shortest distance. The field work was carried out along the traverse lines. Local knowledgeable persons including community representatives, traders, teachers, journalists and political leaders were interviewed individually to reflect upon the problems regarding the Integrated Water Resources Management of Chalan Beel area including Beel Halti Development Project.

## 4. ECOLOGICAL CHARACTERISTICS OF CHALAN BEEL AREA

Chalan Beel is one of the largest freshwater marsh and biodiversity abounding wetland of Bangladesh. Unlike haors of the north-east it is not vulnerable to unpredictable flash flood. Chalan beel was formed when the Old Brahmaputra River diverted its water into the new channel of the Jamuna. Chalan beel was probably a back swamp before it greatly expanded with the inclusion of abandoned courses of the Karatoya River and the Atrai River and became a vast wetland. The formation of the Chalan beel is historically linked with the downfall of Atrai and Baral Rivers. The Atrai or the Gur was the principal feeder channel of Chalan beel, which used to drain the districts of Dinajpur and northern Rajshahi. The Baral worked as an outlet of the beel and eventually found its way into the Jamuna. Lower Atrai Basin is a small physiographic unit that occupies a low-lying area where mixed sediments from the Atrai and Ganges rivers and from the Barind tract overlie the down-warped southern edge of the Barind Tract. The landscape north of the Atrai River is mainly smooth, but floodplain ridges and extensive basins occur to the south of the river. Heavy clay soils are major, but loamy soils occur on ridges in the south and west. The construction of polder projects since the 1960s has improved drainage to some extent. However, deep flooding can still occur within polders as well as outside when there is heavy rainfall locally and when flash floods flow down the Atrai or off the adjoining Barind Tract, causing natural breaches of embankments or cut by the affected people from outside or adjoining polder.

The fertile soils, less migration of nutrients from soils, abundance of moisture and climatic factors helped the Chalan Beel area to provide good vegetation and dependant faunal composition. Two different types of habitats are available in the area. The terrestrial habitat has built up an uneven distribution of highly structured habitats such as homestead gardens as well as uniform monoculture cropland. The aquatic realm also contributes significantly to the biological richness of terrestrial biota during the period when most of the former waterlogged depressions and channels become dry. These habitats allow luxurious growth of aquatic plants during the monsoon period. Vegetation in village groves have good under growths (bush plants, climbers, etc.) as a sign of sound ecosystem. Dominating trees are mangos and jackfruits in higher ridges, coconuts and beetle-nuts in middle and Bonjiga, Gutul and Baroon in the lower parts. Coconuts and bamboos are the vegetation in higher and middle ridges. Timber, fire wood, fruiting, flowering and many medicinal herbs enriched the ecosystem better then any average village groves of the country.

| | |
|---|---|
|  |  |
| “Gutul” is most common wetland plant provides good habitat for birds and reptiles | “Fruit Bats” are commonly observe in some areas on old long tree |
|  |  |
| “Little Egret” on wetland plants | “Little cormorant” is common wetland bird found most of the wetlands |

Gangetic River Dolphin, an endangered mammals being very rare in project area. (Source- WWF)

Fig 1: Biological diversity of Chalan beel

Chalan Beel was formerly an important wintering area for ducks, geese and shorebirds, but now that the wetland dries out in early winter, fewer migrant waterfowl visit the area. During the rainy season, however, the beel remains important for a wide variety of resident waterfowl. Wildlife has suffered badly from the ever increasing pressures from human population and destruction of natural wetland habitats in recent decades. Many species of mammals, birds and reptiles have become rare and in some cases extinct in this particular region, and the large concentrations of waterfowl which occurred as recently as thirty years ago have disappeared. Equally the former legendary fish production of this region was vanishing.

Extensive forests of large Barringtonia trees around the beel, formerly provided an important wildlife habitat (Table 1) and source of firewood for local villagers.

Table 1: Threatened Wildlife Species as per IUCN Red Data Book found in the study area

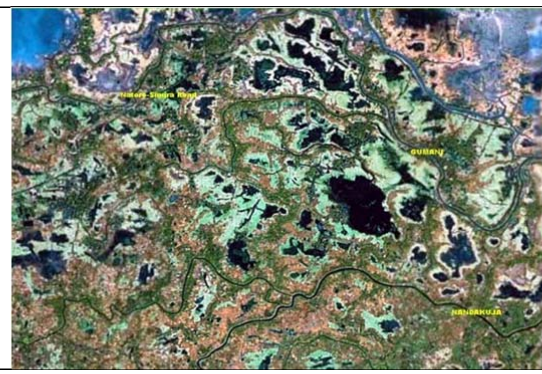
| **Species Name** | Polder | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D | C | B | A | Bogra-2 | Bogra-3 & 4 | Barnai | Baral | Naogaon | SIRDP |
| Birds | | | | | | | | | | |
| Black-headed Ibis (*Threskiornis melanocephalus)* | *** | ** | | | | | | | | |
| Greater Adjutant (*Leptoptilos dubius)* | ** | * | | | | | | | | |
| Lesser Adjutant (*Leptoptilos javanicus)* | *** | ** | | | | | | | | * |
| Grey-headed Fish-eagle (*Ichthyophaga ichthyaetus* ) | * | * | | | | | | | | * |
| White-rumped Vulture (*Gyps bengalensis)* ) | * | * | | * | | | | | | * |
| Orietal Darter (*Anhinga melanogaster* ) | * | ** | | | | | | | | * |
| **Mammals** | | | | | | | | | | |
| Otter (*Lutra perspicillat)* | * | | | | | | | | | * |
| Ganges River Dolphin *(Platanista gangetica)* | * | * | | | | | | | | * |
| Comm. Mongoose (*Herpestes edwarsii)* | * | | * | | | | * | * | * | |
| Bengal Fox (*Vulpes bengalensis*) | * | * | ** | * | * | * | ** | | * | ** |
| Fruit Bat (*Rousettus leschenaulti)* | * | | | | | | | | ** | |
| Civet Cat (*Viverricula indica*) | * | * | * | | | * | | | | * |
| Reptiles | | | | | | | | | | |
| House Lizard (*Hemidactylus brooki*) | ** | * | * | * | * | * | * | ** | * | * |
| Sim Turtles (*Chitra indica*) | * | | | | | | | | | * |

| Species Name | Polder | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D | C | B | A | Bogra-2 | Bogra-3 & 4 | Barnai | Baral | Naogaon | SIRDP |
| Birds | | | | | | | | | | |
| Bengal Monitor/Gui (*Varanus bengalensis* | * | * | * | * | | | | | | * |
| Amphibians | | | | | | | | | | |
| Water Frog (*Rana alticola)* | | | | | * | * | | | | |

**LEGEND: <u>Threatened</u>: Cr** = Critical ; **En** = Endangered ;**Vu** = Vulnerable

However, most of these forests have now been cleared, and today the villagers rely mainly on the aquatic vegetation and herbs growing around the beels for firewood. Finally, the wetlands lost much of their intrinsic value for tourism, particularly during winter when concentrations of waterfowl could be observed, and also provided important opportunities for scientific research and conservation education. The ecological features of individual sub project area are defined below by aerial photography.

**A part of polder A in satellite image showing different ecological features**



**A part of polder B in satellite image showing different ecological features**

**A part of Polder C seen like a colorful mosaic in sattillite image.**

**Satellite image of Polder D**

Fig 2 : Ecological features of individual sub project area

# 5. CONCEPT OF IWRM PLANNING

Integrated Water Management Plan for the study area was developed considering all the existing polders and sub-projects in an integrated manner. The implementation of interventions under this plan created the scope of better flood management and sufficient drainage provision for preventing public cuts made by local people. Moreover, the interventions were likely to create the scope of improving dry season water availability to facilitate surface water irrigation, provide facilities for expansion of fisheries and other wet land resources. The other objective was to conserve the existing ecosystem that was going to be threatened in near future.

The existing problems were being analyzed and the result shows that the project area suffered from tremendous flash flooding in the upstream polders while downstream polders suffer from submergence as a result of back water effect generated due to high water level maintained in the downstream in the mighty Jamuna River during the wet season. Nevertheless, the project area also suffered from shortage of surface water during dry season and is mainly dependent on costly ground water. To briefly describe the concept of present planning, the polders and projects were classified into three clusters and the main river systems where interventions have been chosen for water resources management and environmental conservation.

## 5.1 Water Management in Cluster One

The Nagoan polder has mostly remained as usual. Only improvement work required to repair and maintain the existing regulators that made and assumed to function properly due to lower water stage maintained at Atrai river. And the lower water stage has been created by the management of flood flow from Atrai river in other sub clusters of polders.

## 5.2 Water Management in Cluster Two

The polders located at the south side of the Atrai-Gur-Gumani river has been considered as separate cluster. In this cluster, the main concept was that flood flow from Sib River allowed to enter gradually in polder D at several locations (Tengra and Sabaibeel) which may stop the sudden entry of flood water into this polder and drained through Manshingpur, Zoker Khal and Purba Daulatpur into Fakirni – Barnai and finally reach to Atrai-Gur-Gumani at its downstream reach. It is to be mentioned here that there was a rubber dam at the confluence point of Fakirni and Barnai, which generate sufficient volume of water for dry season irrigation.

Similarly, in polder C, flood flow is allowed to enter from Atrai river through several points at the upstream locations (Sutighaca, D/S of Jotebazer and Bandaikhara) and pass slowly towards downstream and drained out at the downstream reach of Atrai (Udaypur, Joremollika and Patkal). Polder A and B will not allow any flood flow inside the polder but only back flow be allowed to enter through Kenu Sarker Jola and they have been separated to drain out their surface runoff or any flood flow properly through additional regulators at mostly downstream points in each polder.

## 5.3 Water Management in Cluster Three

To manage the problem such as flood flow and drainage, the FS team has divided all the polders into three sub clusters. All the projects/polders located at the north side of the Atrai-Gur-Gumani such as Bogra polder 2, 3, 4 and SIRDP the interventions are proposed so that movement of flood flow from one after another such as Bogra polder 2 to Bogra polder 3, Bogra ploder 3 to Bogra polder 4 and SIRDP, finally drained properly through Rowtara and Char Lakipur at the downstream of the said river near Bagha Bari. In this cluster provision has also been kept to allow flood flow from Atrai river to Bogra polder 2 at Shomeshpur Bazer and from the Nagar to Bogra polder 3 at Sardanagore to reduce the excess flood flow of Nagar river where frequent breach has been taking place. This facilitates no addition of flood flow at the middle reach of Atrai-Gur-Gumani and keeps these polders free from backwater flooding problem. However, open breach has been considered and to be remain open at Handial where frequent breaches have occurred as the local people who live in small unprotected areas cut the embankment every year to save their land from back water flooding of Atrai river.

### 5.4 Water Management of the Main River Systems

In addition to the water management in each polder, water management of the main river system has been planned to be made through construction of interventions such as rubber dams and cross regulators. Cross regulator at Godai river has been proposed for meeting the dry season irrigation water requirement. Similarly, one rubber dam on Atrai river, one rubber dam on Barnai river at the downstream of Fakirni-Barnai River confluence in Shreepur, one rubber dam on Nandakuja River and one cross regulator on Godai river serves the purpose of meeting up the dry season irrigation requirement. The following map shows the location of proposed and existing interventions.


**Map 1: Location of proposed and existing intervention**

## 6. ACCEPTANCE OF IWRM PLAN

Integrated Water Resources Management in Chalan Beel area including Beel Halti Development Project concept is very much in line with the people's thinking which would allow gradual and distributed flooding among the polders through the existing river systems.

People accepted the concept of IWRM plan allowing gradual and distributed flood mechanism which has been termed as "Controlled Flood" rather than full flood control. The effective implementation of project plans was also encouraged them to cultivate Aman crops and reduce the water scarcity during recession period. Additional crops could be cultivated during post monsoon season. However, they were very much concerned about the proper operation and maintenance of the proposed and existing water control structures of the project area. They were ready to take the responsibility of operation and maintenance with proper training and the source of operational fund. Stakeholders felt that a well-defined operational policy is needed for both the beneficiaries and mother authority BWDB which should be included in the project planning and be implemented during the same project period.

## 7. CONCLUSION

IWRM plan for Chalan beel area was a systematic process for the sustainable development, allocation and monitoring of water resources based on the perception of water as an integral part of the ecosystem, a natural resource and social and economic goods, whose quantity and quality determine the nature of its utilization. Aquatic and terrestrial wildlife habitats of study area have been changed with improvements in water management concept. Proposed interventions and its operation have protected the terrestrial and aquatic vegetation coverage against flood water and draught which were the main causes of ecosystem vulnerability in the project area. Many species of threatened wildlife including insects, mammals, reptiles and birds have been rehabilitated in this area. This integrated water management planning approach addressed the water issues as like conjunctive use of surface and groundwater to save the threaten ecosystem; Preservation of bio-diversity; Promotion of culture fisheries and allowing flood plain fisheries in Chalan beel area.

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# ENVIRONMENTAL IMPACTS OF USING SAND FILLED GEO-BAG TECHNOLOGY UNDER WATER IN RIVER EROSION PROTECTION OF MAJOR RIVERS IN BANGLADESH

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## ABSTRACT

Geotextile bag or geobag, a geosynthetic product made of polyester; polypropylene or polyethylene has been used world wide for protecting riverbanks and hydraulic structures from severe scouring and erosion. In Bangladesh, geobags have been used under water in protective works since 1999 for its cost effectiveness and sustainability. The first large scale adoption of Geobags was through the Jamuna Meghna River Erosion Mitigation Project (JMREMP) of BWDB supported by the ADB. Since 2002, JMREMP has been using sand filled Geobags under water with cement concrete (CC) blocks along the major rivers of the country like Meghna and Jamuna. This study was conducted to assess the Ecological Impacts of using Sand-filled Geo-Bags under water as a protective measure of river erosion. The overall methodology of this study was a kind of systematic and sequential multidisciplinary approach that included application of expert judgment, stakeholder consultation, local people’s perception and simulation. The impact identification and evaluation was carried out comparing the protective works using geobags with CC block and protective works without geobags. Followed by the risk characterization and categorization, the risk assessment frame work was formulated and employed to assess the overall risk of using geobag. Geobag technology possesses minimal impacts on fish resources and facilitates fishing activities. The protective works using geobag protects the terrestrial habitat while it shows some negative impact on aquatic ecosystem by altering the habitat of the benthic community and local shifting of the migratory routes of the dolphin. On the other hand it facilitates the algal community to grow. Moreover, geobags is also friendly for the wildlife like jackal, fishing, cat, amphibians for accessing river while assorted dumped CC blocks make barrier or difficulties of accessing river for the wildlife.

**Key Words:** River bank erosion, protective measures, Sand filled Geobag, Ecosystem habitat, Eco-friendly, Fisheries habitat and Ecological risk

## 1. INTRODUCTION

Protection of the river bank along the major rivers of Bangladesh has always been considered as a challenging engineering task against the nature and Bangladesh Water Development Board (BWDB) has been practicing different technology for controlling river bank erosion with the purpose of protecting lives and livelihoods. Its impact on environment especially on ecosystem is also a debating issue. In response to national concern on effective erosion

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protection measure and its cost effectiveness, BWDB has adopted sand-filled geo-textile bags (Geo bags) technology in many places for protective works at eroding riverbanks since 1999 while the technology has been being popular world widely due to its easier installation, cost effectiveness and technical efficiency [1, 2 and 3]. It was first used in Bangladesh during FAP-21 project to protect the riverbank erosion of the Jamuna River [2]. The Jamuna-Meghna River Erosion Mitigation Project (JMREMP), supported through ADB loan 1941 BAN (SF), is using geo-bags substantially from the year 2002 to protect the riverbank erosion of Jamuna River [4]. The major vision and choice of the project are to develop innovative, cost effective, environment friendly and sustainable riverbank protection solutions and it suggests adopting the technology of using sand filled geobags under water in major rivers of the country [2].

In response to concerns of different stakeholders, Bangladesh Water Development Board (BWDB) felt that environmental impact assessment of the use of geobags placed under water to protect eroding riverbanks might be carried out before envisaged nationwide extension of using this technology. This paper has been prepared based on the EIA study carried out by CEGIS as a technical adviser of BWDB [see 5] and only the ecological impacts including fisheries are presented here.

## 2. COST EFFECTIVENESS OF GEOBAG

In compare to conventional erosion protection work using C.C. block, gravel, hard rock etc, sand filled geobags technology involves less cost. World widely it has been seen that erosion protection work using Geobags requires less installation and maintenance cost [1], light weight equipment, less space for construction works, transportation cost, less energy requirement [6]. A joint study of Bangladesh University of Engineering and Technology (BUET), BWDB and Institute of Water Modeling (IWM) reveals that Geobag used in different revetment work along the major rivers of Bangladesh (Jamuna and Meghna) results 40% to 60% cost reduction [2]. The constructing materials (sand) of geobag are locally available and cost-effective compared to importing boulders from other countries. The manufacturing of geobags and quality control of the bags are easy compared to the C.C. blocks and boulders.

## 3. TECHNICAL EFFICIENCY

Sand filled Geobags work as a substitute of C.C. blocks used as dumping material, even though geo-bags are sometimes used as filter material below C.C. blocks [7]. A physical modeling study under JMREMP [3] found that launching performance of sand filled geobags is better than C.C. block but lower than rounded and angular rock. The joint venture study of BWDB, BUET and IWM suggests [2] that the launching performance of geobag could be found similar to hard materials if area coverage method is applied instead of mass dumping method. The major advantages of Geobags are its availability and easier implementation. Geobags are readily available and transportable (when empty) and can be easily filled with local sand and formed with a range of sizes to fit specific application. On the other hand, main demerit of geobag is its high sensitivity to UV radiation and highly alkaline or acidic water [9 and 10]. Solar UV radiation stimulates its polemeric ageing process. Depending on its constituent strains' properties, its life expectancy could be reduced 15% to 75% in one year exposure [9]. Ageing due to UV radiation could be protected by using some stabilizers [11]. Geobags available in our markets have resistance to 160 kilo Langley per year solar radiation [5] while Bangladesh falls in the zone of 180 to 140 kilo Langley per year solar radiation [12]. Highly acidic and alkaline water could also significantly reduce geobags' property through chemical degradation [10] and fortunately major rivers of Bangladesh show neutral pH (6 to 7) [2 and 5].

## 4. USE OF GEOBAG IN BANGLADESH

The sand filled geobags were firstly used in Bank Protection and River Training Pilot Project, FAP 21/22 at limited extend. Later, in Pabna Irrigation and Rural Development Project (PIRDP) and Meghna Dhonagoda Irrigation Project (MDIP), sand filled geobags were used under the aegis of Jamuna Meghna River Erosion Mitigation Project (JMREMP) during 2002. As on 2006-2007, sand filled geobags have been used under water successfully in approximately 20 km of River bank protection work [2]. Recently, this technology has been used for protecting river bank along the Major rivers of Bangladesh i.e Jamuna, Ganges, Padma and Meghna.

## 5. METHODOLOGY

This study was carried out following the guideline for Environmental Assessment of Water Management Projects [8] and the Environmental Assessment requirements of Asian Development Bank (ADB). The environmental impact of sand filled geobags used under water has been made comparing with protective works using only C.C. Block. The environment intervened by protective works using only C.C. Block was considered as control environment. Comparing with this control environment, the impacts of sand filled geobags on Environment were identified.

### 5.1. Study area

The study was conducted by investigating two similar reaches (hydraulic, socio-economic and environmental consideration): one is protection with geo-bags in addition to C.C. blocks under water (study area) and other (control area) being protected by using C.C. blocks only. In order to examine the effects of saline and non-saline water on geobags, four major rivers (Ganges, Padma, Jamuna and lower Meghna) were selected covering both saline and non-saline zone, which gave a comprehensive context of the whole country. In total 6 control areas and 6 study areas were selected as summarized in the Table 1.

Table 1: List of control and study area

| Zone | River | Location | Control/study area |
|---|---|---|---|
| Non Saline | Ganges | Boiddnathpur, Chapai Nawabganj | Study area |
| | | Boiddnathpur, Chapai Nawabganj | Control area |
| | Padma | PIRDP, Bera Pabna | Study area |
| | Jamuna | PIRDP, Bera Pabna | Control area |
| | | Sirajganj Hardpoint | Study area |
| | | Sirajganj Hardpoint | Control area |
| Saline | Lower Meghna | Horar Hat, Bhola | Control area |
| | | Hakimuddin Bazar, Borhanuddin | Study area |
| | | Baliakandi, Tazumuddin | Study area |
| | | Ramprashad, Tazumuddin | Study area |
| | | Ramprashad, Tazumuddin | Control area |

### 5.2. Materials and methods

The study was carried out through interdisciplinary approach while a multidisciplinary team was involved. Local people participation was ensured through PRA and RRA approach. World standard EIA process consisting with a composite set of adhoc, checklist and matrix methods was employed in the EIA study where both secondary and primary data were used. Local knowledge was incorporated in the study process through Stakeholder Consultation, Key Informants Interview and Focus Group Discussion (FGD).

### 5.3. Impact evaluation and risk characterization

Considering all potential and observed impact, risk assessment was accomplished eventually after characterizing and categorizing the risk of each potential and observed impact of using geo-bags under water. For better understanding and screening, word scenarios were developed for each categories of the risk. The basis of risk characterization was likeliness and consequence of the impact. Followed by the risk characterization and categorization, a risk assessment framework was developed that was employed to assess the overall environmental risk of using geobag. An empirical scale was developed to limit the subjective assessment of the risk. Table 2 shows the risk assessment framework. The process of the risk assessment was carried out through workshop where expertise of the EIA study team members as well as the experience of BWDB Engineers were utilized to finalize the risk matrix.

Table 2: Risk assessment framework

| **Risk assessment framework** (Without application of mitigation and management measures) | | COMPONENT | | CONSEQUENCE | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Ecosystem** | **Terrestrial and Aquatic Ecosystem** | No or insignificant negative impact | Localized, short time degradation of sensitive ecological habitat | Localized long term/ short term, widespread, degradation of ecological habitat | Widespread, long term degradation of ecological habitat, | Permanent degradation of ecological habitat |
| | | **Fisheries** | **Fish Habitat, production and composition** | No or insignificant negative impact | Localized, short time degradation of fish habitat | Localized long term/ short term, widespread, degradation of habitat, species proportional change in fish composition | Widespread, long term degradation of fish habitat, and change fish composition, effects on sensitive habitat and species | Permanent degradation of fish habitat, extinction of any fish species |
| | | | **Ranking** | Insignificant | Minor | Moderate | Significant | Catastrophic |
| **IKELIHOOD OF OCCURANCE** | **Likelihood Descriptions** | **Ranking** | Index | 1 | 2 | 3 | 4 | 5 |
| | Consequence occurs immediate after the project implementation | Frequent | 5 | 5 | 10 | 15 | 20 | 25 |
| | Conditions may allow the consequence to occur during the project lifetime | Likely | 4 | 4 | 8 | 12 | 16 | 20 |
| | Exceptional consequences to occur within the project lifetime | Occasional | 3 | 3 | 6 | 9 | 12 | 15 |
| | Conditions do not seem to occur any consequence except some extreme cases | Seldom | 2 | 2 | 4 | 6 | 8 | 10 |
| | Reasonable to expect that the consequence will not occur though it has rare possibility to occur | Rare | 1 | 1 | 2 | 3 | 4 | 5 |

| | | | | |
|---|---|---|---|---|
| **1- below 5:** Low risk, mitigations may be applied | **5- below 10:** Risk is Acceptable, mitigations may be applied | **10 – below 15:** Medium risks, risk reduction is required | **15 – below 20:** High risks, mitigations must be applied | **20 to – below 25:** Extremely high, mitigations must be applied |

## 6. GENERAL DESCRIPTION OF THE PROTECTIVES WORKS IN THE STUDY AREA

Though the design and specifications are different in different protective works, in general protective works were found combined typed where C.C Block and sand filled geobags were placed under water. The design includes, earth filled compaction, slope pitching works over geotextile, assorted block placing and geobag placing on berm and geobag dumping. There are three different sizes of geobags that are used in protective works: Type A- 175 kg, Type B- 150 kg, and Type C- 126 kg.

## 7. ECOLOGICAL IMPACTS OF USING SAND FILLED GEOBAG UNDER WATER

### 7.1 Impacts on ecosystem

#### *7.1.1 Impact on water quality*

Geobags used under water in protective works are chemically inert. Chemical analysis of river water quality at study sites found within the standard of DoE. Water turbidity near geobags using protective works is found very lower than that of C.C. block using protected sites.

#### *7.1.2 Impact on ecosystem habitat*

The C.C. block using protective work requires huge site clearance activities including removal of top soil, and vegetation. The construction works includes stone crashing, mixing, block casting, construction materials transportation and storage, and vehicle movement may source the fugitive particulate matter that might have impact on surrounding ecosystem habitat especially on roadside vegetation, agricultural ecosystem and riverine ecosystem. There will be potential of same impact during emergency dumping and rehabilitation if further construction activities are required.

On the other hand, there is no such negative impact or condition that might allow having potential negative impacts of using geobags on ecosystem habitat. The negative impacts associated with site clearance and construction activities are minimal. During the dumping, water turbidity increases that might affect habitat quality. Compare to protective works using only C.C. blocks, geobags are more effective in arresting sediment [2] that improves the water transparency, which is helpful for ecological productivity. However, these impacts are localized, temporal and reversible.

During operational phase, the resultant negative impact of geobag use is also minimal. Some small amount of land is required for stocking of sand and geobags for emergency dumping.

#### *7.1.2 Impacts on terrestrial flora*

C.C. Block using protection works involve huge site clearance and base stripping activities. Moreover, the airborne particulate matters may be spreading over the surrounding agricultural field, homestead, social and roadside vegetation that might reduce floral productivity. In case of geobags using technology, base stripping and construction activities are minimal and result less impact on terrestrial flora.

#### *7.1.3 Impacts on terrestrial fauna*

C.C. block used under water and on bank slope may make the accessibility to river difficult for few terrestrial fauna like, Jackel, Bangel fox, fishing cat and amphibians. The assorted blocks over the bank slope may restrict the river from easy access for drinking, bathing and hunting purposes of mentioned wildlife and livestock. On the other hand, Geobag has no such impacts on river access.

### *7.1.4 Impacts on aquatic flora*

Like C.C. block using technology, during construction phase, geobag using technology has some impacts on aquatic flora like floating and submergible plants due to covering the limnetic zone. But the impacts are local and short term. Due to high siltation rate, the limnetic zone will be resuscitated. However, geobags also provide grounds for some floating plants and algal community. Algal communities are found more frequently and densely in geobag dumping zone than that of C.C. block.

### *7.1.5 Impacts on aquatic mammals*

Ganges, Padma, Jamuna and Meghna are the important migratory routes of Dolphin, the sensitive aquatic mammals. Dolphins choose thalweg as their migratory route. The dumping activities (in both case of C.C. block and sand filled Geobag) may cause the shifting of their migratory route temporary. But the dumped sand filled geobags don't block the free movement of the mammals like hard edges of C.C. blocks.

### *7.1.6 Impact on benthic community*

C.C. block doesn't cover the complete benthic zone. In that case, benthos community can easily grow in interlock and the gap between blocks. On the other hand, dumped Geobags completely cover the benthic zone of the river bank slope that might impact on benthic habitats. However, it has been come out from the field observation that the impacts on benthic zone are local, short term, and reversible. The high siltation rate over the geobags covers the dumped geobag within a year and restores the benthic habitat.

## 7.2. Impact on fisheries

### 7.2.1. *Impact on fish habitat*

During dumping, the fish habitat and assemblages near river bank might be disturbed and some damage of benthonic and planktonic community might be resulted. In addition, the covering of river bed with geobag in limnetic zone may have some effects on some fishes e.g Ayre (*Aorichthys aor*), Rita (*Rita rita*), boal (*Wallago attu*), Pangas (*Pangasius pangasius*), different types of baim, gutum (*Lepidocephalus guntea*), bala (*Glossogobius giuris*) and some small fish species by limiting their feeding opportunity. The regeneration of algae and benthos community over the dumped geobags were found during field visit that indicates the restoration of food sources for fish. The local fishers also support the indication of restoration of fish habitat.

### *7.2.2 Impact on fish migration*

Fish uses the river channel as a migratory route for feeding and breeding purpose and shelter for brood, post larvae and juvenile stages. Fish migration may be affected locally for short term during dumping and it might happen in both cases of protective work. The prudent impact is due to shifting of thalweg. Shifting of thalweg due to enhanced sedimentation rate and control of bed scouring may results in local shifting of fish migratory routes. Geobag has more functional effectiveness to control the bed scouring than that of CC block [2].

### *7.2.3 Impact on fish production*

Sediment and dust material runoff from the construction activities during the construction may cause increase in river turbidity that may reduce fish breeding and fertilization of fish eggs. Hence the potential of generating dust and fugitive materials is higher in CC block using protective works than that of goebag using protective works, the impact on fish production during construction will be minor in case of geobag using technology of protective works.

### *7.2.4 Impact on fish species composition*

The overall fish composition of the river depends on habitat and availability of food. Surface fishes may be affected during the dumping of geobags. Likewise the C.C. block use, the surface fish species may also shift locally for short term in case of geobag using protective work. The covering of the river bed of the limonitic zone by geobag may affect the bottom fishes. After placing of geo-bags, the fishes those live in holes (e.g. ell and cat fish) may migrate from protective areas. Field observation and fishers perceptions support that the underwater environment is restored within one or two year that would favor the habitat for ells and cat fishes again.

### *7.2.5 Impact on fishing effort*

In C.C. block dumped area, fishers can't use any gear for fishing. Irregular shape of the blocks causes damage to their nets. The space between the blocks helps fishes to hide from nets. On the other hand, no such impact has been noticed in the geo-bags dumped areas.

## 8. RISK ASSESSMENT

Each of the aforementioned potential and observed impact was evaluated through the risk assessment framework (Table 2 in methodology) to characterize the risk that also depicts priority what should be taken into consideration during formulating environmental management plan. This additional assessment and evaluation of the risk of each impact will direct the policy makers to decide whether the impact would be acceptable or not; whether the impact would require the mitigation, enhancement contingency and monitoring measures. The summery of the risk assessment is briefed in Table 3 where it is seen geobags use under water possess low risk of affecting fisheries which might be acceptable and medium risk of affecting ecosystem which requires adoption of mitigation measures.

Table 3: Risk characterization and assessment

| **Sl no.** | **Key potential impact** | **Likelihood** | **Consequence** | **Risk** | **Subjective meaning of Risk** | **Response/ Action** |
|---|---|---|---|---|---|---|
| Risk on Fisheries | | | | | | |
| 3 | Impact on terrestrial habitat: minor impact during construction by sourcing fugitive particulate matter | 3 | 2 | 6 | Risk is Acceptable, mitigations may be applied | Mitigation measure may required during construction phase |
| 4 | Impact on Aquatic habitat: Have local, short time and reversible impacts on benthic communities | 4 | 3 | 12 | Medium risks, risk reduction is required | EMP with mitigation and monitoring measures for pre, during and post construction phase |
| 5 | Local shifting of migratory route of dolphin due to shifting of thalweg | 4 | 3 | 12 | Medium risks, risk reduction is required | EMP with mitigation and monitoring measures for pre, during and post construction phase |
| Risk on Ecosystem | | | | | | |
| 6 | Impact on Fish Habitat: Condition may affect cat fish and ell habitat locally and for short time. Combined method facilitate fish assemblage | 4 | 2 | 8 | Risk is Acceptable, mitigations may be applied | EMP with mitigation, and monitoring is required |
| 7 | Impact on Fish production: No significant change | 4 | 2 | 1 | Risk is Acceptable, | Mitigation and monitoring measures |

| Sl no. | Key potential impact | Likeli hood | Consequ ence | Risk | Subjective meaning of Risk | Response/ Action |
|---|---|---|---|---|---|---|
| | | | | | mitigations may be applied | may be adopt |
| 8 | Impact on Fish composition: Local, short time and minor reduction of cat fish and eel. | 4 | 2 | 8 | Risk is Acceptable, mitigations may be applied | Mitigation and monitoring measures are required |

## 9. CONCLUDING REMARKS

Use of sand filled geobags under water in erosion protection work is being popular due to its cost effectiveness, availability and easier implementation. Some recent studies support that its technical efficiency is similar or sometimes better than use of hard material. Bangladesh Water Development Board has implemented numbers of river bank erosion protection works using sand filled geobag under JMREMP and is going to adopt this technology widely in erosion protection works of the country. Prior to nationwide adoption of this technology, the interaction between goebag and environment has been assessed through EIA and this paper presents only the ecological impacts of geobags use under water.

Despite the cost effectiveness, there are potentiality of resulting some negative impacts like short term shifting of some surface and bottom fishes, covering of river slope bed in limnotic zone, temporal alteration of benthonic habitat and local shifting of Dolphin migratory route due to induced sedimentation. However, these impacts are acceptable and could be reduced by adopting mitigation measures. In compare to C.C. block use the construction and post-construction impacts are very minimal as it involves less construction activities, generating less construction waste and no chemical alteration to water quality. At the end it can be concluded that, in compare to C.C. block use, the geobag use is more ecosystem and fisheries friendly.

However for better environmental sustainability, an Environmental Management Plan should be adopted with detail plan for mitigating negative impacts, enhancing expected benefits and regular monitoring of EMP implementation and resulted impacts. Farther research might be carried out in developing an appropriate Environmental Management Plan that would be easier in following and implementing.

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# STUDY OF CYCLONE SIDR AND ANALYSES OF SOME EXISTING SHELTERS AT FEW CYCLONE PRONE AREAS USING GIS

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## ABSTRACT

Bangladesh is a disaster prone country. The country faces grave poverty conditions, which are accentuated by natural calamities like cyclone. In 15 November, 2007 a very severe cyclonic storm Sidr attacked the country which causes a huge damage. This project is done using GIS for identification of areas which were mostly damaged due to Sidr based on data of damage and locations of existing cyclone shelters of six thanas from highly affected Barguna and Potuakhali district. From the prepared maps it is found that 50-100% people are affected in Bagerhat, Barguna, Pirojpur and Jhalokati district; 20-50% people are affected in Barisal, Potuakhali and Madaripur district and most people died in Barguna, Bagerhat, Pirojpur and Potuakhali. 30-60% houses are completely destroyed in Bagerhat, Barguna, Jhalokati district and 15-30% in Potuakhali and Pirojpur districts; crops of 30000-250000 acres are completely destroyed in Barguna, Bagerhat, Barisal, Pirojpur, Potuakhali, Jhalokati district. A large number of livestock was killed in Barguna, Pirojpur, Bagerhat, Jhalokati and Gopalganj district. The maps of cyclone shelters show that existing condition of cyclone shelters in Galachipa thana is comparatively better than others whereas the existing condition of cyclone shelters in Barguna sadar, Amtali thana, Dasmina thana, Bauphal thana and in Kalapara thana is not so good according to the demand.

**Keywords:** Cyclone, Sidr, Cyclone Shelter, Damage, GIS, Bangladesh, Killa.

## 1. INTRODUCTION

Bangladesh, an alluvial deltaic plain, has an approximate area of 147,570 sq.km bounded between 20°34’ to 26°38’N latitude and 88°01’ to 92°41’E longitude. The population of the country is around 150 million. Bangladesh has been subjected to frequent natural disasters in many forms, particularly cyclonic storms and tidal surges. The funnel-shaped northern portion of the Bay of Bengal causes tidal bores when cyclones make landfall, and thousands of people living in the coastal areas are affected. From 1797 to 1998, 67 major cyclone storms and tidal surges have been reported **[5]**. It is estimated that a total 775,303 people died in the coastal areas and offshore islands of Bangladesh within the last 222 years (1775-1997) time **[6]**, only due to cyclone and storm surges. Recently a very severe cyclonic storm Sidr attacked the country which causes a huge damage. Total damages came close to $450 million. The entire cities of Potuakhali, Barguna and Jhalokati district were hit hard by the storm surge of over 5 meters (16 ft) **[1]**. Among the deadliest cyclones in Bangladesh, Sidr is one of the most as it left long term effect on human life and environment.

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About a quarter of the world heritage site Sunderbans were damaged. In 2007 though Sidr cause less loss of human life in compare to that in 1970 and 1991's cyclone, it left a great economic and environmental damage which the country cannot yet overcome.

This paper focuses on major damage done by severe cyclonic storm Sidr with the help of GIS to make easier the relief work and rehabilitation process and to reduce losses in future cyclone. Cyclone shelter centers are the most wanted place for the people during cyclone. Most of the cyclone shelters are built by the government of Bangladesh and Bangladesh Red Crescent Society for protecting human lives in the cyclone prone coastal areas of the country. At present PWD/IDA, BDRCS and various NGOs are also constructing a few cyclone shelters. In the 30 years after the 1970 cyclone, over 2000 cyclone shelters were constructed in the coastal regions of Bangladesh. According to Ministry of Food and Disaster Management the available no. of cyclone shelters were 1800 in the year 1993, 1841 in 1997 and 2033 in 2001**[7]**. In this paper location of cyclone shelters under categories of existing, under construction, proposed and existing killas are shown using GIS to help decision making in establishment and relocation of cyclone shelters.

## 2. STUDY AREA

The study area of the project is cyclone affected areas of Bangladesh for study of damage of cyclone Sidr. For location of cyclone shelter centers, 6 thanas in cyclone prone area were taken.

Table 1: List of thanas **[2, 3, 4]**

| District Name | Thana Name | Area in Sq. Km. | Population | Existing Shelters on July 1993 | Proposed Shelters on July 1993 | Under construction Shelters on July 1993 | Existing Killas on July 1993 |
|---|---|---|---|---|---|---|---|
| Barguna | Amtali | 721 | 259757 | 6 | 43 | 0 | 1 |
| | Barguna | 454 | 237613 | 5 | 82 | 1 | 0 |
| Potuakhali | Bauphal | 487 | 304959 | 3 | 64 | 0 | 0 |
| | Kalapara | 483 | 202078 | 30 | 85 | 1 | 1 |
| | Dasmina | 352 | 117000 | 9 | 39 | 0 | 4 |
| | Galachipa | 1268 | 326000 | 40 | 84 | 3 | 21 |

## 3. MAP PREPARATION AND DATA PROCESSING

The required data for the project was collected from SPARRSO, Disaster Management Bureau Bangladesh, BCA and Library of Civil Engineering department, BUET. The relevant maps and attribute tables and maps for analysis were prepared by using ArcGIS 9.2 software. The map of the track collected in JPEG format was imported to the software. Then corresponding latitudes and longitudes were input to fit the map to world map. Then the track was drawn and attribute table was prepared to input corresponding data. To input district wise damage and other data, relevant fields were added to the district attribute table. They are listed in table 2. Using data from table 2 maps showing percent population affected, percent houses damaged, people died, crops damaged fully and partially, livestock died and trees destroyed in color gradient was prepared. The maps are shown in appendices. The prepared table is shown below:

Table 2(a): Table showing data of damage (From Disaster Management Bureau, Bangladesh)

| District Name | Population | Affected People | Percent Population Affected | No. of people died | Crops Damaged (Full) | Crops Damaged (Partial) |
|---|---|---|---|---|---|---|
| Bagerhat | 1549031 | 1221788 | 78.874 | 810 | 58215 | 237483 |
| Barguna | 848554 | 843669 | 99.424 | 1292 | 227403 | 83202 |
| Barisal | 2355967 | 846076 | 35.912 | 97 | 45275 | 223563 |
| Bhola | 1703117 | 147718 | 8.673 | 42 | 22350 | 148862 |
| Chandpur | 2271229 | 175579 | 7.730 | 5 | 6550 | 19301 |
| Chittagong | 6612140 | 15295 | 0.23 | 21 | 1976 | 4989 |
| Comilla | 4595557 | 70527 | 1.534 | 0 | 2500 | 30104 |
| Cox's bazar | 1773709 | 8555 | 0.48 | 7 | 245 | 1276 |
| Dhaka | 8511228 | 15180 | 0.178 | 6 | 450 | 9114 |
| Faridpur | 1756470 | 154540 | 8.798 | 16 | 23200 | 75542 |
| Feni | 1240384 | 156 | 0.012 | 0 | 87 | 263 |
| Gopalganj | 1165273 | 257354 | 22.085 | 35 | 8958 | 34248 |
| Jessore | 2471554 | 223608 | 9.047 | 2 | 103 | 2008 |
| Jhalokati | 794231 | 763211 | 96.094 | 47 | 117308 | 67908 |
| Khulna | 2378971 | 525616 | 22.094 | 18 | 12464 | 78292 |
| Kishoreganj | 2594954 | 18140 | 0.69 | 0 | 4500 | 16087 |
| Lakshmipur | 1489901 | 55695 | 3.738 | 2 | 18500 | 127483 |
| Madaripur | 1146349 | 595000 | 51.904 | 41 | 3330 | 9460 |
| Manikganj | 1285080 | 4200 | 0.326 | 0 | 6807 | 42622 |
| Moulvibazar | 1612374 | 755 | 0.046 | 2 | 45 | 280 |
| Munshiganj | 1293972 | 102322 | 7.907 | 8 | 3080 | 6553 |
| Narail | 698447 | 35024 | 5.014 | 1 | 7615 | 21656 |
| Narayanganj | 2173948 | 57998 | 2.667 | 12 | 6889 | 1297 |
| Narsingdi | 1895984 | 306538 | 16.167 | 3 | 2350 | 34301 |
| Noakhali | 2577244 | 217300 | 8.431 | 1 | 3125 | 19625 |
| Potuakhali | 1460781 | 611125 | 41.835 | 457 | 60440 | 254835 |
| Pirojpur | 1111068 | 1011359 | 91.025 | 400 | 72963 | 81909 |
| Rajbari | 951906 | 3775 | 0.39 | 1 | 3200 | 9359 |
| Satkhira | 1864704 | 212133 | 11.376 | 20 | 2858 | 45460 |
| Shariatpur | 1082300 | 423023 | 39.085 | 17 | 20536 | 43235 |

Table 2(b): Table showing data of damage (contd.)

| District Name | No. of Household | No. of houses damaged | Percent Houses Damaged | No. of livestock died | Trees Destroyed |
|---|---|---|---|---|---|
| Bagerhat | 323505 | 118899 | 36.75 | 207085 | 20000 |
| Barguna | 179968 | 95412 | 53.01 | 593571 | 1000000 |
| Barisal | 474076 | 41470 | 8.747 | 962 | 300000 |
| Bhola | 328670 | 15389 | 4.682 | 7658 | 150000 |
| Chandpur | 433768 | 10342 | 2.384 | 70 | 81673 |
| Chittagong | 1240537 | 603 | 0.048 | 4654 | 1200 |
| Comilla | 828168 | 806 | 0.097 | 0 | 1400 |
| Cox's bazar | 296109 | 40 | 0.013 | 3 | 1500 |
| Dhaka | 1796950 | 15 | 0.001 | 0 | 9000 |
| Faridpur | 349458 | 1000 | 0.286 | 52 | 153300 |
| Feni | 223049 | 45 | 0.020 | 0 | 450 |
| Gopalganj | 221986 | 24133 | 10.87 | 94492 | 17000 |
| Jessore | 524127 | 295 | 0.056 | 0 | 350 |
| Jhalokati | 144923 | 69685 | 48.08 | 91329 | 320000 |
| Khulna | 499324 | 17323 | 3.469 | 13652 | 45170 |
| Kishoreganj | 534770 | 55 | 0.010 | 765 | 12000 |
| Lakshmipur | 288736 | 1479 | 0.512 | 2 | 700 |
| Madaripur | 231655 | 4991 | 2.154 | 30 | 30444 |
| Manikganj | 276932 | 750 | 0.271 | 5 | 10000 |
| Moulvibazar | 292889 | 60 | 0.02 | 56 | 850 |
| Munshiganj | 250850 | 2804 | 1.117 | 0 | 8000 |
| Narail | 141071 | 3629 | 2.572 | 0 | 750 |
| Narayanganj | 453627 | 476 | 0.104 | 153 | 2000 |
| Narsingdi | 385361 | 24 | 0.006 | 10802 | 160000 |
| Noakhali | 460394 | 980 | 0.212 | 250 | 700 |
| Potuakhali | 287101 | 53291 | 18.56 | 17184 | 175000 |
| Pirojpur | 232962 | 63896 | 27.42 | 735411 | 750000 |
| Rajbari | 191492 | 3789 | 1.978 | 0 | 2000 |
| Satkhira | 390745 | 5293 | 1.354 | 162 | 35400 |
| Shariatpur | 213677 | 27993 | 13.10 | 159 | 776429 |

**4. FINDINGS**

Based on the prepared map and attribute table the following outcomes are obtained.

**From data of damage:**

The obtained maps show intensity of damage from lighter to darker color in increasing order for each map. From the observation of the track of SIDR, it is found that the areas near the center of the track were affected most and areas far from center line were less affected. The intensity of damage is also less in the land areas as the cyclone is cut off from its moisture source. The figure below shows track of Sidr.

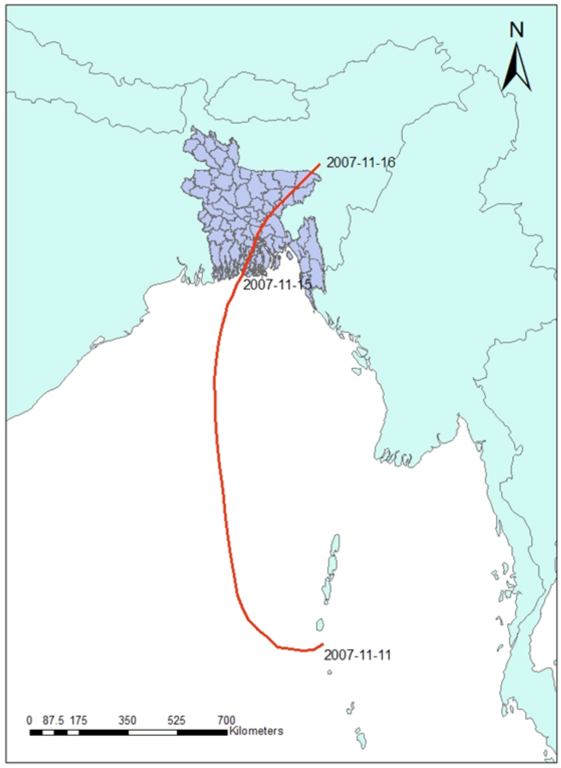



Fig 1: Track of Sidr (Using Satellite image from SPARRSO)

From the prepared maps several identifications can be made:

1. Areas where most people are affected by the cyclone
2. Areas where most houses are damaged
3. Areas where most crops are damaged
4. Areas where most livestock is killed
5. Areas where most trees are destroyed

From fig 2 it is found that people in Barguna, Pirojpur, Jhalokati, Bagerhat were highly affected which is 50 to 100 percent. Districts like Barisal, Potuakhali, Madaripur were moderately affected ranging from 20 to 50 percent. Other maps from fig 3 to 7 shows that most people died in Barguna, Bagerhat, Pirojpur and Patuakhali; in Bagerhat, Barguna, Jhalokati district 30-60% houses were completely destroyed; in Patuakhali and Pirojpur district15-30% houses were completely destroyed; in Barguna, Bagerhat, Barisal, Pirojpur, Patuakhali, Jhalokati district crops of 30000-250000 acres were completely destroyed. A large number of livestock killed in Barguna, Pirojpur, Bagerhat, Jhalokati and Gopalganj district.

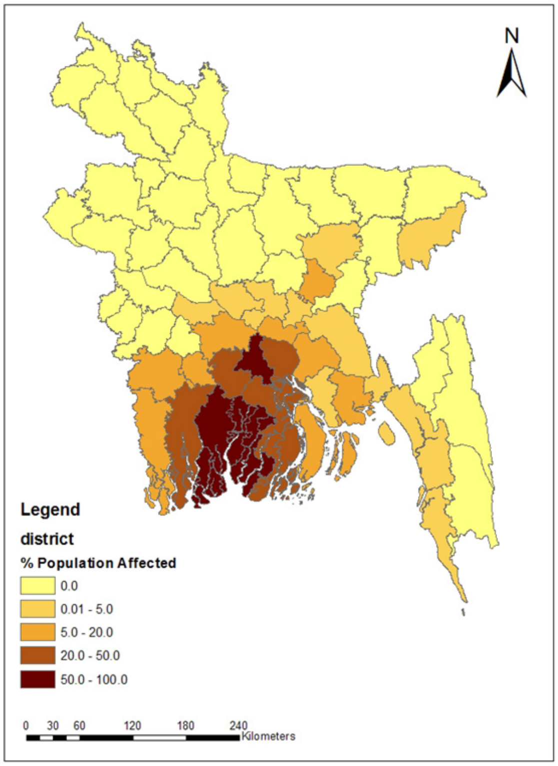



Fig 2: Percentage of people affected

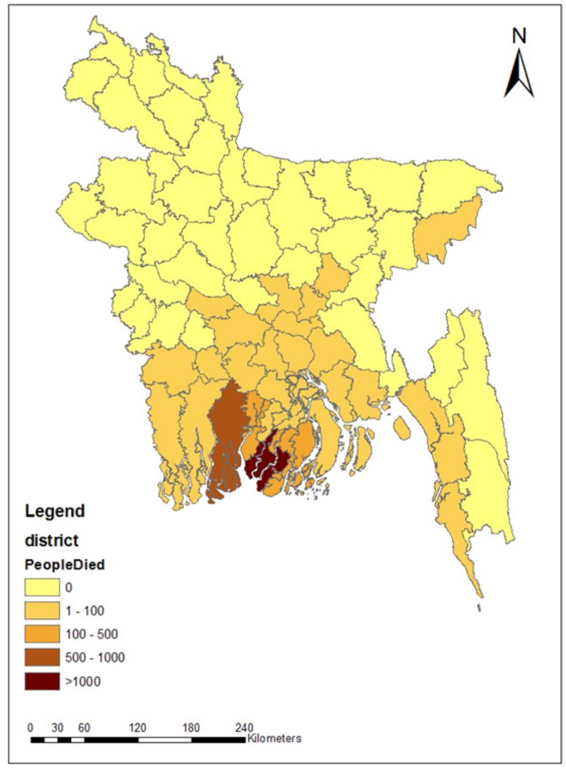



Fig 3: No. of people died

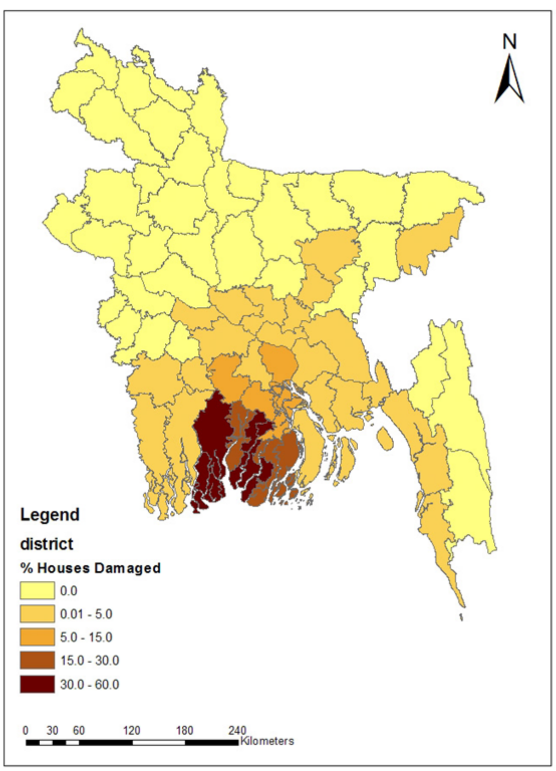



Fig 4: Percentage of houses damaged

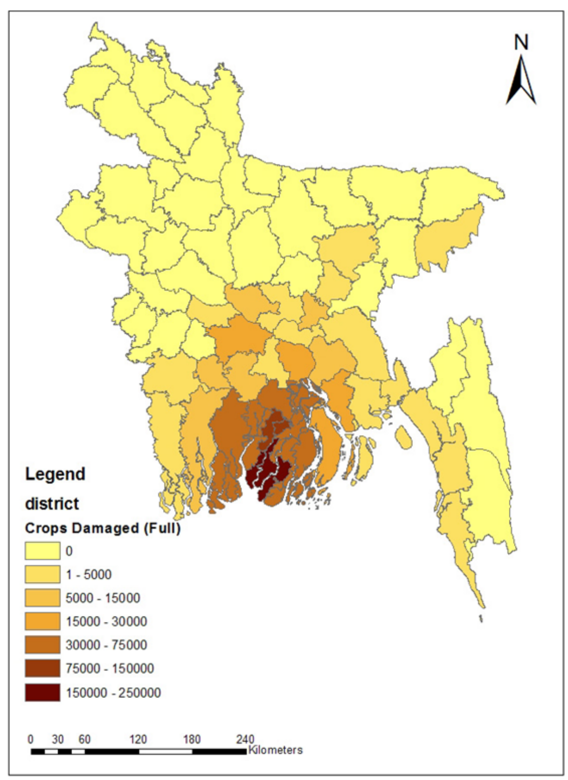
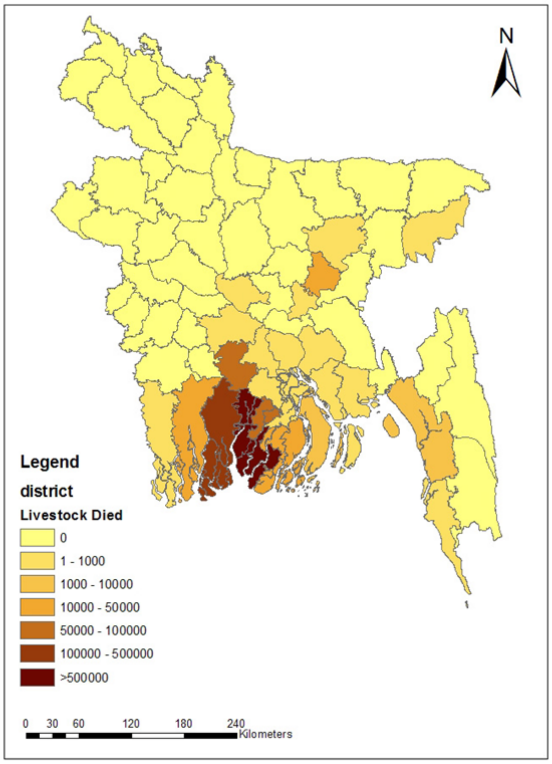



Fig 5: Crops damaged (fully) in acres



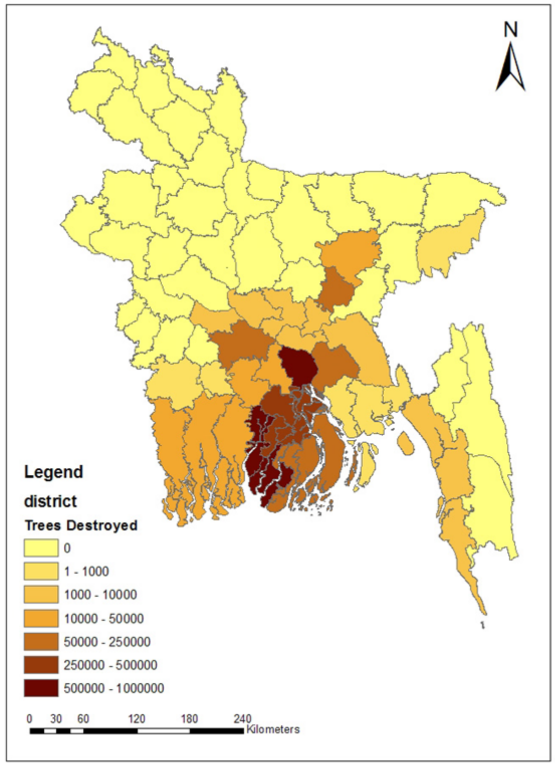




Fig 6: No. of livestock died

Fig 7: No. of trees destroyed

From these identifications some steps can be taken to recover present losses and reduce losses in future cyclone which may be:

**I. Relief work can be done on priority basis:**

Areas where people were most affected by the cyclone will need relief most. So, more relief should be sent initially to those places. Then to the other less affected areas. Coordination between different government and non government organizations can be done for proper distribution of relief. Otherwise one area will get more than enough compared to other affected areas. Relief like dry food, water, and clothing should be supplied in sufficient amount.

**II. Rehabilitation can be done gradually on demand:**

Needs of household should be given much priority. The areas where most houses were damaged should be given preference. Housing assistance should be given to the vulnerable people. Financial institutions should be encouraged to give low or interest free housing loan. It is needed to design and promote cyclone-resistant houses. Thus it can be said that houses should not only be build back but also should be build back better with a view to reduce risk.

Lots of crops also damaged, livestock died and boats drowned in the cyclone causing great loss to the farmers and fishermen. To recover this losses some action plan may be taken such as:

- Fishermen community should be supported
- Poor farmers should be supported
- Awareness training to sea going fishermen
- More killas should be build for livestock in the cyclone prone areas

**III. Measures can be taken to recover damages of environment and forests:**
Lots trees destroyed during cyclone in many areas. Over four million trees destroyed which will create a large impact on the environment and also on the economy. As mentioned earlier a quarter of Sunderbans were damaged. The map showing where the most no. of trees destroyed will help to take action plans to those areas. The actions may be:

- Impose ban on cut/collection of forest assets
- Social forestry initiatives
- Plantation of saline and storm tolerance trees

**From analyses of cyclone shelter centers:**
According to Ministry of Food and Disaster Management around 2000 cyclone shelter centers are located in Bangladesh. Additional 2000 are needed. A digital map showing existing locations will help in this regard. It will assist in choosing locations for new ones and in case of relocation for old ones. It may also help locating nearest shelter center in case of evacuation.

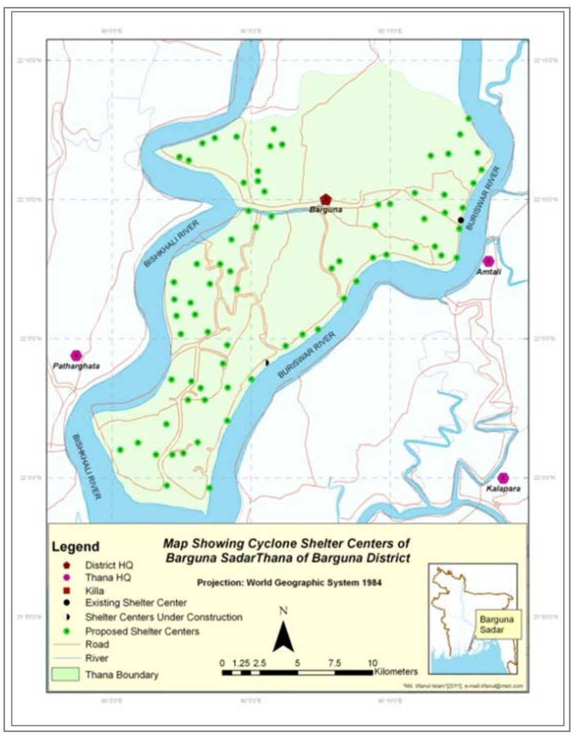



Fig 8: Barguna Sadar (Barguna)

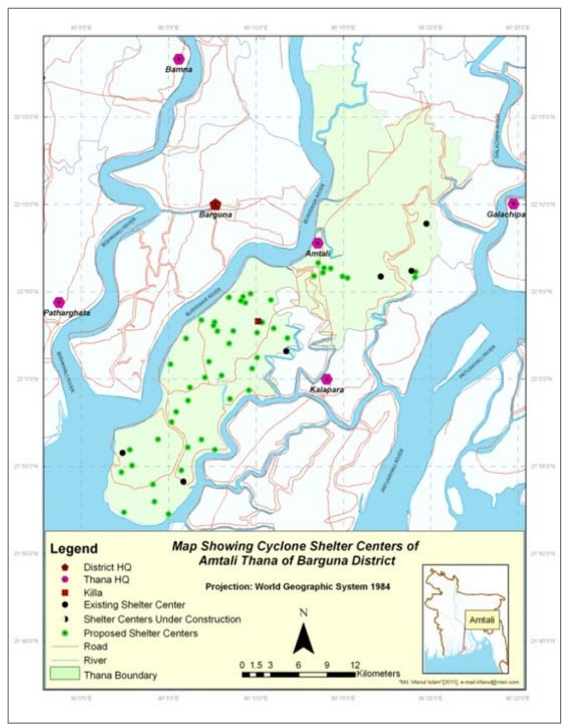
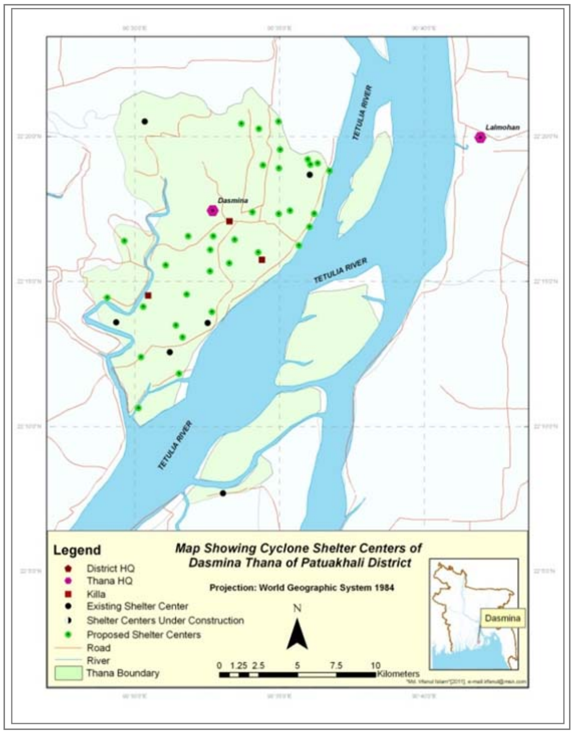



Fig 9: Amtali (Barguna)



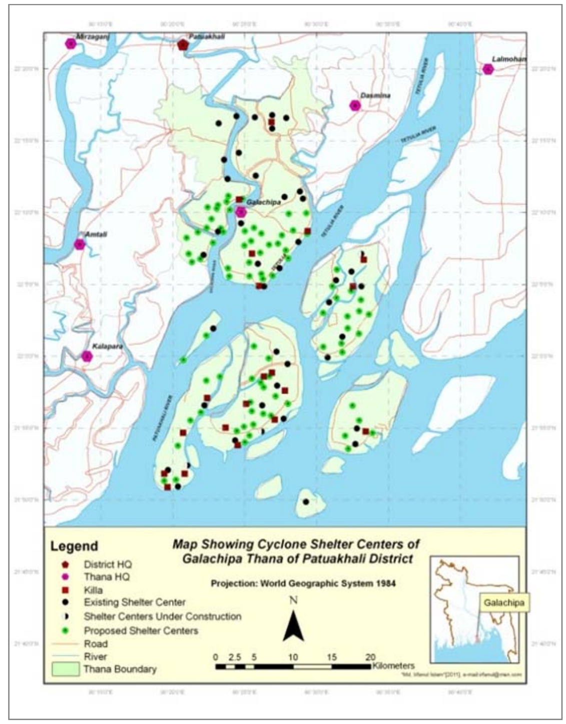
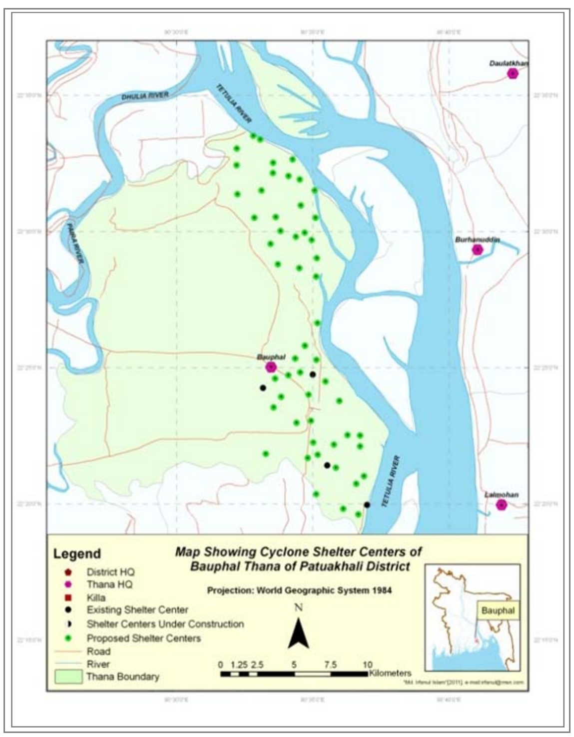




Fig 10: Dasmina (Patuakhali)

Fig 11: Galachipa (Patuakhali)



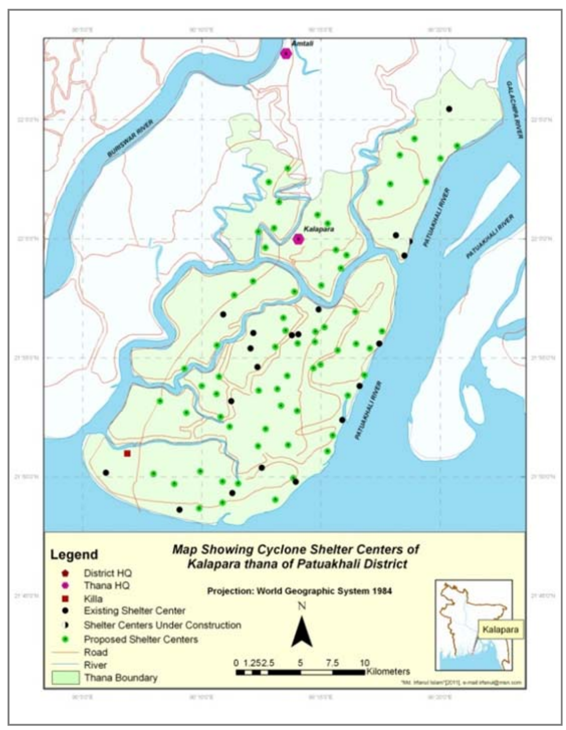




Fig 12: Bauphal (Patuakhali)

Fig 13: Kalapara (Patuakhali)

From the previous analysis it is found that in Barguna most no. of people and livestock were killed but the fig8 shows that there was no killa in Barguna sadar and only one shelter center under construction. Fig9 shows Amtali thana of Barguna district. Here only one killa exists and no shelter center was under construction. Patuakhali was also a highly affected area. Fig10 shows Dasmina (Patuakhali) where 4 killas exist and no shelter center under construction. Fig 11 shows Galachipa thana of this district. The existing condition of this thana was comparatively better than others. Fig12 shows Bauphal thana where no killa exists. In Kalapara thana shown in fig13 only one killa exists and one cyclone shelter under construction.

## 5. CONCLUSIONS

Bangladesh faces various disaster problems every year where cyclonic disaster is a major one. Being a developing country, severe cyclonic storm hinders the economic progress of the country. For proper planning and implementation in any section there should be exist a rich database and information system. In this case GIS can be an effective tool. In Bangladesh, practice of GIS is not common. During cyclone or any other disaster, government faces various problems in rescue, relief and rehabilitation activities. Besides a great problem arise ahead in decision making to reduce losses in future cyclone and relocation of a cyclone shelter or establishment of a new one. A complete GIS based information system in those sectors will help the government in relief and rehabilitation process during various disasters especially during cyclone and setting up required shelter centers in required location. It is experienced that shelters have served the purpose by providing shelters to the cyclone ravaged people during cyclone period. But past experiences also show that shelters were, and are not in proper use, also not properly maintained and managed during normal period. A complete information system of existing situation and location of cyclone shelters may help in monitoring and to lessen the problem. At present climatic change due to global warming is a major issue for human being and living being in the world. Scientists predict that cyclone like Sidr will become common in coastal areas and low land countries like Bangladesh. So preparation to face these types of severe cyclones and to reduce losses for that disaster a rich database and information system is urgently required for Bangladesh.

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# INVESTIGATION ON STRENGTH OF CEMENT STABILIZED SOIL OF SUST CAMPUS

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## ABSTRACT

Soil stabilization is used extensively in road and airfield construction. In particular, soil-cement appears to be a favorite among the engineers. In this work the strength characteristics of cement stabilized soil from different sites of SUST campus was investigated. Six different soil samples were used for this purpose. Different percentages of Portland cement were mixed with different samples to stabilize the soil in the laboratory. The cement proportions were 7, 10 and 12 percent of dry soil by weight. The unconfined compressive strength was obtained in the laboratory after 3 and 7days. From the 7 days experimental results it can be concluded that the strength of stabilized soil has increased considerably then the untreated soil in which cement content is 12%. From the 3 days experimental results it can also be concluded that the strength of stabilized soil has increased considerably then the untreated soil. It was also found that the maximum strength varies for 7%, 10%, 12% cement content for different samples. The increment of strength for 7, 10 and 12% cement from 3 days to 7days for sample 1 were 69.2%,3.28%, 248.7%, for sample 2 were 2850%, 406%, 318%, for sample 3 were 398.6%, 696.8%, 390.7%, for sample 4 were 852.1%, 508.9%, 1899.6%, for sample 5 were 329.2%, 673.6%, 1046.3% and for sample 6 were 832.4%, 1084.4%, 1361.6% respectively.

**Keywords:** Soil, Strength, Stabilization, Cement, Unconfined compressive strength, SUST, Construction.

## 1. INTRODUCTION

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil**. [1]** Cement stabilization of soil began with a trial on Salisbury Plain in 1917. The technique has since gained acceptance as an alternative for improving substandard materials, especially for road bases. **[2]**

Soil stabilization is a very important term in geotechnical engineering. For rapid civilization various construction works have been invented. Most of them are constructed over the ground surface such as buildings, drainage, skyscrapers etc some of them are below the surface like road pavements, tunnels, pipe work, foundations etc. All those work make a bond to the underground and surface soil which transmit and then distribute the loads to the beneath of the earth. If soil is stabilized it gains a huge strength to hold structures to their own place. The requirement of stabilization is given below:

(1) For strong, long lifespan buildings.
(2) For stability of slopes

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(3) For underground tunnels
(4) For proper water supply pipeline works
(5) For airport engineering
(6) For stability of embankments
(7) For stability, durability of various hydraulic structures
(8) For stability of retaining structures.

There are three types of soil-cement. The first type is compacted soil-cement that contains sufficient amounts of cement to harden the soil and enough moisture for both compaction and hydration of the cement. The second type is cement modified soil which is an unhardened or semihardened mixture of soil and cement. Only enough cement is used to change the physical properties of the soil. The third is plastic soil-cement. It is a hardened mixture of soil and cement that contains at the time of placing, enough water to produce a consistency similar to that of plastering mortar. The three basic materials needed when working with soil-cement are soil, portland cement, and water. The soil can almost be any combination of gravel, sand, silt, or clay. **[3]**

## 2. OBJECTIVES OF THE STUDY

If the soil on the ground surface possesses sufficient bearing capacity it was recommended to construct road pavement, drainage surface. But in Sylhet region most of the soil mass is consist of sandy soil and changes year to year due to heavy rainfall making sub-soil condition unstable. Therefore, to improve the sub-soil condition cement of different percentage are mixed with the natural soil and laboratory tests are performed to investigate the strength & deformation characteristics of stabilized soil.

Objectives of the study are as follows:

(1) To find out the soil behavior treated with cement.
(2) To establish the relationship between strength & deformation characteristics with various percentage of cement.
(3) To observe the Stress-Strain behaviors of remolded soil.
(4) To determine the increment of strength with increment of days.

## 3. METHODOLOGY [4]

The tests that were performed for unconfined compression strength test data are:

1. Sample collection
2. Laboratory test
    a. Specific gravity test.
    b. Grain size analysis.
3. Classification of soil
4. Preparation of remolded sample for unconfined compression test,
5. Curing of mould,
6. Unconfined compressive test.

## 4. DATA ANALYSIS AND RESULTS [5]

The tests were performed for six samples. Here data analyses for six samples are shown below:

**Sample 1:**
Specific gravity: 2.5
Sand: 82%   Silt: 16%   Clay: 0.6 %

### Unconfined Compression Test Data for 3 days

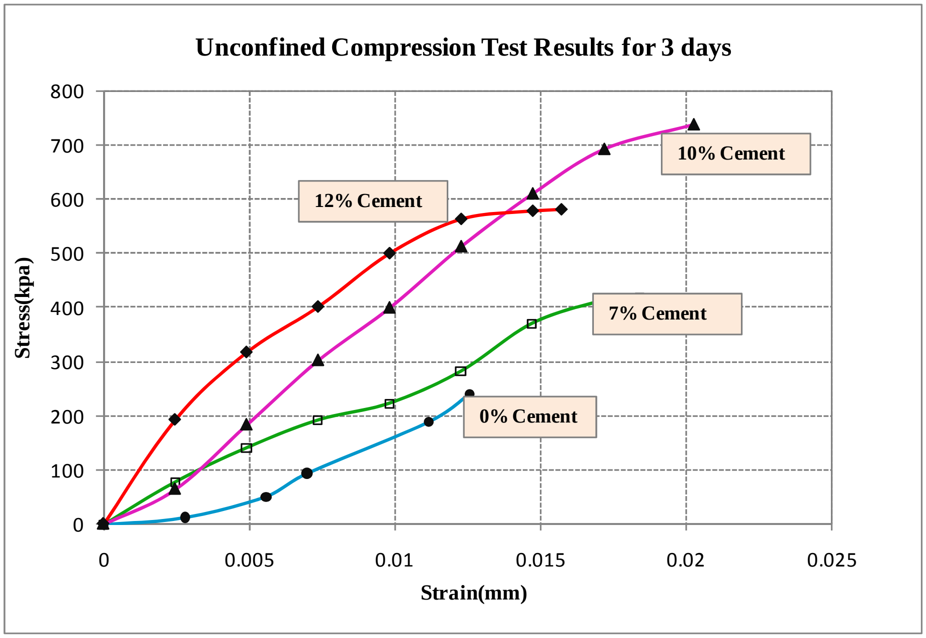


Figure 1: stress-strain diagram for 3 day curing for Sample 1

### Unconfined Compression Test Data for 7 days

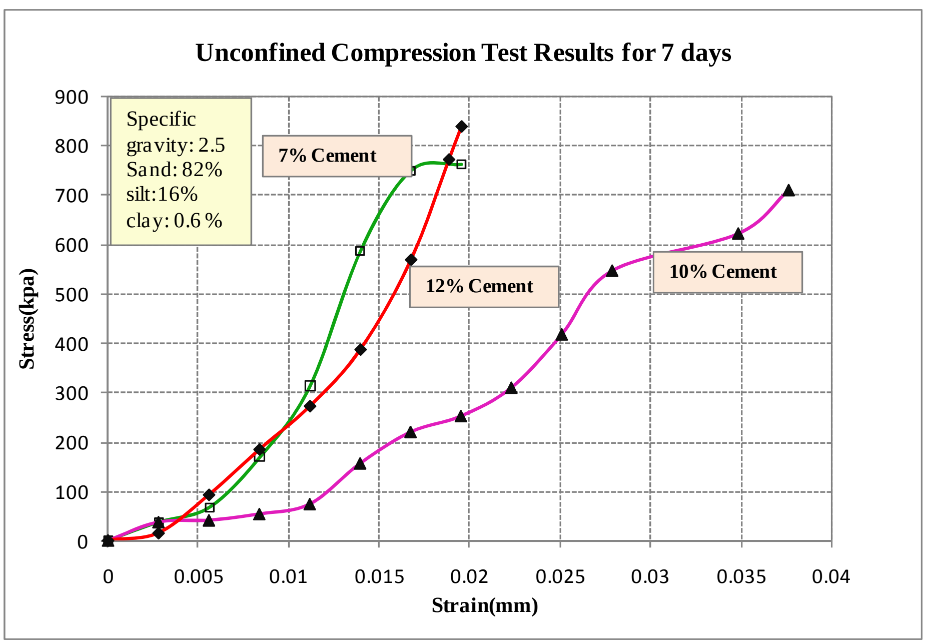


Figure 2: stress-strain diagram for 7 day curing for Sample 1

**Sample 2:**
Specific gravity: 2.5
Sand: 91.7%  Silt: 4.5 %  Clay: 0.4%

### Unconfined Compression Test Data 3 days

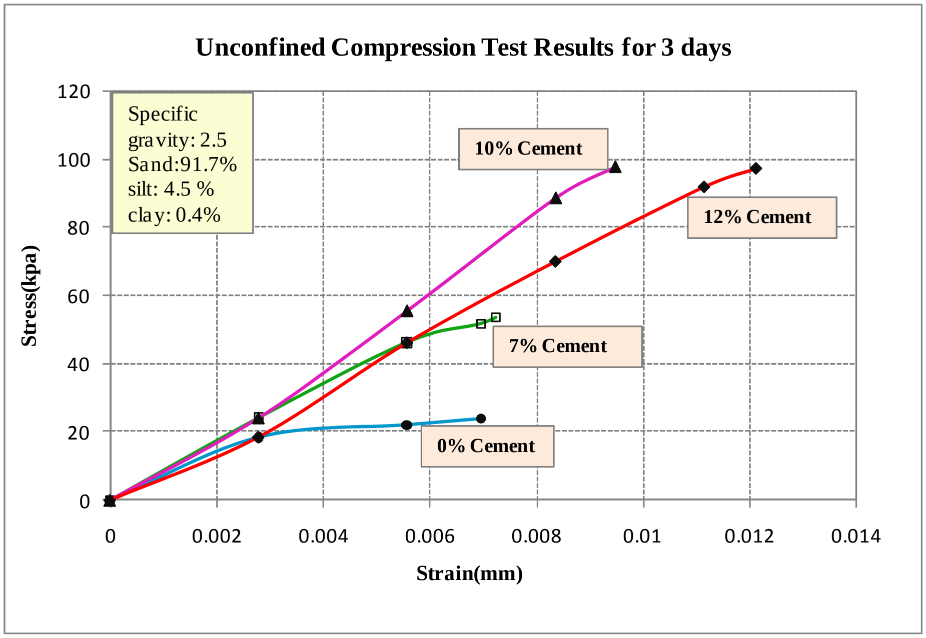


Figure 3: stress-strain diagram for 3 day curing for Sample 2

### Unconfined Compression Test Data for 7 days

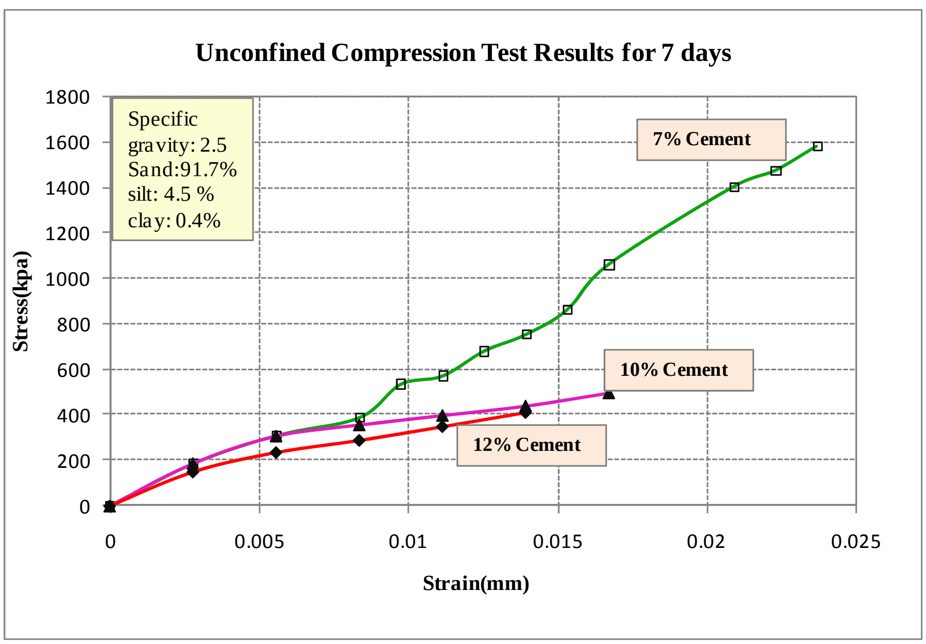


Figure 4: stress-strain diagram for 7 day curing for Sample 2

**Sample 3:**
Specific gravity: 2.5
Sand: 94 % Silt: 4.9 % Clay: 0.9 %

### Unconfined Compression Test Data 3 days

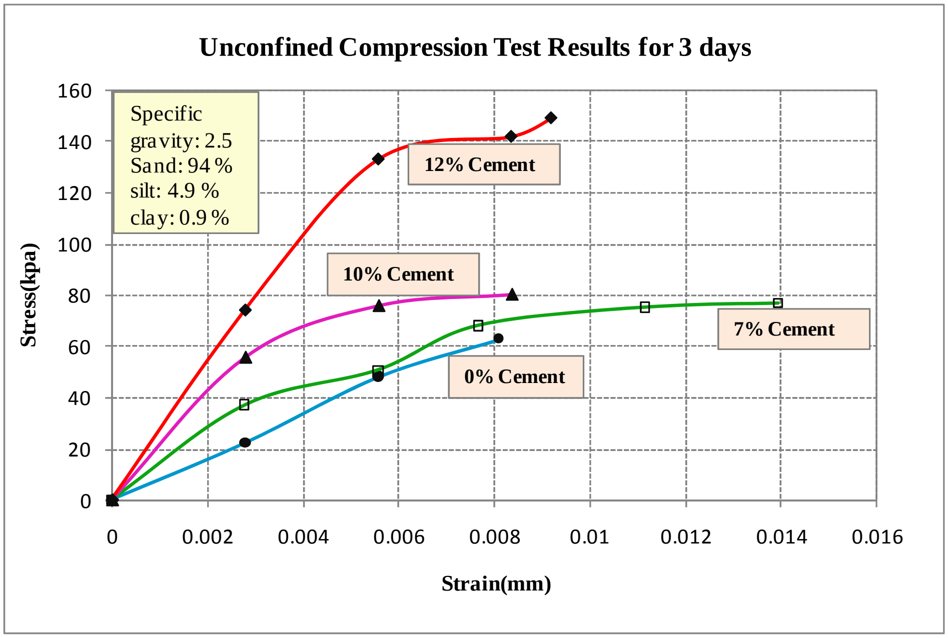


Figure 5: stress-strain diagram for 3 day curing for Sample 3

### Unconfined Compression Test Data for 7 days

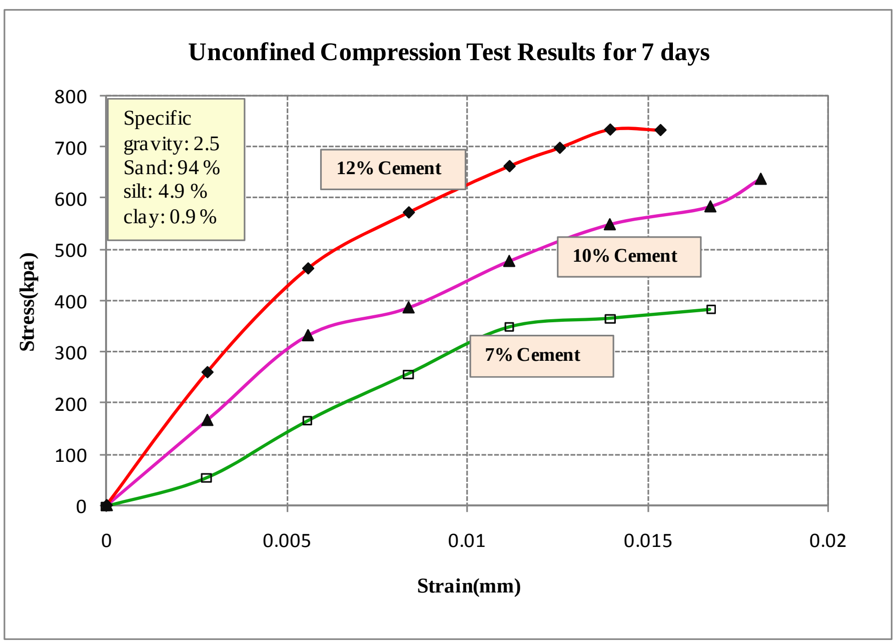


Figure 6: stress-strain diagram for 3 day curing for Sample 3

**Sample 4:**

Specific gravity: 2.52

Sand: .79%    Silt: 18.2%    Clay: 2.3 %

### Unconfined Compression Test Data 3 days

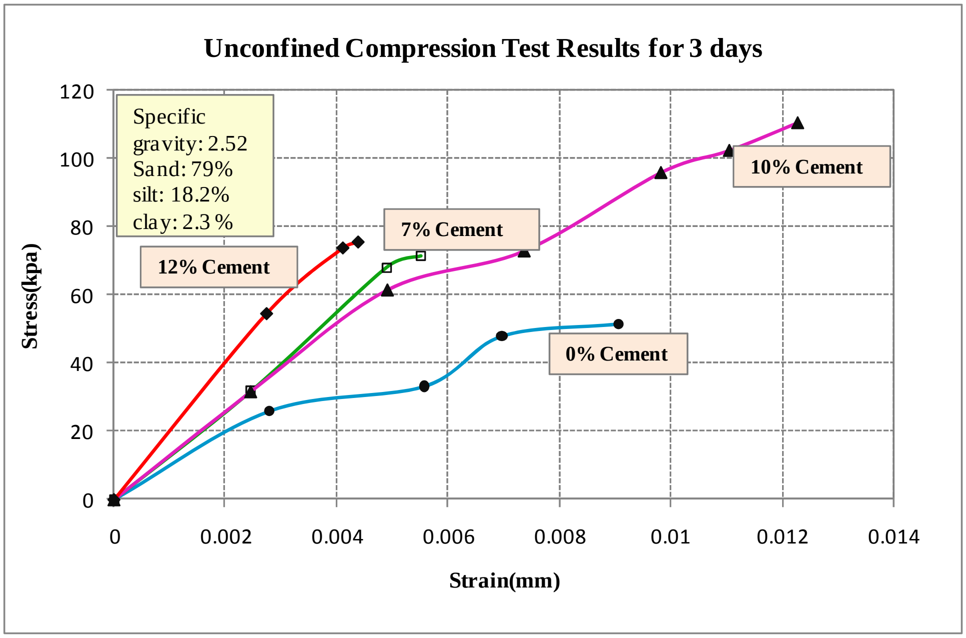


Figure 7: stress-strain diagram for 3 day curing for Sample 4

### Unconfined Compression Test Data for 7 days

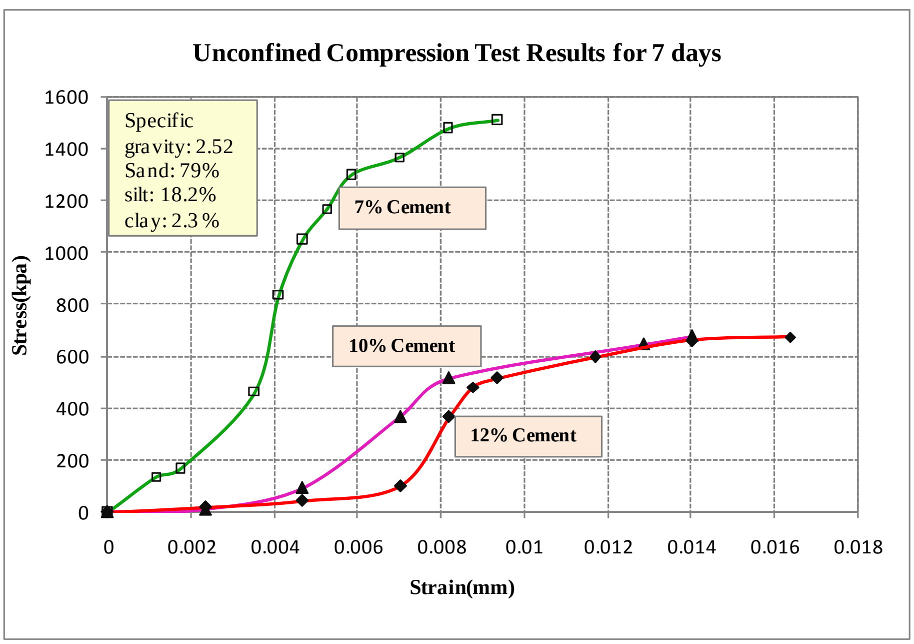


Figure 8: stress-strain diagram for 7 day curing for Sample 4

**Sample 5:**
Specific gravity: 2.51
Sand: 71% Silt: 18.8% Slay: 1%

### Unconfined Compression Test Data 3 days

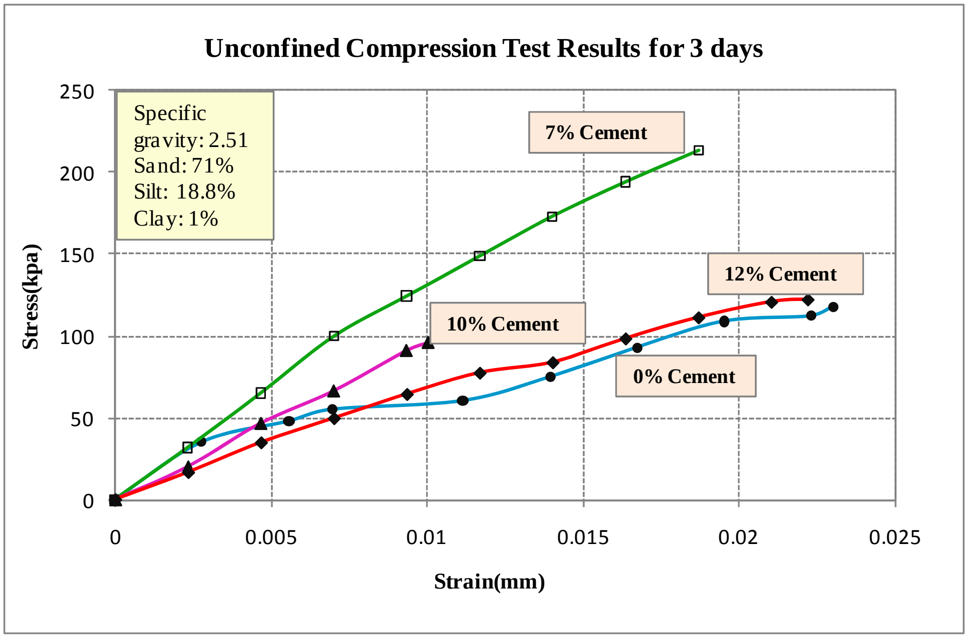


Figure 9: stress-strain diagram for 3 day curing for Sample 5

### Unconfined Compression Test Data for 7 days

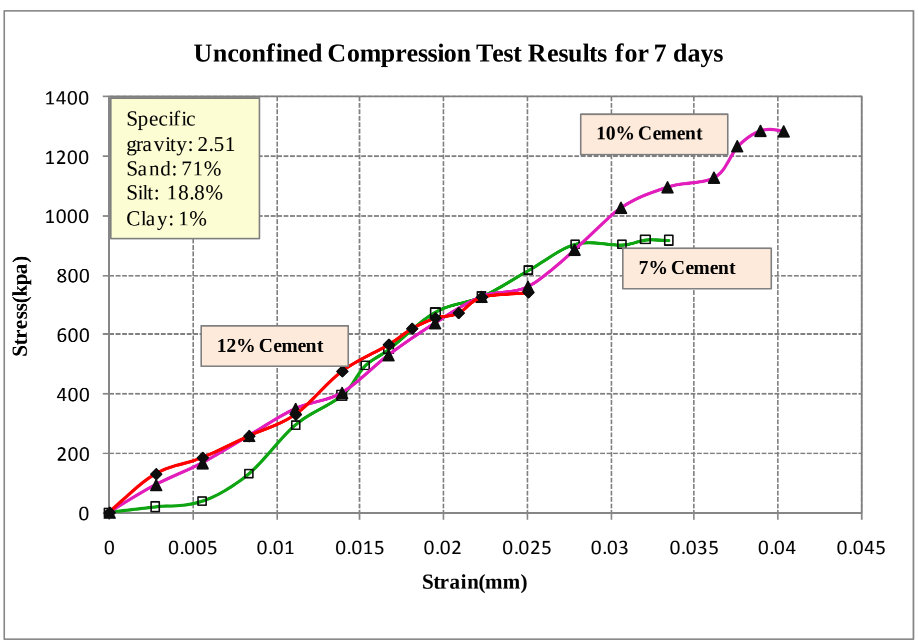


Figure 10: stress-strain diagram for 7 day curing for Sample 5

**Sample 6:**
Specific gravity: 2.5
Sand: 70 % Silt: 24 % Clay: 6%

### Unconfined Compression Test Data 3 days

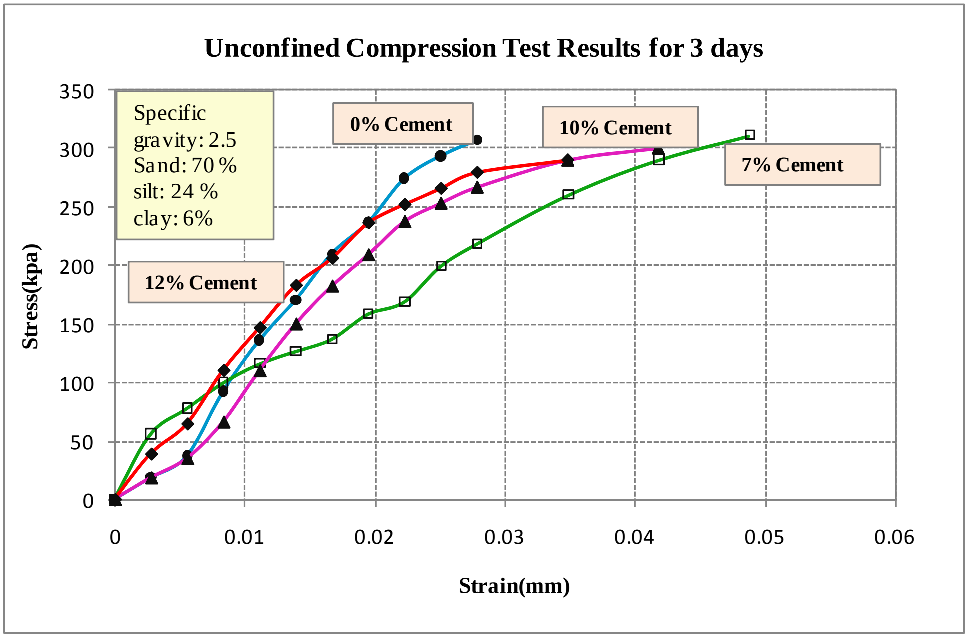


Figure 11: stress-strain diagram for 3 day curing for Sample 6

### Unconfined Compression Test Data for 7 days

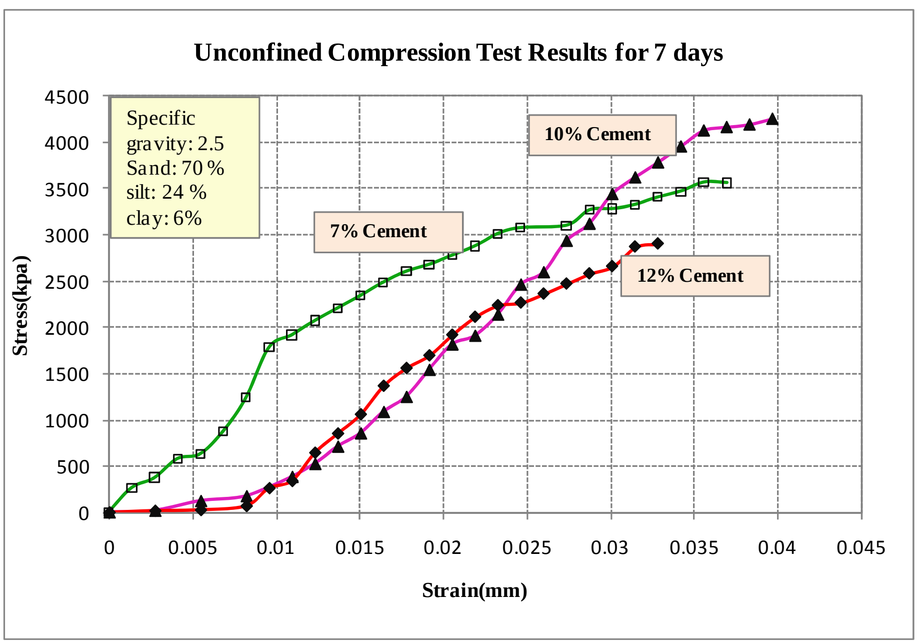


Figure 12: stress-strain diagram for 7 day curing for Sample 6

**Table 1: Unconfined Compressive strength test results for 3 days**

| Cement content (%) | Unconfined Compressive Strength (kpa) | | | | | |
|---|---|---|---|---|---|---|
| | Sample1 | Sample2 | Sample3 | Sample4 | Sample5 | Sample6 |
| 0 | 240.3 | 23.98 | 62.66 | 51 | 118 | 307.08 |
| 7 | 418.6 | 53.5 | 76.95 | 71 | 213.4 | 311 |
| 10 | 737.4 | 97.5 | 80.15 | 110.7 | 96 | 300.8 |
| 12 | 579.5 | 97.5 | 149.12 | 75.4 | 112 | 290.5 |

**Table 2: Unconfined Compressive strength test results for 7 days**

| Cement content (%) | Unconfined Compressive Strength (kpa) | | | | | |
|---|---|---|---|---|---|---|
| | Sample1 | Sample2 | Sample3 | Sample4 | Sample5 | Sample6 |
| 7 | 708.14 | 1578.3 | 383.7 | 676 | 915.9 | 2899.8 |
| 10 | 761.6 | 493.3 | 638.6 | 674 | 742.7 | 3562.6 |
| 12 | 838 | 406.8 | 731.8 | 1507.7 | 1283.8 | 4246.08 |

**Table 3: Increment of strength from 3 to 7 day**

| Cement content (%) | Increment (%) | | | | | |
|---|---|---|---|---|---|---|
| | Sample1 | Sample2 | Sample3 | Sample4 | Sample5 | Sample6 |
| 7 | 69.2 | 2850 | 398.6 | 852.1 | 329.2 | 832.4 |
| 10 | 3.28 | 406 | 696.8 | 508.9 | 673.6 | 1084.4 |
| 12 | 248.7 | 318 | 390.7 | 1899.6 | 1046.3 | 1361.6 |

From the above analyses the findings are:

- ❖ The unconfined compression strength varies with different proportion of cement. And from observation it is seen that the strength also depends on the soil properties. For different combination of sand, silt and clay the strength varies with different proportion of cement.

- ❖ In 3 days data if the proportion of silt is higher, highest strength for 7% or 10% cement content was obtained. And for 7 days the highest strength gains for 12% cement content.

- ❖ It also shows that in 3 days data if the proportion of sand is higher in soil, highest strength for 12% cement content was found. And for 7 days the highest strength gains for 12% cement content.

- ❖ In 7 days data if good proportion of clay is present in soil, highest strength for 12% cement content was found.

## 5. CONCLUSIONS

Based on the test results presented and discussed in above the following conclusions are reached:

a) For stabilization purpose cement can be used as stabilizing agent.
b) The strength increases with increment of percentage of cement content.
c) Improvement of SUST soil by mixing cement for the construction of shallow foundation and sub grade for roads can be done.
d) For 12% cement content the soil gets higher compressive strength value after 7 days.
e) For quick stabilization (in 3 days), 7% or 10% cement can be used otherwise for higher percentage of sand, 12% cement should be used.
f) The compressive strength with the curing period.
g) For economical purposes the percentage of cement should be used as much strength as required for construction.

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# PLANNED, SAFE AND ENVIRONMENT FRIENDLY CITIES OF BANGLADESH: INTEGRATING THE ROLES OF TOWN PLANNERS, ARCHITECTS AND ENGINEERS

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**ABSTRACT**

Town Planners, Architects and Engineers are among intellectual professionals of Bangladesh. They are mainly working in the Development Authorities, City Corporations, Municipalities, Urban Development Directorate, Public Works Department, Local Government Engineering Department, Department of Architecture, Roads and Highways Department, Bangladesh Power and Water Development Boards and some other relevant government organizations. Their major roles and responsibilities are preparation and implementation of Master Plans or Urban Area Plans through controlling master plan landuses, designing buildings and establishments, development of infrastructures and ultimately providing utility service facilities to the urban people of the cities and towns. The roles and responsibilities of the Town Planners, Architects and Engineers have been specified in their respective charter of duties, laws, by-laws, policy documents and urban area plans. In spite of these, the cities of Bangladesh are facing a number of problems i.e. traffic congestions causing wastage of man time hours and fuel energy, accidents etc.; unplanned and unauthorized constructions; collapse of buildings and fire hazards; water, air and sound pollution; inefficient solid waste management; waterlogging, drainage congestion and poor sanitation; encroachment of rivers, canals and water bodies; disappearance of parks, open space and playgrounds etc. There is immense scope of making the cities of Bangladesh planned, safe and environment friendly if the Town Planners, Architects and Engineers work together maintaining their respective professional ethics, sincerity, commitment, devotion and patriotism. The paper aims to highlight the statutory roles and responsibilities of the Town Planners, Architects and Engineers; problems and limitations in their integration; and suggestions for integrating the roles of Town Planners, Architects and Engineers towards making the cities of Bangladesh Planned, Safe and Environment Friendly.

**Key Words:** Town Planner, Architect, Engineer, Planned City, Safe City, Environment Friendly City

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## INTRODUCTION AND BACKGROUND

There are a number of Architects, Planners and Engineers in Bangladesh and they are contributing lot in the field of planning and infrastructure development of the cities and towns through working in UDD (Urban Development Directorate), LGED (Local Government Engineering Department), Development Authorities, City Corporations and in Consultancy Firms that are involveed in City/Town Master Plan preparation and construction of different infrastructure (buildings, roads, bridges, culverts, drains etc.) in the cities and towns. Even, a number of Town Planners, Architectects and Engineers are found to work with NGOs, Civil Society Organizations (like BAPA) and different Research and Development organizations. All have significant integrated role for creating planned, safe and environment friendly cities as well as overall development of Bangladesh. Now a days, Architects and Engineers are getting Town Planning degree from different universities of Bangladesh and abroad. Similarly, Town Planners are also interested in getting more knowledge and education on Architecture and Engineering.

Bangladesh lies well within an active seismic zone and is prone to earthquakes. Cities mainly Dhaka, Chittagong and Sylhet are mostly vulnerable to earthquakes. As the number of high rise buildings in the cities is increasing gradually, it is very important to consider the important aspects of building design, detailing and building construction as per Bangladesh National Building Code. Apart from the small hilly region in the southeast and the northeast, Bangladesh is a vast plain land adjacent to the Bay of Bengal. The coastal areas are prone to severe cyclonic weather. This is why wind force analysis is also very important for high rise buildings in the country. Design wind pressures for buildings and structures is determined for any height on the basis of height, exposure and gust, direction of wind relative to structure, roof slope, importance of the structure and wind stagnation pressure. It is a common practice among design engineers in Bangladesh to use earthquake forces for designing buildings ranging from 8 to 20 stories, and wind for buildings higher than 20-stories. Engineers neglect the combination of earthquake and wind load on account of the assumption that the earthquake and severe wind will not act simultaneously on the structure (F. Atique and Z. Wadud 2001).

Building codes of most countries specify safe practices for various stages and for various elements of building construction. In order to provide safe and healthy habitat, all activities related to building construction such as planning, design and construction needs to be regulated properly. Technological and socio-economic developments in recent times have led to remarkable increase in demand for more and more sophistication in buildings resulting in ever increasing complexity. Buildings are products of a multi-disciplinary profession involving specialized professional inputs from disciplines like Architecture, Fire prevention, Materials science, Structural engineering, Geotechnical engineering Construction technology, Electrical engineering, Mechanical engineering, Acoustics, Sanitation and plumbing technology, Chemical engineering, Law, etc. It is therefore imperative that a uniform standard of practice covering all aspects of planning, design and construction of buildings, including the service facilities provided in it such as electrical, mechanical, sanitary and other services, be followed to ensure safety, minimization of wastage in construction and optimum return for the user. In the Building code each of the above aspects are addressed adequately by professionals specializing in the relevant disciplines to ensure safety and comfort of the users of the buildings (HBRI, 2010).

The planning of towns, cities and villages was done on a scientific footing in India even in Vedic times. Some of the principles and theories of town planning are contained in the literature of ancient times such as rig Veda, Atharva Veda, Yajur Veda, Puranas, Samhitas, Shila-shastras, Niti-shastras, Smriti-shastras, etc. It is quite clear that the principles underlying the planning of an ancient Indian village more or less resembled those of the modern garden cities. The profession of a town planner possessed a high social status in the ancient times. An intensive training was given to the Sthapati (i.e. architect or town planner) and thus the architects and town planners were chosen from the upper strata of society. *Vishvakarma* is traditionally known as the divine architect and he is credited to have spread the knowledge of silpa-shastras. Even today *Vishvakarma* is worshiped by the artisans. Varanasi was a principal urban center in the time of Buddha and it is said to be the oldest city of the world (Rangwala et. al).

In India, the various States have passed Town Planning Acts to enforce planning actions. The main source of all these T.P Acts is the English Town Planning Act of 1909. The main provision of the English Town Planning Act of 1909 is that local authorities are given power to prepare and enforce town planning schemes on open lands in the city and on its fringe. New Delhi, Chandigarh (Punjab), Gandhinagar (Gujrat), Durgapur (West Bengal), Ulhasnagar (Maharastra), etc. are called as the planned cities. For the purpose of looking after the planning and execution of new cities or new parts within metro-centers, various organizations such as DDA (Delhi Development Authoritry), CIDCO (City and Industrial Development Corporation), CMPO (Calcutta Metropolitan Planning Organizations), HUDCO (Housing and Urban Development Corporation), etc. set up by the government (Rangwala et. al).

Louis I Kahn, a renouned Architect designed the entire Parliamentary Building i.e. Jatiyo Sangsad complex of Bangladesh, which includes lawns, lake and residences for the Members of the Parliament (MPs). In consideration of one of the foremost architects of the late twentieth century, Kahn received the AIA Gold Medal in 1971 and the RIBA Gold Medal in 1972. He was elected a member of the American Academy of Arts and Letters in 1971. First, Muzharul Islam was given to design Jatiya Shangshad Bhaban by the government. But, Islam brought his teacher Louis Kahn into the project to do a signifant work for future generation. Muzharul Islam assisted Kahn at the project. Kahn's key design philosophy optimizes the use of space while representing Bangladeshi heritage and culture. External lines are deeply recessed by porticoes with huge openings of regular geometric shapes on their exterior, shaping the building's overall visual impact. The lake on three sides of the Bhaban, extending up to the Members' hostel adds to site's aesthetics and also portrays the riverine beauty of Bangladesh. The assembly building received the Aga Khan Award for Architecture in 1989.

LGED and UDD have been involved in preparing Master Plans for the District and Upazila level towns/municipalities of Bangladesh. Engineers, Architects and Town Planners have been working as Project Directors, Consultants and technical experts in these projects. UDD is the central government plan making organization, in commensurate with the governemnt’s policy of decentralization of administration stated preparation of the physical plans for the distrct headquater towns. The plan implementation strategies in the form of updating the plan proposals, legal back up for execution of the plan, deployment of technical manpower for administering the development control etc. are pointed out in the plans (Alam and Murtaza, 2006). The Infrastructure Improvement Section (IIS) of LGD (Local Government Division) of MLGRDC (Ministry of Local Government Rural Development and Cooperative) is responsible for the implementation of all physical infrastrusture works and headed by the head of the engineering department of the concerned Paurashava. As the Town Planners are involved in preparation of the town Master Plans, a number of Town Planners have been employed in 'A' class Paurashavas and it will be for all the Paurashavas in near future for implementation of the proposals. Commercial, industrial and even residential buildings of now adays of almost all the cities and towns are found aesthetically and artistically designed with the help of Architects coming from the Architecture Departments of different universities. But, there is no positions of Architects in the Paurashavas. The responsibility of school construction, repair and supply of school furniture lies with the Facilities Department (FD) and LGED (Wikipedia 2011).

Basis of Megacity planning and management should be the effort to provide access to all minimum requirements for the poor. The city should also try to strengthen its financial resources to cover the cost of development and maintenance. There is also need to strengthen its own technical and planning manpower capacity and reduce its dependence on foreign technical assistance. At the same time donors should also change their attitude and refrain from imposing foreign experts and consultants in urban development programmes (Islam, 1996).

## OBJECTIVES OF THE STUDY

The objectives of the study are

i) to highlight the statutory roles and responsibilities of the Town Planners, Architects and Engineers

ii) to point out the problems and limitations in integration of the roles and responsibilities of the Town Planners, Architects and Engineers

iii) to draw some recommendations for integrating the roles of Town Planners, Architects and Engineers towards making the cities of Bangladesh planned, safe and environment friendly.

## METHODOLOGY

Books, reports, conference papers, encyclopedia, write ups on City Master Plans and Structure Plans etc. are reviewed for the study.

## TOWN PLANNING, ARCHITECTURE AND ENGINEERING FOR CITY PLANNING AND DEVELOPMENT

Urban, city, and town planning integrates land use planning with provision of various amenities such as widths of streets, drainage lines, water supply lines, parks, playgrounds, etc. to meet with the future requirements to improve the built, economic and social environment of the cities and towns. Urban planning can include urban renewal, by adapting urban planning methods to existing cities suffering from decay and lack of investment. Architecture is a style and method of design and construction of buildings and other physical structures mainly within the cities and towns. It deals with the space within the site surrounding the buildings as that have their principal purpose of human occupancy or use. Engineering is the discipline, art, and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize improvements to the lives of people. Engineering is often characterized as having three main branches-1) Chemical engineering, 2) Civil engineering and 3) Electrical engineering. Civil engineering is concerned with the design and construction of public and private works, such as infrastructure (roads, railways, water supply and treatment etc.), bridges and buildings within and outside the cities.

Distinct characteristics of urban planning of the cities of Harappa, Lothal, and Mohenjo-daro in the Indus Valley Civilization (in modern-day northwestern India and Pakistan) lead archeologists to conclude that they are the earliest examples of deliberately planned and managed cities. The streets of many of these early cities were paved and laid out at right angles in a grid pattern, with a hierarchy of streets from major boulevards to residential alleys. Archaeological evidence suggests that many Harrapan houses were laid out to protect from noise and enhance residential privacy; many also had their own water wells, probably for both sanitary and ritual purposes. These ancient cities were unique in that they often had drainage systems, seemingly tied to a well-developed ideal of urban sanitation. The Greek Hippodamus (c. 407 BC) has been dubbed the "Father of City Planning" for his design of Miletus; Alexander commissioned him to lay out his new city of Alexandria, the grandest example of idealized urban planning of the ancient Mediterranean world, where the city's regularity was facilitated by its level site near a mouth of the Nile. The Hippodamian, or grid plan, was the basis for subsequent Greek and Roman cities.

During the Moghul periods, the rulers of India developed few more towns namely Delhi, Lucknow, Lahore, Agra, Fatehpur, Sikri, Ajmer, Ujjain, Bharatpur, Shamadabad, Benaras (Varanasi), Mathura, etc. These towns were more or less traditional and as such no further contribution was made to the science of town planning. These towns clearly bear the influence of Muslim architecture and culture. From the study of history, it is evident that a separate department existed for the construction and development work. The emperor himself headed the department and it included eminent architects, engineers and ministers as its members. In the regime of great emperor Akbar, a Public Works Department was established for the planning and development of construction work and Akbar's ideas about architecture were carried out by his able staff of architects and engineers (Rangwala et. al).

## ROLE OF TOWN PLANNERS, ARCHITECTS AND ENGINEERS IN THE WORLD

Town planners, Architects and Engineers have played and are playing significant role in planning and development of the cities and towns of the world.

The ancient Romans used a consolidated scheme for city planning, developed for military defense and civil convenience following the plan of Greek Hippodamus, Father of City Planning. The basic plan consisted of a central forum with city services, surrounded by a compact, rectilinear grid of streets, and wrapped in a wall for defense. To reduce travel times, two diagonal streets crossed the square grid, passing through the central square. A river usually flowed through the city, providing water, transport, and sewage disposal.

The well known town planner Sir Patrick Geddes (1854-1932) visited India in 1915 to advise the Governor of Madras, Lord Pentland, on the re-planning and redevelopment of some of the old towns. It was owing to his efforts and series of lectures delivered by him in different cities of India that planning was interpreted as not only planning of streets and good houses, but also planning for the people who lived in them, for their economic and social ways and for their ambitions and aspirations. He gave his expert advice for the improvement of about 18 major towns in India. He insisted that a correct diagnosis should be made of evil effects from which the town suffers and then to prescribe the remedies to improve such town. He had successfully overcome the horrors of Edinburgh slums before coming to India.

Le Corbusier (1887-1965), the great Swiss-born French architect with the assistance of Maxwell Fry and Jane Drew of England prepared the Master Plan of Chandigarh, a capital city of Punjab. The ideas of Le Corbusier have greatly influenced the modern town planning. He came of a poor family and worked as a mason in his early days. His work as an Architect and Town Planner is of very high order. He worked with passion, vigour and zest throughout his career of over 50 years of Architecture. Chandigarh is planned on the principle of precincts or super-blocks and they are termed as sectors. Each sector measures about 1.21 km in length and 0.81 km in width. The rectangular sectors are framed with the layout of a grid of main roads. Le Corbusier himself designed the four main government buildings, collectively as Capitol, situated at the northern end of the town. The buildings are the Assembly Hall, the Secretariat, the High Court and the Governor’s Palace. The southern sector is reserved for the industrial development. The central sector contains the city’s civic and commercial buildings. The cultural center with the university is a park is situated in the north-west side. Thus, the city plan contains clear and well-defined centers. Corbusier was sympathetic, kind, emotional and helpful. His physical requirements for living were very plain and modest. For many years, he dined in Paris in a tiny restaurant and drove around in a ramshackle little green car called by him as his frog. His office in Paris too was in the ruins of a monastery. His private workroom in his studio was only a minimum cubbyhole or room where he could reach each wall by hand from his seat (Rangwala et. al).

A large number of BUET alumni are working in the industry and academia both in Bangladesh and outside Bangladesh. Structural Engineer Fazlur Rahman Khan, who designed John Hancock Center (100-story) and Sears Tower (108-story), the tallest building in the United States since its completion in 1974, obtained bachelor's degree in Engineering from Ahsanullah Engineering College, University of Dhaka, which later became BUET.

## PROBLEMS OF THE CITIES AND TOWNS OF BANGLADESH

Unplanned growth and violation and non-implementation of the Master Plan proposals of the cities and towns create gradual problems for the cities and towns. The cities and towns of Bangladesh are facing a number of problems i.e. traffic congestions causing wastage of man time hours and fuel energy, accidents etc.; unplanned and unauthorized constructions; collapse of buildings and fire hazards; water, air and sound pollution; inefficient solid waste management; waterlogging, drainage congestion and poor sanitation; encroachment of rivers, canals and water bodies; disappearance of parks, open space and playgrounds etc.

Like all megacities, Dhaka has many serious problems and these problems overwhelm the few assets of the city such as greenery and open water bodies. Some of the problems have assumed very critical proportions. These include-1) an extreme shortage of serviced land to meet the growing demands for residential development, particularly for housing the low income and poor groups, and resulting in housing shortage, 2) large influx of rural poor and increase in the number of the poor population, resulting in rapid and uncontrolled growth of slums and squatter settlements, 3) inadequate provision of access to basic sanitation and infrastructural services, including clean water, drainage, solid waste, electricity, gas, telephone etc. 4) inadequate provision of roads and other transportation facilities and increasing traffic congestion and absence of appropriate traffic management and control, and consequent increase in the number of fatal incidents, even within city limits, 5) inadequate provision and deterioration of quality of social infrastructural services like health and education, 6) increase in the frequency and severity of floods and of drainage, 7) failure to provide appropriate lands for parks and open spaces, 8) inadequate financial resource for public bodies to provide essential urban services, 9) worsening of the law and order situation, and increase of anti-social and immoral activities, 10) imbalance in the rural urban relations and heightened primacy of the city, and 11) inadequate skilled personnel for planning, development and management of urban expansion and land use (Islam, 1996).

## ROLE AND RESPONSIBILITIES OF TOWN PLANNERS, ARCHITECTS AND ENGINEERS FOR CITY PLANNING AND DEVELOPMENT OF BANGLADESH

Master Plan is the main driving force and guideline for any city and town. Before 1970, city/town Master Plans of Bangladesh were prepared mainly by the European and American consultants and consulting firms having the team of Town Planners, Architects and Engineers. But, since last two or three decades, Master Plans of the cities/towns of Bangladesh are being prepared by the national and local level consultants and consulting firms comprising the team of Town Planners, Architects, Engineers, Geographers, Economists, Statisticians and others.

At present, integration of the roles of Town Planners, Architects and Engineers is mainly ensured in different stages of city/town Master Plan preparation through involvement of the representatives of government sectoral agencies namely PWD (Public Works Department), UDD (Urban Development Directorate), LGED (Local Government Engineering Department), RHD (Roads and Highways Department), Department of Architecture, BWDB (Bangladesh Water Development Board), DOF (Department of Forest), DoF (Department of Fisheries), City Corporations/Municipalities, Port Authorities, Universities, Professional bodies of Engineers, Architects and Planners (IEB-Institute of Engineers of Bangladesh, IAB-Institute of Architects of Bangladesh and BIP-Bangladesh Institute of Planners), IMED (Implementation Monitoring and Evaluation Department), Planning Commission and others in the Technical Management Committees (TMC), Inter-Ministerial Steering Committees (IMSC) and Project Advisory Committee (PAC).

Implementation of the city/town development proposals i.e. land based infrastructure development proposals is done mainly by the government sectoral agencies which are within and outside the cities and towns and are concerned for delivering services and facilities in the cities and towns. Engineers, Architects and Town Planners who are working in PWD, UDD, LGED, RHD, Department of Architecture, BWDB, DOF, DoF, City Corporations/Municipalities, Port Authorities, Universities and other concerned organizations are statutorily responsible and involved for implementation of the land based infrastructure development proposals of the city/town Master Plan proposals.

Town Planners, Architects and Engineers all have significant integrated role for the planned, better and environment friendly cities. Some academic courses related with city planning, implementation and construction management of these three professional degrees have more or less similarities. Now a days, Architects and Engineers are getting Town Planning degree from different universities of Bangladesh and abroad. Similarly, Town Planners are also interested in getting more knowledge and education on Architecture and Engineering.

In past there were and at present there are a number of Engineers as Members of Parliament (MP) and Ministers in Bangladesh. Some of them played and are playing significant role as Ministers of some of the important Ministries. There is an Architect as Minister in the present Parliament. Town Planning is comparatively new profession in Bangladesh and so Town Planners need time to play roles directly at policy level as MPs/Ministers.

## PROBLEMS AND LIMITATIONS FOR INTEGRATING ROLE OF TOWN PLANNERS, ARCHITECTS AND ENGINEERS

There are some problems and limitations for integrating the role of Town Planners, Architects and Engineers in Bangladesh. A number of Town Planners, Architects and Engineers with brilliant and outstanding merit and performance are being graduated from the public and private universities and many of them are working in different fields other than their mother fields. Government organizations have inadequate number of positions for these technical and professional degree holders. Most of the Town Planners, Architects and Engineers are found interested to go abroad for availing more facilities rather than serving Bangladesh, our motherland. Still now, there are no separate and well defined Technical Cadres like Doctors in Bangladesh Public Service Commission for the Town Planners, Architects and Engineers. Town Planning and Architecture faculties are being opened in many public and private technical and engineering universities with mere considerations of scope of works for the coming out Town Planners and Architects. Besides, the recruitment process in many cases is found politically influenced. The general people and political leaders have lack of knowledge on the roles and responsibilities of the Town Planners, Architects and Engineers.

## RECOMMENDATIONS FOR INTEGRATING THE ROLE OF TOWN PLANNERS, ARCHITECTS AND ENGINEERS

- Government should take step to create separate and well defined Technical Cadres like Doctors in Bangladesh Public Service Commission for the Town Planners, Architects and Engineers so that they can work with job satisfaction mostly in their mother subject based positions.
- Government should take step to create more positions for the Town Planners, Architects and Engineers in concerned government organizations related with city/town planning and development so that they can play significant role for making the cities/towns planned, safe and environment friendly.
- Positions of Architects at Paurashava level can be created for making the towns with structures aesthetically and environmentally proper designed.

- Recruitment process for all but especially for the Town Planners, Architects and Engineers can be made free from political and other influences to select the brilliant, meritorious and outstanding performance showing professionals.
- Government should consider some specific facilities i.e. flat system housing, transport etc. for all the civil servants including Town Planners, Architects and Engineers to have strict control on them for making them honest and sincere in delivering their better service to city people. It will help to keep them in country for serving the nation and resist them to permanently go and reside in abroad.
- Government should take step to keep the Town Planners, Architects and Engineers at field level in order to foster community based bottom up town planning and development approaches.
- A common platform for the dialogue of Town Planners, Architects and Engineers for integrating their roles towards planned, safe and environment friendly cities can be created by the concerned ministries, departments and professional bodies namely Bangladesh Institute of Planners (BIP), Institute of Architects of Bangladesh (IAB) and Institute of Engineers of Bangladesh (IEB).
- Training and experience sharing events and programs at national and international level on city planning and development can be undertaken by the concerned ministries i.e. Ministry of Housing and Public Works (MOHPW), MLGRDC and others.
- Separate Building Construction Rules for all the Development Authorities and Municipalities specifying well defined duties and responsibilities of the Town Planners, Architects and Engineers can be made and effective urgently as like as the Building Construction Rules 2008 of RAJUK for Dhaka city.
- Town Planners, Architects and Engineers should come forward with honesty, integrity, sincerity, commitment and devotion like the world renowned sympathetic, kind, emotional, helpful, plain and modest Swiss-born French Architect Le Corbusier who planned the Indian city Chandigarh.
- Professional ethics of the Town Planners, Architects and Engineers with examples of their good practices in Bangladesh and abroad should be inoculated/inherited among the students of Town Planning, Architecture and Engineering Departments of the universities.
- More study and researches can be conducted on the means and ways of integrating the roles of Town Planners, Architects and Engineers. A directory of the renowned Town Planners, Architects and Engineers of Bangladesh and other countries highlighting their contribution to the planned, safe and environment friendly cities can be prepared. It will inspire others to play their roles significantly in their respective fields.
- Politically conscious and committed Town Planners, Architects and Engineers should come forward for upholding the positions of policy makers as parliamentarians for guiding planned, safe and environment friendly cities and development.
- Local urban people can be made aware about the roles and responsibilities of the Town Planners, Architects and Engineers, so that they can take advisory technical assistance, services and supports from the professionals.

## CONCLUSION

Town planners, Architects and Engineers are playing significant role in planning and development of the cities and towns of Bnagladesh and the world. Implementation of the land based infrastructure development proposals as per city/town Master Plans is done mainly by the government sectoral agencies which are within the cities and towns and are concerned for delivering municipal services and facilities. Most of the Town Planners, Architects and Engineers are found interested to go abroad for availing more facilities rather than serving Bangladesh, our motherland. Still now, there are no separate and well defined Technical Cadres like Doctors in Bangladesh Public Service Commission for the Town Planners, Architects and Engineers. Government initiative to facilitate and patronize these professionals is very important for ensuring their integrated roles towards planned, safe and environment friendly cities of Bangladesh. Town Planners, Architects and Engineers should come forward with honesty, integrity, sincerity, commitment and devotion like the world renowned sympathetic, kind, emotional, helpful, plain and modest Swiss-born French Architect Le Corbusier who planned the Indian city Chandigarh.

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# INDUSTRIAL POLLUTION IN KHULNA CITY: CAUSES, CONSEQUENCES AND REMEDIAL MEASURES

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## ABSTRACT

Khulna is the third largest industrial, second largest sea port and a divisional city of Bangladesh. Most of its industries have been established along both the sides of Bhairab and Rupsha rivers. The industries that pollute the urban environment of Khulna are jute, paper and hardboard, shrimp and fish processing, thermal power plant, tannery, cement, battery, salt, ice, food and beverage etc. The industries are found reluctant in establishing individual and central Effluent Treatment Plants (ETPs) for preventing industrial pollution. The effluents discharged into the rivers are polluting water and causing harm to their aquatic species mainly fishes. River water quality is gradually deteriorating and causing detrimental effects on human health also. If the industries are located at suitable locations with ETPs, environment of Khulna City will be better for aquatic species and human health. The paper aims to investigate the causes, consequences and remedial measures of industrial pollution in Khulna City.

**Key Words:** Industrial Pollution, Khulna City, Effluent Treatment Plant

## INTRODUCTION

Industries and industrial development is one of the most important areas of concern for the national economic growth and development. Khulna is a leading industrial town in Bangladesh with its rich industrial heritage. Khulna had an industrial base during the British period when a few sugar and jute industries were set up on the Bhairab-Ruphsa bank. The policy of state capitalism pursued by the then East Pakistan government gave a boost to industrialization through establishment of a good number of industrial enterprises in jute, textile, chemical and metallurgical sectors. In the past, jute processing and bailing, newsprint, shipping and shipbuilding etc. were the main focus of Khulna’s economic activity. Over the period, such important activities gradually faded and new industries and activities are being generated. Among such industrial activities, export oriented fish processing is the most vital. Though the industrial base started to decay after the liberation of Bangladesh, Khulna City still holds the 3$^{rd}$ largest position with respect to the number of industries and industrial labour force in the country. Khulna is earning a lot of foreign currencies and making a significant contribution to GDP growth by exporting shrimp and frozen foods, jute products and consuming different products such as newspaper, hardboard, thermal power plant, jute industries and others. Industrial development is a two-edged sword. The positive side is that it develops the economy of a nation and create opportunities for huge number of populace. The negative side is that it discharges different solid, liquid and gaseous wastes into the soil, sediment, water and air which is harmful to the neighboring population especially to the workers who are associated in the different tiers of industrial activities and surrounding communities who live in and around the industries. Industrial pollution has a long term negative impact as the pollutants do not disappear immediately after dissolved within the matrix but appears in human being after decades through bioaccumulation and biomagnification and causes serious health hazards.

Most of the heavy and medium industries namely paper and hardboard, thermal power plant, tannery, cement, battery, jute, shrimp and fish processing, salt, ice, food and beverage etc. established along both the sides of Bhairab and Rupsha rivers pollute the urban environment of Khulna. The industries are found reluctant in establishing individual and central Effluent Treatment Plants (ETPs) for preventing industrial pollution. The effluents discharged into the rivers are polluting water and causing harm to their aquatic species mainly fishes. River water quality is gradually deteriorating and causing detrimental effects on human health also. Almost all industries in Khulna are situated on the river bank. Many of these industries discharge their toxic wastes into the river polluting its water. This tendency threatens ecology and environment. KDA Master Plan recommends setting up industrial waste treatment plants in high density industrial areas like, Mirerdanga, Daulatpur and Khalishpur (KDA Master Plan, 2001). Study on the industries of Khulna city, their level of pollution with causes, consequences and remedial measures is important for making the Khulna city industrially potential, economically sound, healthy and environmentally better.

## METHODOLOGY

For preparation of this study paper, Master Plan and Structure Plan of KDA, unpublished dissertation of Environmental Science Disciplines of Khulna University are reviewed. Data are collected from the Department of Environment (DOE) Khulna Regional Office. Interviews with the University Teachers and Researchers of Khulna are also conducted for the study.

## INDUSTRIES AND INDUSTRIAL ZONES OF KHULNA CITY

Although the industries, mostly small type are found scattered all over the Khulna city, there are several industrial zones within the KDA Khulna city Master Plan area. Among these Labanchara industrial area is characterized mainly by light to medium scale industries; Khalishpur-Daulatpur and Fulbarigate industrial area is characterized by heavy industries; Shiromoni-Fultala industrial areas are with medium to heavy industries; Lower Noapara industrial area is with heavy industries; and Upper Noapara industrial zone is with medium to heavy industries (KDA Structure Plan, 2001).

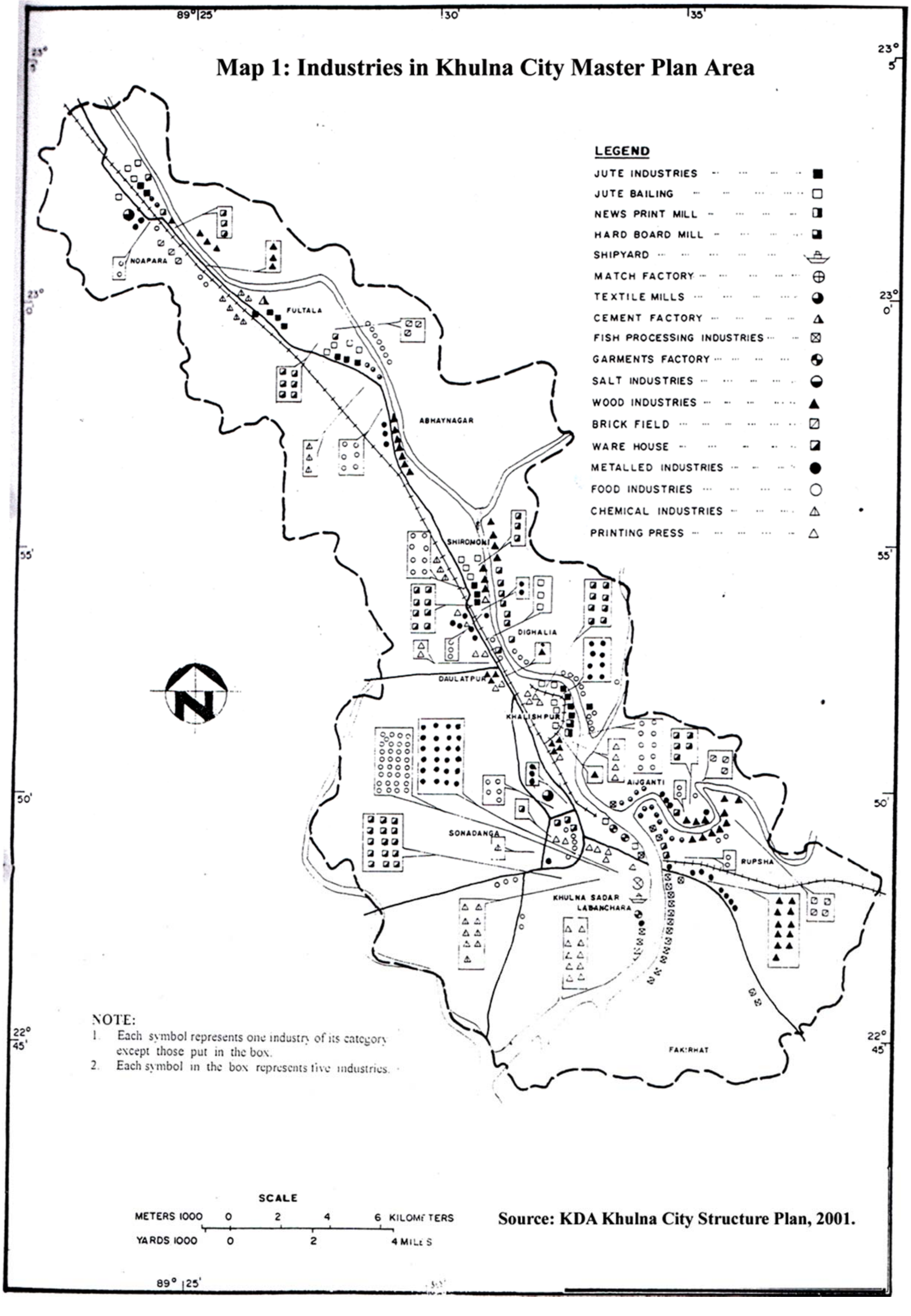
In terms of investment small-scale industries employ a maximum capital of Tk.3 crore, while medium scale over Tk.3 crore upto Tk.10 crore. Investment in large-scale industries go beyond Tk.10 crore. Heavy industries in general include steel, iron and paper industries etc.

These industries consume raw materials, which are heavy and bulky to transport. They produce a product, which is usually substantial. The industries which have employees more than 100 are heavy industries. Medium industries include spinning, weaving, fish, plastics, tanning, manufacturing of machinery etc. Number of employees of these industries vary between 25 to 100. The industries that produce products of domestic use, furniture, ice etc. are the small industries. These industries use raw materials which are light in weight and having employees up to 25.

Large and medium scale industries in Khulna include, jute and jute goods, newsprint and hardboard mills, cement clinker, pharmaceuticals. Small scale manufacturing sector is the largest in terms of number. They comprise 80% of all industrial concerns and are spread all over the Master Plan Area. However, due to small-scale investment they share only about 20-30 percent of the manufacturing sector employment. In terms of number, the other important industrial concerns are food and beverage industries (37.47%), metal and metal fabricating (21.9%) and miscellaneous (16.9%). However, most of these industries belong to small-scale group. Other manufacturing units in the Master Plan Area are, chemical industries, brickfields, rice mill, salt industry, species, rubber and plastic, printing press, transport, etc. (KDA Master Plan, 2001).

Khalishpur Industrial Area with excellent transportation facilities both land and water ways was developed during sixties. The area accommodates 4 jute and jute based industries and two hardboard and newsprint mills. During early 80s these alone shared 30% of all manufacturing employment of the city. Rupsa Strand Road-Labonchora Area is the southern most major industrial area of the city. The important industrial concerns here are, Khulna Shipyard, Dada Match Factory and Bangladesh Oxygen Factory and a large number of wood processing plants. Mirerdanga-Daulatpur Industrial belt is an old industrial area where industries, mostly jute and jute bailing and number of warehouses were developed during early sixties. Due to excellent transportation and export facilities industries were booming here during late sixties. Atra-Shiromoni Area has two planned industrial estates developed by BSCIC on an area of 44.43 acres and KDA on an area of 512 acres. But in both the estates, only a handful of factories have developed. Noapara-Rajghat-Phultala Area accommodates industrial agglomeration that has developed in the recent past. The area accommodates jute and jute goods, textile, leather processing, cement, salt, wood processing (saw mill) and few other manufaturings. Chandani Mahal Industrial Area, on the eastern bank of the river Rupsa - Bhairab has mainly jute-based industries and warehouses developed at this area during 60s. Debnagar Industrial Area, on the other side of the Bhairab River, accommodates jute mills and warehouses. Rajapur, Rupsa on the bank of the river Rupsa and on the south of the Atharabanki river, there are a number of salt and fish processing plants and godowns. On further east at Chandragati area there is large number of brick fields. Jabusa on the east Rupsa accommodates a number of fish processing plants taking advantage of easy water and road communication for transportation of processed goods. The industries of Khulna city are shown in the Map 1.

# Map 1: Industries in Khulna City Master Plan Area




NOTE:
1. Each symbol represents one industry of its category except those put in the box.
2. Each symbol in the box represents five industries.

Source: KDA Khulna City Structure Plan, 2001.

## CAUSES OF INDUSTRIAL POLLUTION IN KHULNA CITY

Main causes of industrial pollution in Khulna city are establishment of most of the industries without site and environmental clearance certificates, non-existence of Effluent Treatment Plants (ETPs) in most of the medium and heavy industries, lack of strict supervision and irregular inspection of industries by DOE, lack of awareness of the industry owners and industrial area surrounding people on industrial pollution issues, absence of punishment for the polluting industries and absence of system of awarding/rewarding for environment friendly operation of industries etc.

Nearly eight hundred big and small industries are located in Khulna city and its surrounding areas. These industries discharge about 10 million gallons of liquid waste, most of which go into the rivers Rupsha and Bhairab and other waters. In addition black smoke that is emitted from these industries pollutes the air. Industries like newsprint, pulp and paper, oil depots, jute, steel and engineering workshops, chemical industries, etc. are the source of pollution. Most of the chemical industries dispose off wastewater into the rivers Rupsha and Bhairab and pollute water. Dust emission is another type of pollutant from industries, particularly from jute mills.

Noxious industries are those that are harmful for environment and affect human health directly. The list of noxious industries includes pesticide, insecticide, leather processing, dyeing, fertilizer, cement, rubber processing, cement, shipbuilding, and power station. The Environment Protection Act 1997 lists 69 [ Rule 7(5) ] such industries. Marking as ‘red’, the Act terms these industries as the most dangerous for environment. On review of the ‘red’ list there are only a handful of noxious industries within the Khulna Master Plan Area. At south Noapara there exist a leather processing and a cement factory. They are sources of water and air pollution. Causes of industrial pollution in Khulna city are briefly discussed below:

### Industries without Site and Environmental Clearance Certificates

There were a total of 262 industries of different categories that should have site and environmental clearance certificates in Khulna Metropolitan area in 2008. Among these, only 34 industries had site and environmental clearance certificates and 228 industries had no such certificates. DOE of Khulna is taking initiative to bring all the industries under site and environmental clearance certificates to control industrial pollution and making city environment better (DOE Khulna Office, 2011). In some cases KDA can not play strong role to have control on industrial establishments due to local socio-political environment.

### Industries without Effluent Treatment Plants (ETPs)

Number of red category industries that severely pollute environment was 16 in 2008. Among those only 3 industries had Effluent Treatment Plants (ETPs) and 13 had no ETPs. Department of Environment (DOE) of Khulna is trying to convince the industry owners to establish ETPs for their industries to control industrial pollution (DOE Khulna Office, 2011). Most of the industries in Khulna city have no ETPs and so polluting its rivers, canals, water bodies and surrounding environment. But, the industries that severely pollute the environment need to have ETPs.

**Lack of Strict Supervision and Irregular Inspection of Industries by DOE**

DOE does not have strict supervision and regular inspection of industries that pollute the environment. This is due to inadequate number of staff and absence of developed system.

**Absence of Punishment for the Polluting Industries**

Punishment for the polluting industries by the concerned organizations i.e. DOE, KDA and KCC for industrial and environmental pollution is found quite absent. If there would have strict punishment system, the industries that pollute environment would take necessary steps to control industrial pollution.

**Lack of Coordination among KDA, DOE, KCC and Socio-political Leaders**

There exists lack of coordination among KDA, DOE, KCC and local socio-political leaders (Civil Society representatives and elected representatives) to take initiative for controlling industrial pollution of Khulna city. KDA, DOE, KCC and local socio-political leaders should take joint initiative to have strict control on industrial establishments.

**Lack of Awareness of the Industry Owners and Industrial Area Surrounding People**

The industry owners and city people, mostly of surrounding areas of industries have lack of awareness on the causes, consequences and remedial measures of industrial pollution. Due to this, the industry owners are found reluctant in establishing industries with site and environmental clearance certificates and ETPs. City and surrounding people of industries could put pressure on the industry owners and concerned organizations i.e. DOE, KDA and KCC for taking measures to control and check industrial pollution.

**Absence of Awarding/Rewarding for Environment Friendly Operation of Industries**

It is almost found absent of the system of awarding/rewarding the industries for their environment friendly operations. This system can encourage the industry owners to operate the industries with provision of industrial pollution control measures.

## POLLUTION LEVEL OF MAJOR INDUSTRIES IN KHULNA CITY

Different industries have different level of pollution in Khulna city. This is enumerated below:

**Goalpara Thermal Power Station**

In different steps of cooling water system, wastewater is produced. From river water is supplied to condenser tube through cooling water pump and wastewater is produced which is directly discharged into the river. In same way, water is supplied to hydrogen cooler and turbine oil cooler and wastewater is produced. Again river water is supplied to filter water and oil motor cooler for feed pump through booster pump and wastewater is produced. BOD of the effluent water was 120 mg/l, which is near about three times higher than the standards (Islam, 2002).

**Hardboard Mill**

The hardboard mill of Khulna city which had major negative pollution effect has been laid off for about last 3 years. But, with the re-opening of the laid off jute industries, it will also be functional soon. Wood is mainly used for hardboard production. Wastewater is produced during wood processing. Pulping and forming machine produce a huge amount of wastewater. The color of wastewater is reddish which contains high BOD, COD, TDS and Chloride. A laboratory result of BOD was 325 mg/l but the industries standard in only 50 mg/l. The COD of the wastewater was 415 mg/l but the standard is 200 mg/l (Islam, 2002).

**Newsprint Mill**

Like hardboard mill, newsprint mill also has negative pollution effect. It is also laid off for about last 3 years and it will be functional soon. The major portion of the pollution from papermaking originates from pulping process. The screened bark effluent contains fine particles of bark and wood and some dissolved solids. Additional sources of waste from wood preparation are pressing of rejects prior to burning and floor drainage.

A study of DOE in 2001 reported that the newsprint mill into the river daily spews some 46 lakh gallons of liquid substance and it produces 29500 mt. of BOD per year. Water quality tests show a huge proportion of COD and BOD, which exceed the standards, provided by DOE. Wastewater contains TDS 172 mg/l but paper industries standard is 100mg/l. BOD of wastewater was 230 mg/l but standard is 30 mg/l. Newsprint wastewater also contains high COD. The results of COD were 564 mg/l but paper industries standard is 300 mg/l.

**Jute Industry**

DOE treats Jute as a small-polluted industry in respect to other heavy industries along the rivers. The sources of liquid waste discharged are in the washing and screening stage of the operation. In the loom, the wastes are mainly of dust which creates a serious air pollution problem. The wastewater discharged in the screening stage contains bleaching chemicals, which results in the increase of BOD and COD level. On an average the jute industries discharge about 19 metric tons of BOD in each year. Crescent Jute Mill poured some 5 lakh gallons of liquid wastes alone into the river Bhairab. The wastewater of Crescent Jute mill contains high TDS that was 200mg/l but according to Jute industries standard it should not be greater than 6-9 mg/l. BOD of effluent water was 180 mg/l which was higher than the standard BOD 150 (Islam, 2002).

**Fish Processing Industries**

Fish processing requires the use of a considerable quantity of water for cleaning the fish, transportation of waste materials and cleaning plant equipment and floors. The discharge of this water with and without preliminary screening into adjacent rivers and lakes, consequently pollute their water. Major contaminants produced from these fish processing plants are BOD, Suspended solids, and Chemical oxygen demanding wastes.

A study of DOE in 1997 reported that about 12.53 metric tons of BOD is produced each year from these industries. Wastewater of a fish processing industry name Jahanabad Fish Processing industry contained TDS value of 987 mg/l. The Electrical Conductivity (EC), Chloride content, BOD and COD values of the wastewater of the Jahanabad Fish Processing industry were respectively 1396, 156.1 mg/l, 198 mg/l and 218 mg/l, which all were higher than the normal standard.

Ambient air pollution is not that serious in Khulna, compared with other large cities. Air borne particles (SPM) constitute major pollutants followed by lead and NOx, which were found in large quantities near bus stations and along the major transportation corridors. The concentration of NOx was found to be between 73 and 202 micrograms/$m^3$, while the upper limit is almost twice the standard for commercial areas. Presence of SOx, NOx and SPM makes ambient air high, which is particularly in the industrial areas, bus stations and commercial areas.

## CONSEQUENCES OF INDUSTRIAL POLLUTION IN KHULNA CITY

There are many direct and indirect consequences of industrial pollution in Khulna city. Untreated liquid industrial waste has its negative impact on fish resources in the rivers and wetlands. Industrial pollutants that fall into the Bhairab and Rupsha rivers ultimately make their way into the Bay of Bengal through the ‘Sundarbans’ the largest mangrove forest in the World. It has negative impact on the biodiversity as well as ecology and environment of the Sundarbans. Noxious industries are harmful for environment and affect human health directly. The industries discharge different solid, liquid and gaseous wastes into the soil, sediment, water and air which is harmful to the neighboring population especially to the workers who are associated in the different tiers of industrial activities and surrounding communities who live in and around the industries. Industrial pollution has a long term negative impact as the pollutants do not disappear immediately after dissolved within the matrix but appears in human being after decades through bioaccumulation and biomagnification and cause serious health hazards. Industrial workers and other city people who generally bath in the polluted river and connected canal water are vulnerable to various skin diseases. People who use the polluted water for other domestic uses i.e. washing utensils, cooking and even toilets are also at both short and long term health risks.

## RECOMMENDATIONS AND REMEDIAL MEASURES TO CONTROL INDUSTRIAL POLLUTION IN KHULNA CITY

Following recommendations and remedial measures can be significant to control industrial pollution in Khulna city:

### Establishment of Industries with Site and Environmental Clearance Certificates

Most of the industries of Khulna city have no site and environmental clearance certificates. These industries are located at such locations that enhance industrial pollution. So, all the industries need to be established with their site and environmental clearance certificates.

### Establishment of Industries with Effluent Treatment Plants (ETPs)

Most of the medium and heavy industries of Orange B and Red category in Khulna city have no ETPs and are polluting its rivers, canals, water bodies and surrounding environment. So, the industries that severely pollute the environment must need to establish ETPs.

### Strict Supervision and Regular Inspection of Industries by DOE

At present DOE does not perform strict supervision and regular inspection to the pollutant industries mainly due to its inadequate number of staff and absence of developed system. So, it is important to ensure strict supervision and regular inspection to the pollutant industries by DOE. It will put pressure to the industry management for taking effective measures for controlling pollution. Government should take necessary steps to increase its staff strength and develop a good and sustainable system thereof.

**Exemplary Punishment for the Polluting Industries**

As the punishment system for the polluting industries by the concerned organizations i.e. DOE, KDA and KCC is found quite absent, they are polluting the city environment. Exemplary punishment system for the polluting industries can be made effective for controlling industrial pollution.

**Exemplary Awarding/Rewarding for Environment Friendly Operation of Industries**

Exemplary awarding/rewarding can encourage the industry owners to operate the industries with provision of industrial pollution control measures. So, the system of exemplary awarding/rewarding of the industries for their environment friendly operations can be practiced and maintained in accountable and transparent way.

**Effective Coordination among KDA, DOE, KCC, NGO-CBO, Socio-political Leaders**

As there exist lack or absence of coordination among KDA, DOE, KCC, NGO-CBOs, local socio-political leaders for controlling industrial pollution of Khulna city, there should have effective coordination among these organizations and persons to take joint initiatives for planned industrial establishments and controlling industrial pollution.

**Enforcement of KDA City Master Plan Landuse Zoning for Industries**

Industries of different categories have several of impacts on environment. Considering the level of environmental impact the Department of Environment has classified industries into four categories. These are Green, Orange A, Orange B and Red. Green industries/processing units have minimum adverse affect on their surroundings.

Printing Press, Restaurant, Carton/Box making/printing packaging, Cinema Hall, Dry Cleaning and Jewelry etc. are Orange A category industries. Orange A category industries should be allowed in mixed and commercial zones, as alternative location other than industrial zone. None from Orange A list should be allowed in residential areas. KDA should take a liberal stand regarding approval of Green category industries in areas other than industrial zone like, mixed and commercial areas. These should not be allowed in residential areas. In mixed and commercial areas, the plants that might emit high level of smoke or create intolerable noise or odor should not be accorded permission. Hotel, multistoried apartment and commercial building; Refrigerator repairing, Tyre retrading, Garment and Sweeter knitting, Public toilet etc. are the Orange B category industries. Orange B category industries may be allowed to be set up in mixed and commercial zones. None of the Orange B category industries should be allowed in residential areas. The plants should not be allowed in mixed or commercial areas if they emit too much smoke or creates intolerable noise or odor. Red industries should not be permitted at any place other than zones marked as industrial. As per guideline of the Master Plan, noxious industries can be established/shifted on KDA earmarked 61.25 acres land on the northern confluence of the Rupsha-Atharabanki rivers which lies outside the main city. The areas around the site belong to low density rural settlement and agricultural use. Therefore, there is possibility of minimum damage to life and property due to any hazard or environmental/ecological degradation caused by noxious industries. Besides, the industrial plants can discharge their affluent (after treatment) into the river, which will be carried down to the sea without polluting the upstream areas.

**Development of Industrial Estates/Plots on KDA Earmarked Industrial Zones/Sites**

KDA Master Plan earmarks appropriate and suitable lands as industrial zones/sites for planned and environment friendly industrial development of Khulna city. So, KDA or any other agency, public or private, can develop industrial estates/plots in the industrial zones/sites for accommodating planned and environment friendly industries.

**Strengthening Documentation and Research System of Concerned Organizations**

Documentation and research/data preservation system on industrial development issues of Khulna city in DOE, KDA, KCC, Universities, libraries and NGOs and CBOs is found unsatisfactory. So, these concerned organizations should take steps to strengthen, update and modernize their documentation and research/data preservation system.

**Making Awareness of the Industry Owners and Industrial Area Surrounding People**

City and surrounding people of industries can not put pressure on the industry owners and concerned organizations i.e. DOE, KDA and KCC for taking measures to control and check industrial pollution. For this, their awareness raising is important. NGOs and CBOs along with concerned government organizations can take projects on awareness raising issues.

## CONCLUSION

Khulna city still holds the 3$^{rd}$ largest position with respect to the number of industries, industrial labour force and contribution to the national economy of Bangladesh. Number of industries is gradually increasing with the increase of its area and population. Most of the medium and heavy industries have no site and environmental clearance certificates and ETPs and so, high pollution level of these industries is harmful for city environment and human health. Site and environmental clearance certificates and ETPs; strict supervision and regular inspection of industries by DOE; exemplary punishment for the polluting industries and exemplary awarding/rewarding for environment friendly operation of industries; effective coordination among KDA, DOE, KCC and socio-political leaders; enforcement of KDA City Master Plan landuse zoning for industries; development of industrial Estates/Plots on KDA earmarked industrial zones/sites; strengthening documentation and research system of concerned organizations; and making awareness of the industry owners and industrial area surrounding people etc. can play significant role in controlling industrial pollution for making Khulna city industrially potential, economically sound, healthy and environmentally better.

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# STRATEGIC ADAPTATION OF SUSTAINABLE CROP PRODUCTION IN SALINE REGION OF BANGLADESH DUE TO GLOBAL WARMING

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## ABSTRACT

Global warming i.e. climate change is an important issue now-a-days. It causes sea level rise and that affect the coastal areas of Bangladesh. Bangladesh is a deltaic country with total area of 147,570 km$^2$. The major part (80%) of the country consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Terraces with an altitude of 20-30 m cover about 8% of the country, while hilly areas with an altitude of 10-1000 m occur in the southeastern and northeastern part. The coastal region covers almost 29,000 km$^2$ or about 20% of the country. Again, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The dominant crop grown in the saline areas is local transplanted Aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman rice. Salinity problem received very little attention in the past. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of crops. Thus combating land salinization problem is vital for food security in the country through adoption of land and crop management strategy.

**Key Words:** Global warming, salinity, crop production and adaptation.

## 1. INTRDUCTION

Climate change is an important issue now-a-days. Various human activities are making the world hot to hotter. The ultimate result is global warming, i.e. climate change. Rising temperature in the atmosphere causes sea level rise and affects low lying coastal areas and deltas of the world. In 1990, Intergovernmental Panel on Climate Change estimates that with a business-as-usual scenario of greenhouse gas emission, the world would be 3.3 $^0$C warmer by the end of the next century, with a range of uncertainty of 2.2 to 4.9 $^0$C [1]. With rise in temperature, sea level will rise because of thermal expansion and ice melt.

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Bangladesh is perspiring with different types of natural disasters. In the foreseeable future, the country is likely to be affected by the biggest ever, long lasting and global scale human induced disaster- the climate change and sea level rise (CCSLR). Bangladesh is thought to be one of the most vulnerable countries of the world to CCSLR.

IPCC estimates predict that due to the impact of climate change, sea level in Bangladesh may rise by 14 cm by 2025, 32 cm by 2050 and 88 cm by 2100. There are a number of environmental issues and problems that are hindering development of Bangladesh. Salinity is a current problem, which is expected to exacerbate by climate change and sea level rise. Salinity intrusion due to reduction of freshwater flow from upstream, salinisation of groundwater and fluctuation of soil salinity are major concern of Bangladesh. Cyclones and tidal surge is adding to the problem. Tidal surge brings in saline water inside the polders in the coastal area. Due to drainage congestion, the area remains waterlogged, increasing the salinity [2].

## 2. BANGLADESH: COUNTRY CHARACTERISTICS

The physical, social and economic conditions of Bangladesh are relevant to its status as one of the most vulnerable countries to climate change.

Bangladesh is one of the largest deltas in the world, formed by a dense network of the distributaries of the rivers Ganges, Brahmaputra, and the Meghna, and more than 230 major rivers and their tributaries and distributaries. The total land area is 147, 570 sq km and consists mostly of low, flat land. 80 per cent of the land is floodplain, and only in the extreme northwest do elevations exceed 30 metres above mean sea level, making the majority of Bangladesh (with the exception of the highlands) prone to flooding at least part of the year, with the floodplains of the north western, central, south central and north eastern regions subject to regular flooding [3]. Between 30-70 per cent of the country is normally flooded each year. The extent of flooding is exacerbated by the sediment loads brought by the three major Himalayan rivers, coupled with a negligible flow gradient, which increases congestion.

## 3. COASTAL AREA

### 3.1. Physiography:

Tidal and estuarine floodplains cover almost 98% of the coastal area. Small areas (2%) with river floodplains and peat basins are found in the northern part of the coastal area.
Tidal floodplains occur in Satkhira, Khulna, Bagerhat, Pirozpur, Jhalukhati, Barisal, Patuakhali, Chittagong and Cox’s Bazar district. They cover a total of 18,65,000 ha or about 65% of the coastal area. Estuarine floodplains occur in Noakhali, Bhola and Patuakhali districts and in the north-western part of Chittagong district. They cover about 9,37,000 ha or about 33% of the coastal area [4].

### 3.2. Land Characteristics:

The coastal saline area lies about 1.5 to 11.8 meters above the mean sea level. The Ganges river meander floodplain systems are standing higher than the adjoining tidal lands. The tidal floodplain has a distinctive, almost level landscape crossed by numerable interconnecting tidal rivers and creeks. The estuarine islands are constantly changing shape and position as a result of river erosion and new alluvial deposition. Peat basins are located in some of the low lying areas between the Ganges river floodplains and tidal floodplains occurring in the western part of Khulna [5]. These areas are subject to flooding in the monsoon season and water logging in parts of the basin areas in the dry season. Tidal flooding through a network of tidal creeks and drainage channels connected to the main river system inundates the soil and impregnates them with soluble salts thereby rendering both the top and subsoil saline [4].

## 4. INGRESSION OF SOIL SALINITY

Salinity ingress also causes an increase in soil salinity, especially when farmers irrigate their lands with slightly saline surface water at the beginning of the low flow period. SRDI [5] reported that, soil salinity levels south of Khulna and Bagerhat towns ranged between 8 to 15 dS/m during the low flow season. It is also reported that, several subdistricts (such as Kachua, Mollahat, and Fultali) south of the Sundarbans „" known to be non-saline in the pre-Farakka period „" have began to develop soil salinity during the low flow seasons of 1980s. The anticipated results of salinity ingress will be, at a minimum, of the same order for climate change induced low flow regime compared to similar effects shown by deliberate withdrawal of flows at Farakka barrage. The anticipated sea level rise would produce salinity impacts in three fronts: surface water, groundwater and soil. Increased soil salinity due to climate change would significantly reduce food grain production. Even at present, some parts of coastal lands are not being utilized for crop production, mostly due to soil salinity; and this situation would aggravate further under a climate change scenario. A modeling exercise has indicated that, under the changed climate conditions, the index of aridity would increase in winter. Consequently, higher rates of capillary action from an increased rate of topsoil desiccation would accentuate the salinity problem.

## 5. SEA LEVEL RISE AND SALINITY INTRUSION

A direct consequence of sea level rise would be intrusion of salinity with tide through the rivers and  stuaries. It would be more acute in the dry season, especially when freshwater flows from rivers would diminish. According to an estimate of the Master Plan Organization, about 14,000 sq km of coastal and offshore areas have saline soils and are susceptible to tidal flooding. If some 16,000 sq km of coastal land is lost due to a 45 cm rise in sea level, the salinity front would be pushed further inland. The present interface between freshwater and saline water lies around 120 to 160 km inland in the southwest, and this could well be pushed northward as far as central Jessore region in the event of a sea level rise .

## 6. HOW SALINITY THREATEN PRODUCTIVITY

Threat to Agriculture Production: Effect of saline water intrusion in the estuaries and into the groundwater would be enhanced by low river flow, sea level rise and subsidence. The adverse effects of saline water intrusion will be significant on coastal agriculture and the availability of fresh water for public and industrial water supply will fall. Agriculture is a major sector of Bangladesh's economy and the coastal area of Bangladesh is very fertile for growing rice. Increase in salinity intrusion and increase in soil salinity will have serious negative impacts on agriculture. he presently practiced rice varieties may not be able to withstand increased salinity.

The food production does not seem to have a better future in the event of a climate change. In Bangladesh, rice production may fall by 10 % and wheat by 30 % by 2050 (Climate change in Asia ‘too alarming to contemplate’-report, IPCC [7].

## 7. STRATEGY FOR MANAGEMENT OF COASTAL SALINE SOILS

a. Protective embankment: Land may be protected from inundation of saline water through establishment of embankment of suitable size. The recommended size should be 1 meter high above the high tide level.

b. Provision of sluice gate on the embankment: Their should be provision of sluice gate in the embankment system to remove excess water and also to prevent ingress of saline water during high tide

c. Leveling of land: Land should be properly leveled to prevent accumulation of water in the low-lying patches with shallow ground water tables and to facilitate uniform drainage of excess water. It will help to apply irrigation water uniformly in the field in rabi season, facilitate uniform germination of seeds and better growth of crops.

d. Storing of excess rainwater for irrigation: A part of the excess water stored in pond after meeting the requirements of the kharif season can be utilized during the dry period for rabi crops.

e. Selection of salt tolerant rice variety: BRRI Dhan 47 is salinity tolerant rice variety recommended for Aus and Boro season. It can tolerate salinity level of about 8 dS/m and can produced about 6 t/ha under saline condition. The variety needs to be spread as fast as possible.

f. Introduction of crop in rabi (winter) season: Cropping intensity can be increased in about 0.596 million hectares of very slight (S1) and slightly saline (S2) areas by adopting proper soil and water management practices with the introduction of salt tolerant crop varieties.

g. Keeping land covered in winter and summer months: Ground water is saline and present at a shallow depth (about 1.0 meter). Keeping lands fallow leads to high salinity in soil due to evaporation of excessive soil moisture. Therefore, it is recommended to avoid fallowing of lands during rabi season. Salt tolerant crops should be chosen and grown. This will lower the profile salinity.

h. Fertilization of crops: Since, soils in general are poor in fertility with low organic matter content, it is necessary to apply appropriate fertilizers to boost up crop production. Potash fertilizer has an added advantage under soil salinity. It lowers down Na uptake by plants and of course increases K uptake. Thus K fertilization protects crops from harmful effects of Na.

i. Provision of sub-surface drainage: In many parts of the coastal area, salinity is very high. To grow crops successfully in those areas, it is necessary to bring down the salinity by leaching the salts. It is also necessary to lower down the water table and maintain it blow the critical depth to prevent salt effect on crops grown. To achieve the objective, a proper sub-surface drainage has to be installed to keep the ground water at least 1 meter below the soil surface. This technology is effective but somewhat expensive.

## 8. RESEARCH FINDINGS

Table 1 shows that salt tolerant accession found in the diverse germplasm of wheat, examined in this experiment, could be useful for the screening of salt tolerant genotypes. The study also revealed that, germination and other parameter viz, root and shoot lengths were markedly reduced at salinity above 12 dS/m [1].

Table 1. Maximum and minimum values, mean and coefficient of variation of 45 wheat gnotypes for salinity related characters under different levels of NaCl salinity

| | Germination percentage | | | | | Shoot length (cm) | | | | | Root length (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| Max. | 100 | 98 | 95 | 85 | 35 | 12 | 7.4 | 5.5 | 3.9 | 2.7 | 12 | 8.6 | 7.7 | 6.1 | 3.6 |
| Min. | 92 | 19 | 16 | 0 | 0 | 8.8 | 3.5 | 2.7 | 0 | 0 | 6.8 | 2.8 | 2.8 | 0 | 0 |
| Mean | 85 | 68 | 56 | 22 | 6 | 11 | 5.6 | 4.3 | 2.0 | 0.71 | 9.6 | 6.5 | 5.9 | 2.5 | 0.9 |
| CV (%) | 8.5 | 17 | 15 | 26 | 34 | 9.8 | 15 | 12 | 8.7 | 10.7 | 14 | 20 | 14 | 11 | 14 |
| F-test | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |

$T_{1=}$control, $T_{2\,=}$8dS/m, $T_{3=}$ 12dS/m, $T_{4=}$ 12dS/m and $T_{5=}$ 20dS/m ; Source : Uddin, [8]

Vegetative and heading stages were the most affected stage than grain-filling stage when treated with NaCl salinity (Table 2).

Table 2. Summary mean of important economic characters of selected wheat genotypes to salinity under three growth stages

| Growth stage | Days to heading | Days to maturity | Plant height (cm) | Spikes/ plant (no.) | Grains/ plant (no.) | 1000-grain weight (g) | Grain yield (g/plant) |
|---|---|---|---|---|---|---|---|
| Vegetative | 61.87 a | 99.47 a | 79.51 b | 4.76 b | 31.26 b | 43.66 b | 5.75 b |
| Heading | 60.27 b | 98.33 b | 79.66 b | 4.79 b | 28.70 b | 39.06 c | 5.22 b |
| Grain filling | 61.20 a | 99.58 a | 82.33 a | 5.21 a | 33.05 a | 45.45 a | 6.51 a |

Source : Uddin, [8]

No single parent contained all the desirable traits. P45 and P33 were appeared to be the best general combiner for salt tolerance traits. The cross P1 X P15, P11 X P15 and P15 X P22 were found the best specific combiner for the traits. The best cross-involved poor x poor general combiner indicating over dominance and transgressive segreegation for resistance of salt in wheat (Table 3).

Table 3. Estimates of general combining ability (GCA) effects for different salinity traits in a 8X8 diallel cross of wheat under salinized condition

| Characters / Parents | Shoot length (cm) | RSL (%) | TDM (g/plant) | RSDM (%) | RTDM (%) | Score (RTDM) | Score (visual) |
|---|---|---|---|---|---|---|---|
| P1 | 0.93* | 0.81 | -0.14* | 16.08** | -11.39* | 1.07* | 0.50 |
| P11 | 1.07** | -2.46 | 0.11 | -4.23 | 6.22 | -0.20 | 0.13 |
| P15 | 1.00* | 1.22 | -0.04 | 8.35 | -4.39 | 0.50 | 0.27 |
| P22 | -3.00** | 0.93 | -0.15* | 9.32 | -18.65** | 0.63 | 0.13 |
| P24 | 0.60 | -0.04 | 0.03 | -2.98 | 6.25 | -0.47 | -0.03 |
| P33 | 0.80* | 0.13 | 0.28** | -27.00** | 30.21** | -1.67** | -0.63* |
| P40 | 0.60 | -0.03 | -0.05 | 0.50 | -1.48 | 0.33 | 0.01 |
| P45 | 0.91* | -7.78** | 0.29** | -24.99** | 26.32** | -2.86** | -0.96** |
| SE (±) | 0.28 | 1.05 | 0.05 | 4.21 | 4.12 | 0.32 | 0.25 |

* and ** indicate significant at 5% and 1% probability, respectively; (Source : Uddin, [8]

## 9. CONCLUSION

Soil salinity is a worldwide problem. Bangladesh is no exception to it. In Bangladesh, salinization is one of the major natural hazards hampering crop production. Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degrees of salinity. Agricultural land use in these areas is very poor. Declining land productivity with shift towards negative nutrient balance is among the main concerns with food security problem in the country. Thus combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy.

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# SHEAR STRENGTH PARAMETERS (C & Φ) OF NON-PLASTIC AND LOW TO MEDIUM PLASTIC SILT WITH SPT (N) VALUE

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## ABSTRACT

Soil is the stratified product of two complex natural process of physical and chemical weathering, which exhibits non-homogeneity, anisotropy and in-elasticity [5]. So the properties of soil is very much complex to determine and will exhibit a huge variation in its engineering properties with strata. It is a common practice to use empirical model based on SPT (N) value or CPT ($q_c$) for determining the shear strength parameters of any soil type as to perform the tests for each layer of soil is very much expensive and difficult. This study is conducted to develop a simplified model to predict the shear strength parameters for non-plastic and low to medium plastic silt based on corrected SPT (N) value. It is found that that the presence of a large amount of silt (which is generally cohesionless in nature) in soil imparts newer characteristics as that of a soil containing a predominant part of clay or sand.

**Key Words**: Shear Strength Parameters (C & φ), Standard Penetration Resistance (N), Non Plastic Silt, Low and Medium Plastic Silt.

## 1. INTRODUCTION

Cohesion (C) and angle of internal friction (φ) which are commonly known as shear strength parameters (C & φ) are the basic engineering properties of soil. Determination of cohesion is the predominant part of determining the bearing capacity of soil. ASTM has suggested a lot of test procedures to determine the shear strength parameters, but it is expensive and difficult to perform all the tests for each layer of soil sample in a borehole. So SPT (N) and CPT ($q_c$) based empirical model is used for obtaining an approximate average value of cohesion and angle of internal friction. A lot of research works have been conducted in Bangladesh as well as in many other countries of the world to develop a SPT (N) based model for cohesion of a cohesive deposit [1][5]. The current practice is to correlate $q_u$ with SPT (N) is shown in Eq. 1.

$$q_u = K*N \text{ (kPa)}, \quad \ldots\ldots (1)$$

Where, K is the proportionality factor. The value of K suggested by different researchers varies over a wide range of about 7 to 25 depending upon various cohesive deposits at different regions/countries [1]. The correlation between SPT (N) value and $q_u$ for cohesive soils as suggested by Terzaghi and Peck (1948 and 1967) are presented in Table 1. These correlations give the value of K = 12.50 to 13.33[1].

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The correlation between SPT (N) and unconfined compressive strength by Sowers (1953 & 1962) for cohesive deposits are presented in Table 2 and the values ranges between 6.7 to 24 for different soil types. A site-specific correlation for Bangladeshi soil suggested by Shamima Aktar et al. (2010), where the value of K = 15[5]. Another correlation has been suggested by M. Sirajuddin et al. (1996), where the values of K vary from 13.5 to 18.2 for different type of cohesive deposits with respect to Bangladeshi site condition. Some research works have been conducted to correlate angle of internal friction (φ) with SPT (N) value. The correlation between SPT (N) and angle of internal friction (φ) suggested by Shioi and Fukui (1982) is shown in Eq. 2 and Eq. 3.

$$\phi = \sqrt{18N'_{70}} + 15 \quad \text{.........................................................................(2)}$$

$$\phi = 0.36N_{70} + 27 \quad \text{.........................................................................(3)}$$

Sand is purely cohesion less, on the other hand clay is purely cohesive, but what about silt? Silt is also cohesion less in nature, if they are not contaminated with clay[7]. Few pure silt deposits are found in nature. Most deposit contains some clay particles (with the resulting plasticity/cohesion) or quantities of fine to medium sand[6]. This study is conducted to predict the behavior of silt mixed with clay or fine to medium sand.

Table 1: Correction between SPT (N) value & unconfined compressive strength of cohesive soil (after Terzaghi and Peck, 1948 & 1967)

| SPT (N) value | Unconfined Compressive Strength, $q_u$ (kPa) |
|---|---|
| 0 - 2 | <25 |
| 2 - 4 | 25 - 50 |
| 4 - 8 | 10 - 100 |
| 8 – 15 | 100 - 200 |
| 15 – 30 | 200 - 400 |
| > 30 | > 400 |

Table 2: Correlation between SPT (N) value and unconfined compressive strength for different soil types (after Sower 1953 & 1962)

| Soil Type | Strength in kPa | | |
|---|---|---|---|
| | Minimum | Average | Maximum |
| Highly plastic clay | 14.4 N | 24 N | 33.6 N |
| Medium to low plastic clay | 9.6 N | 14.4 N | 19.2 N |
| Plastic soil with failure planes | 4.8 N | 6.7 N | 9.6 N |

## 2. METHODOLOGY

Soil samples have been taken from 43 boreholes at five different locations of Dhaka city. The samples are then visually classified into two groups of non-plastic silt and low to medium plastic silt (having a liquid limit less than 50%). In case of low to medium plastic silt, liquid limit test and plastic limit test have been conducted to ensure its plasticity condition and classification according to ASTM 423-66 (liquid limit) and D424-59 (plastic limit). Grain size analysis was performed to non-plastic soil sample groups to ensure its classification according to ASTM D421-58 and D422-63. Silt is cohesionless material but when it is mixed with clay it will exhibit some cohesion (C) and at the same time it will exhibit a little angle of internal friction (φ) however it may be. In this study Direct Shear test (according to ASTM D3080-72) has been used due to its simplicity as well as accuracy. It has been found that the strength parameters (C & φ) obtained from direct shear tests are about as reliable as triaxial values [4]. Finally empirical correlations have been developed among corrected SPT (N) values, cohesion (C) and angle of internal friction (φ).

### 2.1. Correction of SPT (N) values

Standard penetration resistance (N) value used in this study has been corrected to normalize the effects of over burden pressure, energy ratio, borehole diameter, rod length and the presence liner. The recommended correction according to T. L. Youd et al. (2001) is shown in Eq. 4.

$$(N)' = N_m C_N C_E C_B C_R C_S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where, $N_m$ = Measured standard penetration resistance; $C_N$ = Factor to normalize $N_m$ to common reference effective overburden pressure (approximately 100 kPa); $C_E$ = Correction for hammer energy ratio; $C_B$ = Correction factor for borehole diameter; $C_R$ = Correction for rod length and $C_S$ = Correction for samplers with or without liners.

## 3. RESULTS AND DISCUSSION

Field and laboratory data for low to medium plastic silt obtained from subsurface investigation programs have been tabulated in Table 3 to Table 4.

Table 3: Values of cohesion with respect to corrected SPT (N) for low to medium plastic silt.

| Corrected SPT (N′) | Cohesion (ksf) | Corrected SPT (N′) | Cohesion (ksf) | Corrected SPT (N′) | Cohesion (ksf) | Corrected SPT (N′) | Cohesion (ksf) |
|---|---|---|---|---|---|---|---|
| 15 | 1.022 | 17 | 1.329 | 13 | 1.022 | 22 | 1.329 |
| 12 | 1.329 | 4 | 0.613 | 16 | 0.920 | 10 | 1.125 |
| 16 | 0.920 | 11 | 1.125 | 9 | 0.716 | 20 | 1.329 |
| 17 | 1.268 | 23 | 1.227 | 22 | 1.125 | 13 | 1.125 |
| 24 | 1.431 | 12 | 1.227 | 13 | 0.920 | 9 | 0.920 |
| 7 | 0.818 | 15 | 1.268 | 19 | 1.227 | 15 | 1.125 |
| 16 | 1.431 | 10 | 1.022 | 18 | 1.329 | 15 | 1.125 |
| 13 | 1.022 | 16 | 1.227 | 19 | 1.022 | 13 | 1.022 |
| 12 | 0.818 | - | - | - | - | - | - |

Table 4: Angle of response (φ) with respect to corrected SPT (N) for low to medium plastic silt

| Corrected SPT (N′) | Angle of response (φ) | Corrected SPT (N′) | Angle of response (φ) | Corrected SPT (N′) | Angle of response (φ) |
|---|---|---|---|---|---|
| 15 | 12 | 23 | 15 | 16 | 10 |
| 12 | 16 | 18 | 14 | 9 | 9 |
| 16 | 10 | 12 | 13 | 26 | 12 |
| 7 | 10 | 15 | 12 | 13 | 10 |
| 13 | 10 | 10 | 12 | 19 | 12 |
| 17 | 14 | 16 | 14 | 18 | 14 |
| 11 | 12 | 13 | 10 | 19 | 10 |
| 13 | 10 | 20 | 14 | 9 | 9 |
| 22 | 13 | 13 | 12 | 15 | 10 |
| 10 | 11 | 15 | 11 | - | - |

A plot of cohesion against SPT (N′) value is shown in Fig. 1. The plotted graph is a straight line with an equation as shown in Eq. 5. The graph shows that the cohesion increases with the increasing SPT (N) value.

$$C = \frac{SPT(N')}{24.5} + 0.5 \text{ (ksf)} \qquad (5)$$

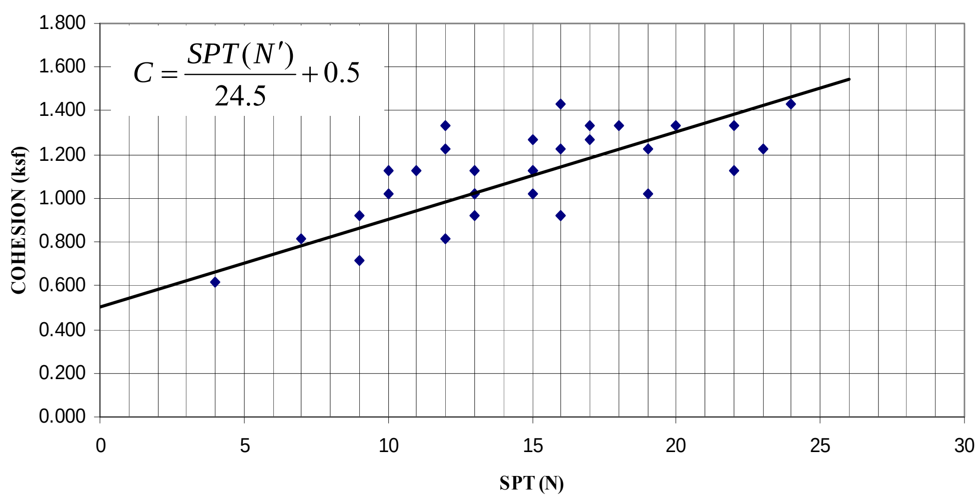


Fig. 1: Correlation between cohesion (C) and SPT (N′) for low to medium plastic silt.

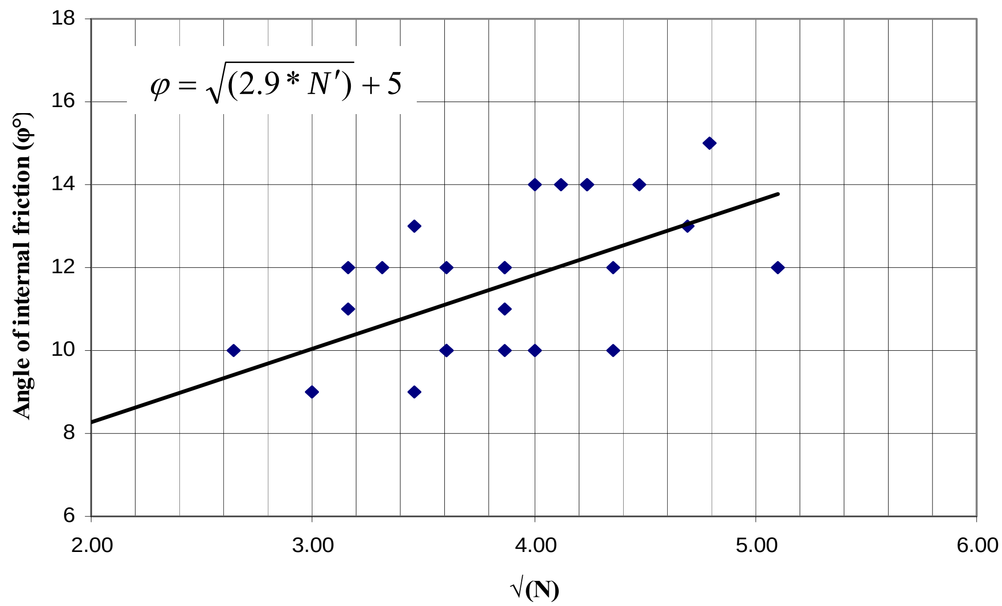


Fig. 2: Correlation between angle of internal friction (φ) and √(SPT (N′)) for low to medium plastic silt

Another plot of angle of internal friction (φ) against square root of SPT (N′) value is shown in Fig. 2, which shows a straight line of equation as shown in Eq. 6.

$$\varphi = \sqrt{(2.9 * N')} + 5 \text{ In degree } (^\circ)\ldots\ldots(6)$$

Angle of internal friction of non-plastic silt obtained from subsurface investigation program is tabulated in Table 5. The graph plotted for angle of internal friction (φ) against square root of SPT (N′) values is shown in Fig. 3 and the obtained equation is shown in Eq. 7.

Table 5: Angle of response (φ) with respect to corrected SPT (N) for non plastic silt

| Corrected SPT (N′) | Angle of response (φ) | Corrected SPT (N′) | Angle of response (φ) | Corrected SPT (N′) | Angle of response (φ) |
|---|---|---|---|---|---|
| 27 | 30 | 34 | 27 | 49 | 27 |
| 20 | 16 | 26 | 23 | 40 | 34 |
| 18 | 18 | 32 | 27 | 46 | 37 |
| 30 | 28 | 25 | 26 | 28 | 32 |
| 21 | 20 | 28 | 26 | 23 | 23 |
| 9 | 15 | 67 | 30 | 26 | 30 |
| 31 | 20 | 40 | 24 | 25 | 32 |
| 25 | 15 | 48 | 37 | 15 | 18 |
| 32 | 22 | 34 | 22 | 30 | 34 |
| 25 | 22 | 74 | 36 | 36 | 34 |
| 21 | 18 | 36 | 32 | 26 | 30 |
| 23 | 27 | 27 | 27 | 27 | 28 |
| 33 | 34 | 34 | 33 | 27 | 29 |
| 16 | 20 | 15 | 16 | 22 | 26 |

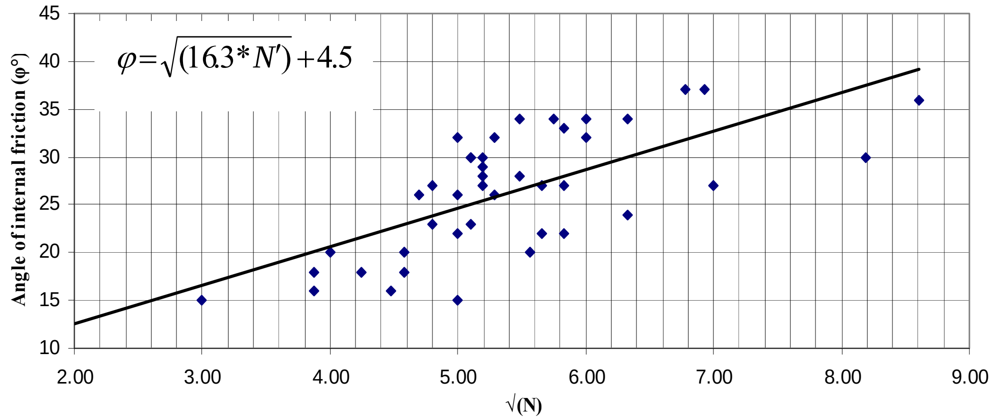


Fig. 3: Correlation between angle of internal friction (φ) and √(SPT (N′)) for non plastic silt

$$\varphi = \sqrt{(16.3 * N')} + 4.5 \text{ In degree } (°)\ldots\ldots(7)$$

It has been observed from the above mentioned equation that cohesion for low to medium plastic silty soil increase with increasing SPT (N′) value but rate of increment is very small compared to the clay deposit and at the same time plastic silt exhibits some angle of internal friction. The same is true for non-plastic silty soil. This type of soil exhibit only angle of internal friction in the laboratory test but the values are comparatively smaller than that of a sand deposit having the same SPT (N) value.

## 4. CONCLUSIONS

The equations stated from Eq. 5 to Eq. 7 may be used as a guide to calculate the strength parameters of low to medium plastic and non plastic silt. Shear strength of soil also depends on confinement pressure; so results from triaxial test on a large number of samples may be used to verify the obtained results.

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# ISSUES OF RAW WATER QUALITY IN THE TREATMENT OF DRINKING WATER AT DHAKA

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## ABSTRACT

Once, presumably cheap and abundant, ground water source inside Dhaka has gradually been depleted so much that no further over extraction is possible. There is no other way but switch over to surface water. But indiscriminate pollution generating human activities surrounding the peripheral rivers of Dhaka have turned the rivers into, especially in dry season, sewage canal ---- making them unsuitable to be a source of drinking water.

The water qualities of the surrounding rivers are deteriorated very much which raised concern among the city dwellers as well as the experts. In the dry season there are complains of water with bad smell and aesthetic problem. There is an underlying assumption that the problems observed during the dry season are linked to problems of removing algae. This problem is again assumed to be caused by increased concentrations of ammonia interfering with the intended removal of algae.

Narrowing down the problem we can observe:

### The Ammonia Problem

The data shows a clearly increasing trend of the average monthly values and max values, both increasing around three mg NH4-N/l over the four year period.

Compared with the initial design criteria for plant I of max 4 mg NH4-N per litre and with the Bangladesh Standard for Nitrate of 10 mg $NO_3$-N the increases are substantial in such a short period and the trend must be taken seriously both in terms of regulatory measures against polluters and in terms of proactive strategies on how to handle the resulting future treatment challenges if pollution prevention is not introduced in a sufficiently timely and effective way.

### The Sulphide Problem

Sulphide has so far not been considered a problem for the operation of the plant as such and has, to the knowledge of the researcher, not been analysed for earlier. Sulphide is however associated with a very offensive "rotten eggs" odour and taste which is detectable at concentrations as low as 0.05 mg/l. It must therefore be removed. Further, sulphides represent an oxygen demand in the water which is significant at high sulphide concentrations.

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**Pollution Problem**

It is clear that the water chemistry of the raw water channel and the plant is very complex and a combination of different measures will be necessary to reasonably mitigate the problems encountered at plant during the dry season.

Looking at the available data and the rather complex situation it may be said that the observed problem of Taste, smell and colour of the treated water during the dry seasons, is due to a combination of the following cause effect relations:

- High concentration of organic substances → creating anaerobic conditions in water body and in sediments → formation of sulphides → water smells as rotten eggs.
- High ammonia concentration → difficult to disinfect → not possible to control algae nor to ensure hygienic quality of water
- Algae growth in DND canal → release of toxic and nuisance substances
- Diluted wastewater → high concentration of organic substances → high chlorine demand and appearance of nuisance substances.
- In this paper an attempt is made to present & analyze the raw water quality data of the said surface water and associated problems in relation to treatment process.

**Key words**: Deterioration of river water quality,High concentration of organics,Algae growth,Cholorine demand, Treatment of drinking water.

## 1.0 INTRODUCTION

### 1.1 Analysis of Issues

**The raw water system**

The raw water supply system and key aspects of its function are as follows:

**Hydraulic aspects**:

- The raw water is pumped from the Lakhya River into the DND canal ( a 4.5 km long open canal, which has a width of 30-70 m and a depth varying between 3 m and 4 m. From the end of the DND canal the water is led by gravity through a closed culvert some 1500 m to the inlet pump station of the SWTP
- The total flow in the Lakhya river changes significantly between the wet season with plenty of water in the river and the dry season, when the 80 % dependable flow is reduced to levels that are around 10 times bigger than the volumes extracted to the combination of Saidabad I and II. In severe low flow situations the water extraction in itself therefore will lead to increases in the concentration levels.
- In the dry season the water movements around the location of the Sarulia pump station are influenced by a tidal back-flow/back-up coming from river Meghna

and pushing water from the downstream areas up towards Sarulia. Some model results indicate that the net flow in the river almost becomes zero during the dry season in the lower reaches [8,9,10].

**Pollution aspects:**

- The pollution of the Lakhya River to a large extent comes from urban sewage and industrial waste into the Balu River and further into the Lakhya River shortly upstream of the Sarulia intake pump station.
- The pollution being discharged through the Norai Khal/Balu River system originates from (at least) 1.5 -2 million people. In the wet season the flow in the Lakhya River is sufficiently high to dilute the pollution to acceptable levels, whereas the concentrations rise to un-acceptable levels during the low flow situation in the dry season.

The DND Canal to some extent works as a treatment reactor. During the wet season there is most likely sedimentation of solids along the canal and in the dry season there is a growth of algae, which removes parts of the pollution in the water, but which also negatively influence the treatment process at the SWTP [9,10].

## 2.0 THE EXISTING PLAN

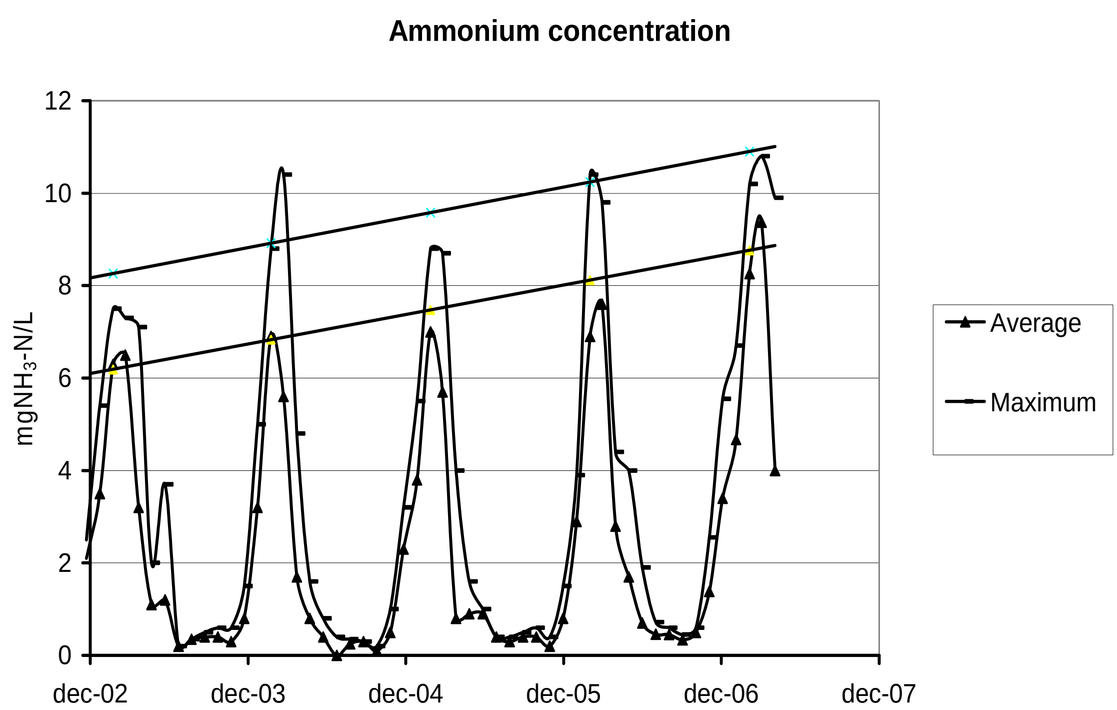


**Fig.1 Ammonium Concentration**

It is worth while noting that the trends above imply that it will continue. The figure below illustrates yearly variations of some key water quality parameters:

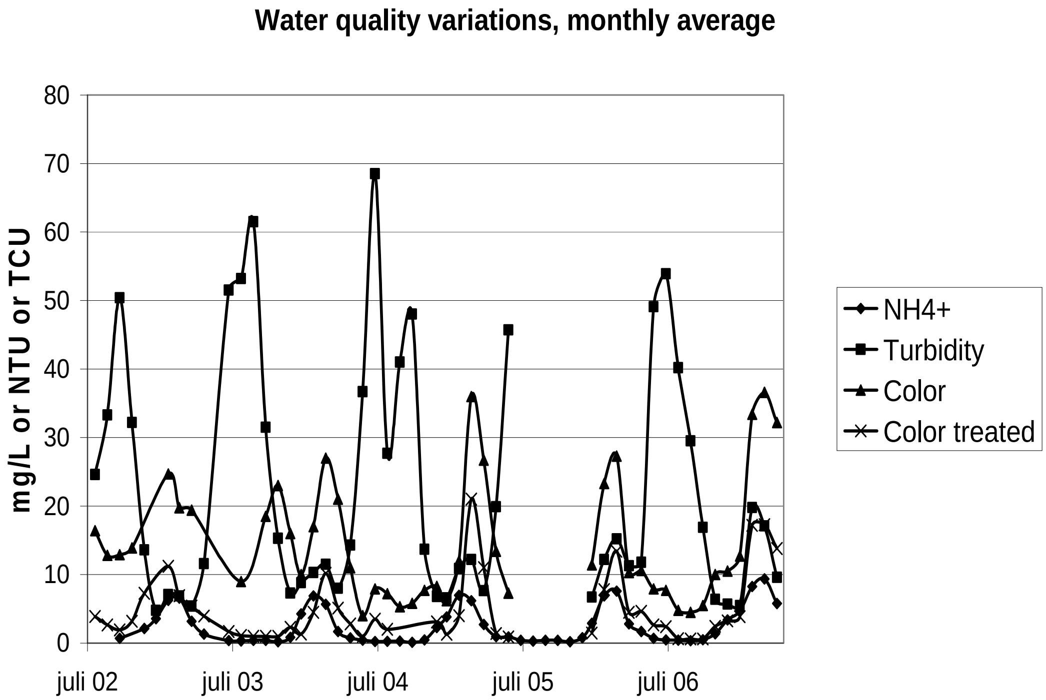


**Fig.2.0 Water Quality Variations**

The figure shows:

- Turbidity are high in the rainy season (May to October) with monthly average values up to 70 NTU;
- Turbidity falls to below 10 NTU at the start of the dry season and then rise slightly during the dry season possibly due to increased concentration of pollutants and/or algae rather than silt;
- Colour in both the raw water and the treated water follows the ammonia trend with high values in the dry seasons and low values in wet seasons;

Colour in treated water varies significantly from less than 2 TCU in wet seasons to more than 15 TCU in the dry seasons. This indicates problems with the treatment processes [2].

## 4.0 WATER QUALITY IN THE DND CANAL

Water was sampled from 6 points located along the DND Canal starting at the intake and ending at the point where water flow through an underground culvert to the WTP.

No significant changes in the chemical quality of the water can be observed from the data, but the data rather indicate (some however not significant) hourly variations of the water quality in the river. This is illustrated by the water flowing through the canal as a plug flow with minimal horizontal mixing and thus sampling point 1 close to the river represent water pumped from the river a few hours before sampling, while sampling point 6 close to the treatment plant represent water pumped from the river approximately 30-40 hours earlier .

On several days the concentration of all the measured parameters have been noted to increase from the first to the last sampling point with the exception of TOC; this parameter decrease with 10-50% but still remains very high when entering the plant.

The principle parameter ammonia does not decrease, which can be understood from the short residence time and the very low oxygen content (50% of the samples lower than 1 mg/l.

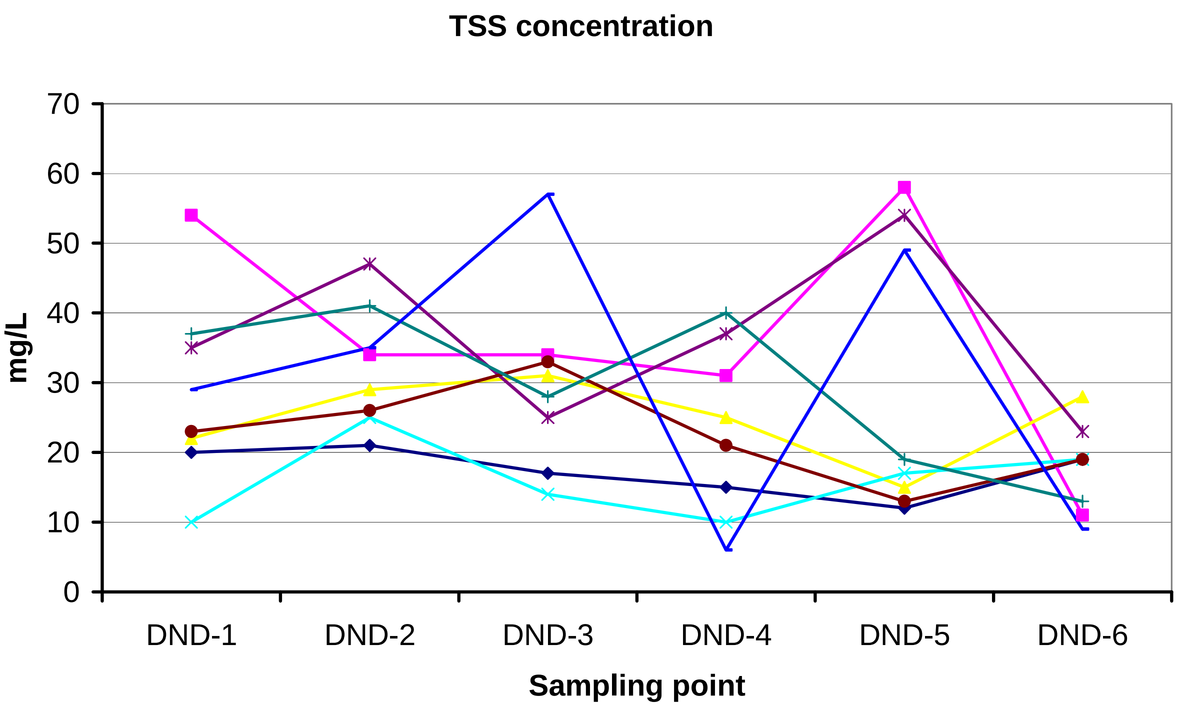


Fig. 3. TSS Concentration

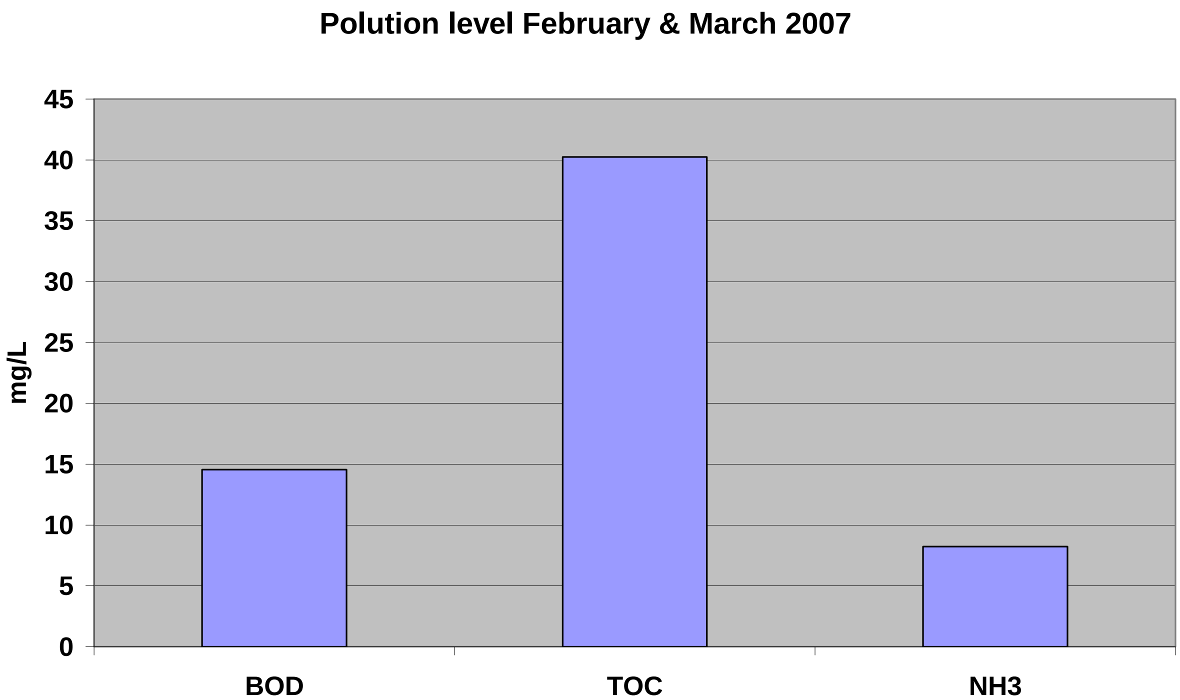


Fig. 4. Pollution Level February and March 2007

The figure shows the average concentration of ammonia TOC and BOD over the sampling period.

A comprehensive analysis of algae in the canal and in the treatment plant was carried out both quantitative (concentration of chlorophyll A) and qualitative (determining the species of the algae present in the water).

The concentration of chlorophyll-A, illustrating the concentration of algae in the water along the DND canal was analysed on nine different sampling days. Average, minimum and maximum concentrations are presented in the figure below.

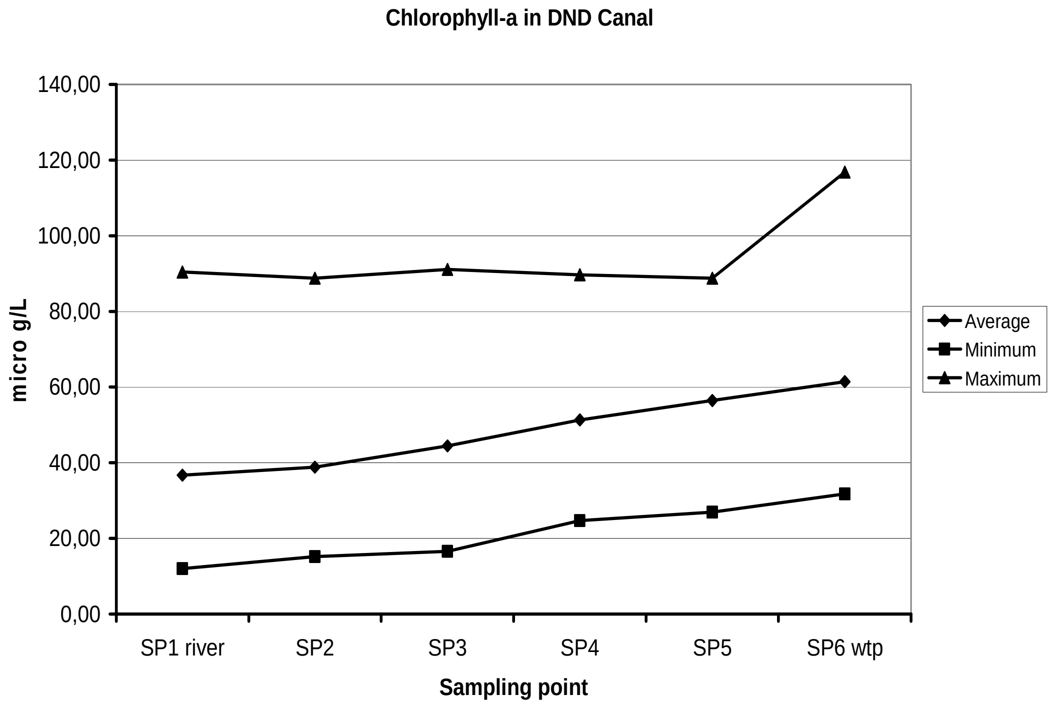

Fig. 5. Chlorophyll-a in DND Canal

Algal growth in DND canal

It can be seen that the amount of algae –which is moderate at the inlet- will on average double (1.5 – 3.8 times increase) during their stay in the canal. This results in a high concentration of algae in the intake of the WTP[1,2,3,4].

## 5.0 ANALYSIS OF DATA FROM THE CANAL

### 5.1 Oxygen demand of the water

The raw water entering the treatment plant during the dry season is anaerobic meaning that the concentration of oxygen is close to zero (anoxic) and that most substances are in a reduced form (low redox potential), like nitrogen is present in the reduced form ammonia, and will contribute to the oxygen demand of the water.

### 5.2 Organic materials

Available data on the concentrations of various indicators for organic materials are a bit confusing. We have measurement of BOD-5 (biological oxygen demand in 5 days); COD (chemical oxygen demand by dichromate); and TOC (total organic carbon).

The data are not always consistent, however, concentrations of COD of around 50 mg/l and TOC of around 100 mg/l have been measured.

It is clear that the observed high chlorine demand (from the breakpoint chlorination attempt) may be due to high concentrations of organic materials.

### 5.3 Algae

The algae are multiplying to a significant level in the Canal. Further, the water quality parameter indicate that the raw water is in reality river water mixed with wastewater and thus there will be a wide range of substances and compounds in the water, which are not related to the algae and which also will create taste and smell nuisance.

The Chlorophyll-a data from the channel indicate:

- that the content of chlorophyll-a builds up from a relatively low level (approx. 20 µg/l) at the beginning of the channel to a higher level (approx. 40-60 µg/l) at the end of the channel near the site of water intake.
- The chlorophyll content can be characterised as high at the end of the channel before point of water intake however not alarmingly high compared to European conditions, where a heavy algae bloom is characterised by a chlorophyll content of 150 µg/l. Normally the chlorophyll content varies over the year depending on the light intensity. During late autumn, winter and beginning of spring the content is higher than in the summer period where the content is lowered due to a higher light intensity [2.3].

## 6.0 NARROWING DOWN THE PROBLEM

### 6.1 The ammonia problem

The analysis shows a clearly increasing trend of the average monthly values and max values, both increasing around three mg $NH_4$-N/l over the four year period.

Compared with the initial design criteria for of max 4 mg $NH_4$-N per litre and with the Bangladesh Standard for Nitrate of 10 mg $NO_3$-N the increases are substantial in such a short period and the trend must be taken seriously both in terms of regulatory measures against polluters and in terms of proactive strategies on how to handle the resulting future treatment challenges if pollution prevention is not introduced in a sufficiently timely and effective way.

### 6.2 The sulphide problem

Sulphide has so far not been considered a problem for the operation of the Saidabad I WTP as such and has not been analysed for earlier.

Sulphide is however associated with a very offensive “rotten eggs” odour and taste which is detectable at concentrations as low as 0.05 mg/l. It must therefore be removed. Further, sulphides represent an oxygen demand in the water which is significant at high sulphide concentrations.

### 6.3 Pollution prevention

Though pollution prevention would be the optimal solution from an environmental and social perspective, the present situation and development in Dhaka strongly indicates that this is not a likely scenario in the near future. Large areas are presently being developed without proper pollution management systems on the west bank of Balu River up-stream of the Sarulia intake.

## 7.0 CONCLUSION

The above points can be further narrowed down to the following problems: Complaints of taste, smell and colour during dry season, and possibly hygienic problems, due to a combination of the following cause effect relations:

- High concentration of organic substances → creating anaerobic conditions in water body and in sediments → formation of sulphides → water smells and tastes rotten.
- High ammonia concentration → difficult to disinfect → not possible to control algae nor to ensure hygienic quality of water
- Algae growth in canal → release of toxic and nuisance substances
- Diluted wastewater → high concentration of organic substances → high chlorine demand and appearance of nuisance substances

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ICETCESD-2011, March 10-12, 2011, SUST, Sylhet, Bangladesh

# HAZARDS IN COASTAL REGIONS OF BANGLADESH: A FOCUS ON TROPICAL CYCLONE AND STORM SURGE

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## ABSTRACT

Bangladesh, located at the head of the Bay of Bengal, is the biggest delta in the world. It is ironic that Bangladesh is subjected to many natural perils including cyclones, cyclone generated storm surges and erosions especially in the coastal region due to its geographical location and topographical condition. Topographically about half of the country is located below the elevation of 7.6 meter with respect to mean sea level (MSL) and an average flood affected area in Bangladesh is around 20% every year. Yet these annual floods are insignificant as compared to the disastrous floods caused by tropical cyclones. This paper has made a historical review on tropical cyclones and storm surges in the coastal region of Bangladesh. From the statistics of 23 devastating cyclones over the world, year 1737 to 1999, with huge death casualties (over 5000 people), it is found that 74% cyclone events happened over the Bay of Bengal, where Bangladesh had to face 59% of Bay events. Moreover, it is found that the death occurred in Bangladesh is 70% of the total death occurred due to tropical cyclone over the world. It is highly suggested in this paper that the old warning and cyclone classification system in Bangladesh is to be overhauled to bring it in the line with the requirements of coastal people. The initiative should be extended to introduce high technology available today in this regard.

**Key Words:** Coastal regions of Bangladesh; Historical review on coastal hazards; Statistical analysis; Bay of Bengal; Cyclone classification; Cyclone warning; Storm surges.

## 1. INTRODUCTION

Bangladesh is located in one of the most sensitive tropical cyclone basins among the seven over the world where storms occur on a regular basis. This basin is known as “North Indian Basin”, which includes the Bay of Bengal, the ultimate destination of all rivers in Bangladesh. The coastlines in the Bay of Bengal have converged in several places. That is why, the incoming surges become more and more constricted along the cross-direction of the river mouth and its amplitude is forced to increase. For that reason, some of cyclone surges occurring here is resulted the most severe in the world. Simultaneous occurrence of a high tide aggravates the effects of a storm surge and thus renders the coastal region much destroyed. The Bay of Bengal experiences high frequency of cyclone particularly in its north-

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eastern side [1]. Usually, cyclones in Bangladesh coastal region move towards north-eastern side [2] and cause heavy damages. Apart from that, lives, crops, livestock, roads, bridges, electricity pylons is destroyed. Salt water contaminates farmland and pollutes supplies of drinking water. In fact, to date, no other natural calamities have surpassed the 1970 cyclone in terms of damages caused to lives and properties in Bangladesh.

The cyclone storm surge features along the Bangladeshi coastline have been investigated by a number of researchers like Jakobsen et al. [3], Azam et al. [4], As-Salek [5] and Murty et al. [6]. Jakobsen et al. [3] described several measurements using numerical models. To lessen the impact of hazards on the coastal region, the government of Bangladesh has taken several initiatives. Flood Forecasting and Warning Centre (FFWC) under the Bangladesh Water Development Board (BWDB) was tried to install an updated coastal flood forecasting system in collaboration with Danish Hydraulic Institute (DHI). Two-dimensional coastal flood modeling software (MIKE 21) was used in this connection but it has yet to reach in the operational level. However, all analyses and measures have been revolved surrounding the historical events. This paper made a historical overview of the coastal events in Bangladesh with respect to tropical cyclone and storm surge. Measures taken to reduce the havoc as well as FFWC's relevant activities are also discussed briefly in this paper.

## 2. COASTAL REGIONS IN BANGLADESH

The coastal region of Bangladesh is hydrologically aggressive and prone to extreme cataclysms with eventual vulnerabilities to the hard core poor. It has 710 km long coastline along the northern tip of the Bay of Bengal. The coast of Bangladesh, based on geomorphologic conditions and hydrological features, can broadly be divided in three distinct regions: the eastern part, the central part, and the western part as shown in Fig 1.

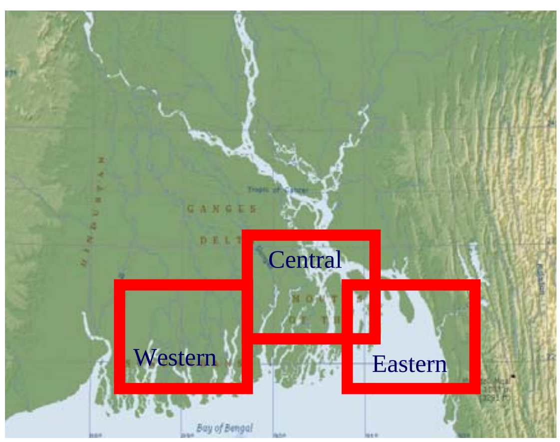


Fig 1: Topography of Bangladesh (Satellite Image)

The coastal region of Bangladesh consists of approximately 42,000 Sq. km. The territorial water of the country is 9,100 Sq. km up to 12 nautical miles. The estimated total marine water is 166,000 Sq. km. The coastal population is 33 million with about same density as compared to the rest of the country [7]. Common facilities are almost absent in their livelihood and thus the poverty rate of the coastal region is higher. The 654 km of sea-facing saline embankment along the coast of Bangladesh gradually built by BWDB over the last four decades is enhancing the degree of safety to life and property of coastal population against the cyclone and cyclone generated storm surges [7]. These embankments are the prime consideration for agricultural safety along the coastal region. The frontline saline embankment along the coast has seldom been learnt to have been overtopped by the past storm surges [7].

In the context if tsunami, it is hopeful, albeit slightly, that the geographical location of Bangladesh in relation to the fault line in the Indian Ocean has itself made the nation's coast less prone to tsunami. Beside this, Sundarban, world's largest mangrove forest, saves the western region of Bangladesh from cyclone (Fig 2).

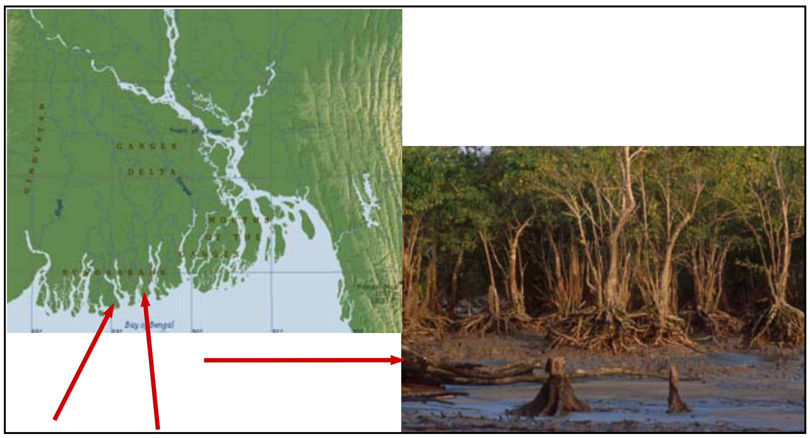

Fig 2: Sundarban saves western part of Bangladesh from cyclone

## 3. TROPICAL CYCLONE IN BANGLADESH

The severe tropical cyclones in Bangladesh mostly occur during pre-monsoon (April-May) and post-monsoon (October-December) seasons. The frequency of occurrence of tropical cyclone in Bangladesh is highly erratic. In fact, the ability of cyclones to quickly change the direction and intensity is one of the most important features making it difficult for the forecasters to tract the cyclone fairly accurate. Fig 3 shows some of the routes followed by the cyclones from 1989 to 2000 after being originated near the Andaman Sea in the Bay of Bengal.

Table 1 describes the classification of cyclonic disturbances provided by Bangladesh Meteorological Department (BMD). Previous cyclone statistics in Bangladesh and its corresponding satellite pictures were taken into consideration to arrange the table that focuses the classification based on maximum wind speed, pressure drop and radius of cyclone. It is shown that the disturbances turn into severe cyclone storm with winds of around 100 km $hr^{-1}$ and radius around 60 km at maximum wind speed.

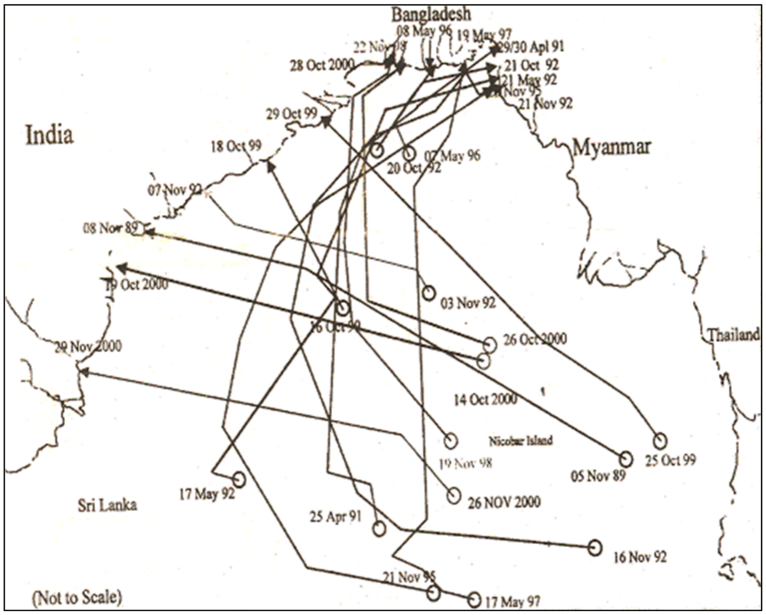


Fig 3: Path of cyclones in the Bay of Bengal 1989-2000 (BIWTA, Bangladesh)

Table 1: Classification of cyclonic disturbances used by BMD

| Classification | Max. wind speed (km $hr^{-1}$) | Pressure Drop (mb) | Radius to max. wind speed (km) |
|---|---|---|---|
| Low | < 31 | --- | --- |
| Well-marked low | 31 – 40 | --- | --- |
| Depression | 40 – 50 | 2 – 4 | 44 |
| Deep depression | 51 – 61 | 4 – 6 | 48 |
| Cyclonic Storm | 62 – 88 | 6 – 12 | 54 |
| Severe cyclonic Storm | 89 – 117 | 12 – 21 | 64 |
| Severe cyclonic Storm of hurricane intensity | ≥ 118 | ≥ 21 | ≥ 74 |

Fig 4 shows the different years with the corresponding death occurred due to the severe cyclones in Bangladesh since 1876. The cyclones killed over 5,000 people in Bangladesh have been considered as the severe cyclones. Fig 5 shows death due to the tropical cyclone over the world. It is found that 74% severe cyclone events happened over the Bay of Bengal in the past, where Bangladesh had to face 59% of Bay events. Among the all considered severe events, cyclones in Bangladesh in 1970, China in 1886, and India in 1737, caused the maximum death about 300,000 people. Moreover, it is found that the death occurred in Bangladesh is 70% of the total death occurred due to tropical cyclone over the world. Only the cyclones taking away over 5,000 human lives have been taken into consideration in the above statistics.

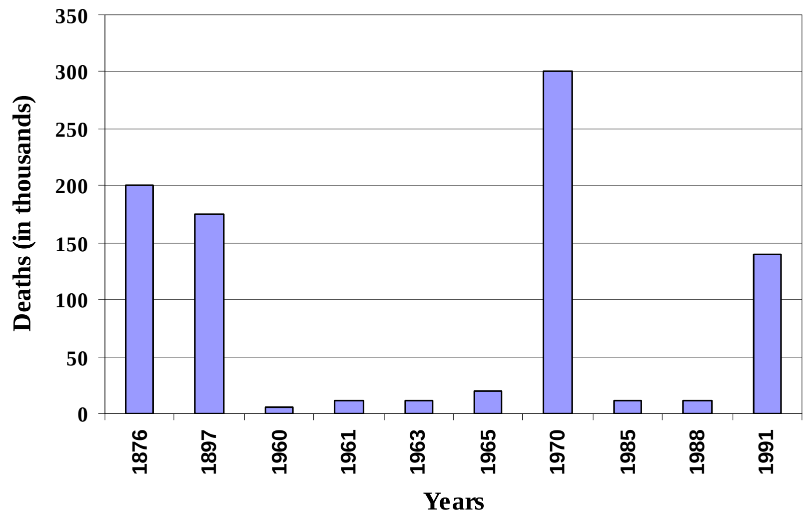


Fig 4: Severe cyclones (Death casualties over 5,000 people) in Bangladesh since 1876.

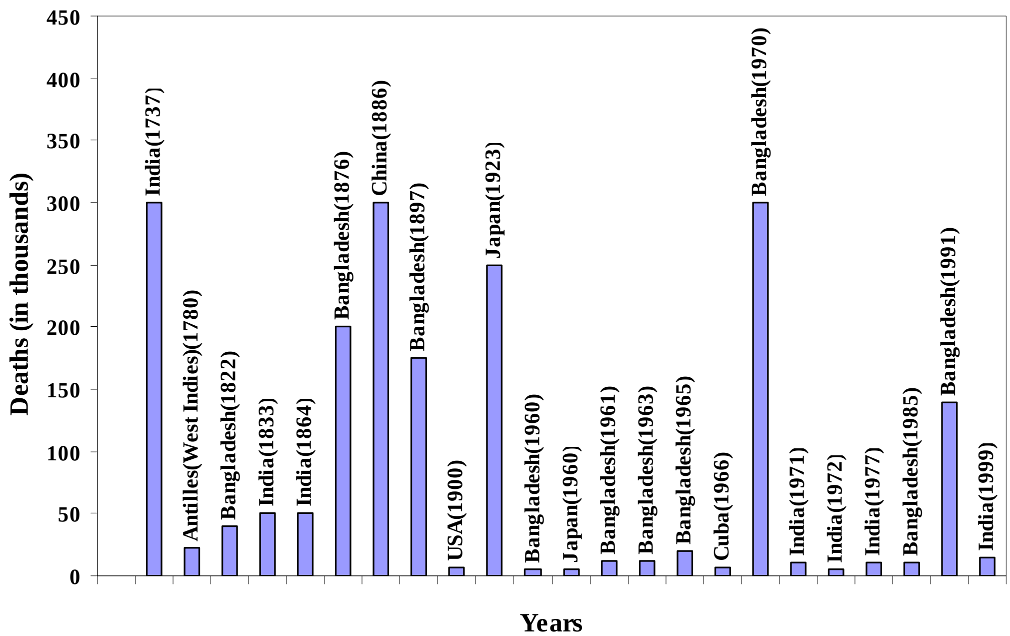


Fig 5: Severe cyclones (Death casualties over 5,000 people) over the world by tropical cyclones (1737-1999)

## 4. STORM SURGES IN BANGLADESH

A storm surge is the rise of water level above the astronomical tide as a result of a tropical and extra tropical event. Usually, varieties of storm events that are associated with hurricanes are responsible to form surges. Storm surge is extremely dangerous and needs to be considered in coastal hydrology. A surge is characterized by both the increase in water elevation and the duration that the water inundates a location. Thus only storm surges have introduced a distinct flooding phenomenon termed as tidal flooding. This kind of flood occurs in the tidal flood plains along the coastal areas of the country. The average land elevation of

Bangladesh is about 7.6 meter above MSL, whereas for coastal and offshore islands is about 1.5 meter (approx.) above MSL. For this reason, the major portion of the waterways in Bangladesh coastal region are located under the tidal influence as mapped in the digital elevation model (DEM) used in FFWC [8]. The sea swells to about 1 to 2 meter during monsoon months from June to mid-September. As a result, when the spring tide occurs during monsoon, most of the tidal plains are affected by flooding. The tide along the coast of Bangladesh is of semi-diurnal type. The variation in tidal range is less than 2 meter to about 6 meter, where maximum current velocities vary from approximately 0.1 m $s^{-1}$ to 4 m $s^{-1}$ in tidal channels [7]. During monsoon, wave heights can exceed 2 meter with periods greater than 6 seconds. Higher waves occur mainly during cyclones. Thus, the situation worsens when storm surges occur along with the tropical cyclone.

In order to prevent tidal flooding as well as to provide protection against cyclonic surges, polders are being built all along the tidal estuary in the coastal areas of the country. But, newly accreted lands in the estuary and in the coast are still subjected to tidal flooding. Storm surges accompanied with the severe cyclone still pose threat of breaching the coastal polders endangering lives of people living in the high-risk zones. There are some major entrances through which tidal waves penetrate into the waterways in Bangladesh coastal, such as: Harin Ghata, Tentulia, Shahbazpur, Hatiya River, The Sandwip Channel, etc.

## 5. MITIGATION MEASURES

In the beginning of 2004, on the occasion of the 49th Annual Convention of the Engineers, the prime minister urged the professionals to work out a strategy for containing coastal and estuarine erosion that hinders the national efforts to alleviate poverty for achieving the Millennium Development Goals (MDG). However, at present, Cyclone Preparedness Programme (CPP) of Bangladesh Red Crescent Society with its 35,000 volunteers (including 2,000 female volunteers) has been contributing tremendously to the reduction of damage and loss of lives and properties due to cyclones. Besides, many voluntary organizations working on disaster preparedness and early warning are keeping watch on impending disasters in Bangladesh. The concerted efforts of BMD, Disaster Management Bureau (DMB), CPP and other government and Non-Government Organizations (NGOs) are trying to make warning systems effective to result in reduction of disasters, human casualties and loss of properties. The disaster preparedness work in the coastal zone of Bangladesh should essentially include the improving cyclone warning system [9], developing of cyclone shelters [10, 11] and building and rehabilitating of coastal embankments.

Coastal flood control measures in Bangladesh are mainly limited to building of earthen embankments, polders, and drainages. As a structural measure, a total of 3,433 km of embankments in the coastal areas have been constructed by the BWDB during the last several decades. Surge waves often damage and breach the earthen embankment. This is due to lack of appropriate design. Besides, the measured surge heights do not represent a complete picture of various parameters that are required to design any structural mitigation measures since there is a huge natural force involved with storm surge. Thus, analysis of historical events could be an efficient tool for optimum design.

## 6. RELEVANT FFWC'S ACTIVITIES

FFWC is one of the most important centres for disaster management in Bangladesh under BWDB. It started with 10 real time flood monitoring stations since 1972. Gauge-to-gauge correlation and Muskinghum-Cunje flood routing model were used for forecasting in the order first. At present, MIKE 11 model with GIS and hydrodynamic modelling for river flood simulation is being used at FFWC for flood forecasting at 52 points over the whole country.

In fact, the use of this high technology was the requirement of the project "Consolidation and Strengthening of Flood Forecasting and Warning Services 2000-2004, Bangladesh" between FFWC and Danish Hydraulic institute (DHI). The extended work schedule of the same project included coastal flood forecasting activities in the year 2005-2006. During that period, two-dimensional coastal flood modelling software (MIKE 21) was introduced at FFWC for coastal flood simulation. Digital Elevation Model (DEM), polder location, boundary condition and wind speed are required as input for executing MIKE 21, whereas water level, current and salinity are forecasted. Flood risk map and design information is final output product. For calibrating the setup of this model for Bangladesh coastal region, several previous cyclones were taken into consideration. However, it has yet to reach in the operational level.

## 7. CONCLUSIONS

As tropical cyclones and storm surges are tied to the fate of Bangladesh coastal region along with bounties of natural resources, it is imperative to try to keep the harmfulness of those natural havocs under a reasonable limit. But clearly, the death toll of a cyclone or a storm surge in Bangladesh is always far out-passing that of other countries due to the lack of people's consciousness. On the other hand, since forecasting is important for coexistence, continual measures have to be taken to update it with respect to the modern technology. The following points can be considered in this context:

1. As an average of 74% tropical cyclones as strong as to take away more than 5,000 lives occurred in the Bay of Bengal as mentioned above, the density of population in the coastal region of the country has to be lessened, while the present population rate in the coastal region is almost the same with the rest of the country.
2. Development of a simplified coastal modelling system needs to be installed to reduce the vulnerability of Bangladesh coastal region. High resolution DEM is to be developed for flood risk mapping in the order first.
3. A research centre should be established to conduct a comprehensive study on tropical cyclones and storm surges.
4. Since an effective coastal flood forecasting system depends on the use of both meteorological and hydrological data, a system is to be installed for prompt data transfer between BMD and FFWC.

5. The existing procedure of “Disaster Plan” or the “Cyclone Preparedness Plan” in the coastal districts of Bangladesh needs considerable strengthening. Overall, people’s consciousness level must be improved.

6. The Government has to pioneer tech-transfer in collaboration with development partners. Thus using latest technologies for forecasting has to be ensured.

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# INFLUENCE OF RICE HUSK ASH ON PROPERTIES OF MAGNESIUM OXYCHLORIDE CEMENT

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## ABSTRACT

Compared to Ordinary Portland Cement (OPC) based products, the Magnesium Oxychloride Cement(MOC) based products have many advantages in terms of compressive strength, bending strength, surface hardness, frost resistance, fungi resistance and low thermal shrinkage at high temperatures. Possibility of the production of MOC from sea water bitterns is the great opportunity to reduce $CO_2$ emission from the construction industry. But MOC is not enough water resistance for out door usages. Many efforts have been made to improve water resistance of the MOC products using additives such as ethyl silicate, organic carboxylic acids and water repellents, either by incorporation in the cement mix prior to the setting or by application to the hardened cement. The most effective method is to stabilize MOC by addition of phosphoric acid. But all these additives are expensive. As a cheap additive, rice husk ash(RHA) was used in this study and the effects of rice husk ash on the properties of MOC was examined. The experimental results indicated that the addition of rice husk ash changed flow property, setting times, compressive and flexural strength development, water resistance and frost resistance of MOC. It might be due to the change of dissolution rate of magnesium oxide and chemical reaction between MOC and rice husk ash. Modified MOC containing a significant amount of rice husk ash has a potential to be utilized in the construction industry. MOC modified with RHA is known as RiceStone.

**Key Words:** Ordinary Portland Cement (OPC), Water resistance, frost resistance, Magnesium Oxychloride cement (MOC), Rice husk ash(RHA), compressive strength and RiceStone.

## 1. INTRODUCTION

World production of OPC is over 3,060 million metric tons and each production of cement increasing by 170 million metric tons. Production of $CO_2$ from these cement production is about equal to the total amount of cement produced[1]. So research on alternative environment friendly cement is very essential. French engineer Stanislas Sorel in 1867 announced the discovery of an excellent cement. This cement type is known by many different names, such as Sorel, magnesite and magnesium oxychloride cement(MOC)[2]. This cement has has many superior properties compared to Portland cement. It does not need wet curing, has high fire resistance, low thermal conductivity, good resistance to abrasion

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surface hardness, frost resistance, fungi resistance and low thermal shrinkage at high temperatures. It also has high transverse and crushing strengths, 7,000-10,000 psi are not uncommon[3]. Magnesium oxychloride also bonds very well to a variety of inorganic and organic aggregates, such as, saw dust, wood flour, marble flour, sand and gravel, giving cement that has high early strength, resilient, conducting and is unaffected by oil, grease and paints[4]. MOC is a type of hydraulic cement formed by mixing proper ratio of caustic calcined MgO powder and $MgCl_2$ solution. Four major crystalline phases are defined for MOC according to molar ratio of $Mg(OH)_2$ to $MgCl_2$ in the chemical composition: $2Mg(OH)_2.MgCl_2.4H_2O$ (P2), $3Mg(OH)_2.MgCl_2.8H_2O$ (P3), $5Mg(OH)_2.MgCl_2.8H_2O$ (P5), and $9Mg(OH)_2.MgCl_2.H_2O$ (P9) However, at room temperature stable phases are only P3 and P5 other two phases are found at higher temperature. High concentrations of MgO ($MgO/MgCl_2$ greater than 5) in the cement paste favours formation of P5 phase, on the other hand, low MgO concentrations leads to the formation of F3 phase[5, 10]. In addition to $MgO/MgCl_2$ molar ratio, $MgO/H_2O$ ratio is an important aspect for mechanical and chemical properties. Low water content is favourable for strength and durability of the pastes[6]. However; the minimum amount of water is limited by workability of the paste. Thus, MOC pastes with high MgO and low water content are desirable. Hardened magnesium oxychloride cement is susceptible to carbonation by $CO_2$ in air. In this process the 3-phase gradually converts into a basic water insoluble magnesium chlorocarbonate hydrate phase, E.g-1[7].

$$3.Mg(OH)_2.MgCl_2.8H_2O + 2CO_2 \rightarrow Mg(OH)_2.2MgCO_3.MgCl_2.6H_2O + 4H_2O \text{..................} (1)$$

Carbonation of 5-phase is also occur but it is much slower. Carbonation may be cause of crack formation in hardened concrete. Although it has high compressive strength and good bonding with others substances, it deteriorates significantly under moist climate due to the leaching of magnesium chloride[8]. Many efforts have been made to improve water resistance of the MOC products using additives such as ethyl silicate, organic carboxylic acids, water soluble phosphate, copper powder and water repellents, either by incorporation in the cement mix prior to the setting or by application to the hardened cement. Among these additives water soluble phosphate showed best result[9]. However, the utilization of these additives increases the cost of MOC based products. Therefore, using waste materials to improve the water resistance and reduce the cost of MOC should be further investigated. In this paper, the effect of rice husk ash(RHA) on properties of MOC was studied. Its flow property, setting times, compressive strength development, water resistance and frost resistance property were examined.

## 2. METHODOLOGY

### 2.1. Materials

The raw materials used in the study were caustic calcined magnesium oxide, magnesium chloride, Rice Husk Ash and Jute fiber.

### 2.1.1. Caustic Calcined Magnesium Oxide

Caustic Calcined magnesium oxide, passing 98.99% (minimum) through 200 mesh sieves, having magnesium oxide (MgO), per cent by mass 85 (minimum), calcium oxide (CaO), per cent by mass 1.5 (maximum), Silicon dioxide ($SiO_2$), per cent by mass 8 (maximum), Alumina($Al_2O_3$), per cent by mass 0.25 (maximum), Ferric Oxide($Fe_2O_3$), per cent by mass 0.25 (maximum), loss on ignition ($CO_2$ and $H_2O$), per cent by mass 2.5 (maximum), and total contents of MgO, CaO, $Al_2O_3$, $SiO_2$ , $Fe_2O_3$ and loss on ignition, per cent by mass 99.2 (minimum) was used.

### 2.1.2. Magnesium Chloride

Magnesium chloride, having magnesium chloride as its hexahydrate form ($MgCl_2.6H_2O$) per cent by mass 99.61(minimum), Magnesium Sulphate ($MgSO_4$) per cent by mass 0.08(maximum), calcium Oxide (CaO) per cent by mass 0.02 (maximum) and Sodium chlorides (NaCl) per cent by mass 0.09 (maximum) was used.

### 2.1.3. Rice Husk Ash

Rice husk ash having, Silicon dioxide ($SiO_2$), per cent by mass 94.7(minimum) magnesium oxide (MgO), per cent by mass 0.8 (maximum), calcium oxide (CaO), per cent by mass 0.8 (maximum), , Alumina($Al_2O_3$), per cent by mass 0.7 (maximum), Ferric Oxide($Fe_2O_3$), per cent by mass 0.3 (maximum), and loss on ignition ($CO_2$ and $H_2O$), per cent by mass 0.7 (maximum) was used.

### 2.1.4. Jute Fiber

Two centimetre long fiber of white jute (*Corchorus capsularis*) was used in all formula as MCC Bangladesh was trying to develop jute cement composite. Jute fiber was collected from local market.

## 2.2. Methods

### 2.2.1. Preparation of Magnesium Chloride Solution

Magnesium chloride solution was prepared in water. Flakes of magnesium chloride hexahydrate was transferred into plastic container to which potable water was added to prepare concentrated solution. This solution was allowed to stand overnight so that insoluble impurities settle at the bottom. The supernatant concentrated solution was taken out in other plastic containers. Concentration of the solution is determined in terms of specific gravity on Baume scale (°Be)(ASTM designation C 250-52 for MOC cement). Temperature correction of Baume scale was done during measuring of the concentration of the magnesium chloride solution.

### 2.2.2. Specimens Preparation

The effect of MOC with rice husk ash on fluidity, setting times, water resistance and frost resistance were studied by incorporating rice husk ash ranging from 0% to 100% by weight of magnesium oxide.

Table 1: Formulas of specimens

| Name | MgO(g) | RHA(g) | Jute(g) | $MgCl_2$ |
|---|---|---|---|---|
| MOC | 100 | 0 | 2.5 | 23°Be |
| RS-10 | 100 | 10 | 2.5 | 23°Be |
| RS-20 | 100 | 20 | 2.5 | 23°Be |
| RS-30 | 100 | 30 | 2.5 | 23°Be |
| RS-40 | 100 | 40 | 2.5 | 23°Be |
| RS-50 | 100 | 50 | 2.5 | 23°Be |
| RS-100 | 100 | 100 | 2.5 | 23°Be |

Two centimetres long jute fiber was used in all specimens 2.5 % by weight of magnesium oxide as MCC Bangladesh was focused to develop jute fiber cement. Total six different RiceStone formulas(RS-10 to RS-100) with one control (MOC) were used for this experiment. There were two types of sample; cubes sample for compressive strength(ASTM designation C 257-52 for MOC cement) and bar samples for flexural strength testing(ASTM designation C 256-52 for MOC cement). Mixing of ingredients was an important part of this experiment. At first all dry ingredients, magnesium oxide powder, RHA and Two centimetre long jute fiber were mixed properly. Then the solution of magnesium was added to that dry mixture and mixed properly according to ASTM designation C 251-52 for MOC cement. The cement pastes were immediately poured in the molds. All samples were removed from the molds after 12 hours curing

### 2.2.3. Fluidity and Setting Time of Cement Pastes

Fresh wet mixture of cement pastes of all different formulas were tested for fluidity and setting times. Fluidity was measured in term of slump height by slump cone according to ASTM designation C 249-52 for MOC cement and the setting times was measured in term of initial and final setting time by Westvaco Needles according to ASTM designation C 254-52 for MOC cement.

### 2.2.4. Compressive and Flexural strength testing

Compressive strength of all cube specimens were determined my hydraulic compressive strength tester according to the guidance of ASTM designation C 257-52 for MOC cement and Flexural strength of all bar specimens were determined by hydraulic flexural strength tester according to the guidance of ASTM designation C 256-52 for MOC cement. Compressive and flexural strength were at 42 days of curing in different conditions.

### 2.2.5. Water and frost Resistance of Specimens

Water resistance and frost resistance were measured in terms of Strength Retention Coefficient (SRC). All samples were first cured in air for 14 days. Watering is not essential for MOC and RiceStone . Then one-third sample was kept for air curing, another one-third was kept in water for 28 days and final one-third was used for 28 alternative freezing and thawing cycle. One freezing–thawing cycle comprised of freezing the specimen at – 18 ± 2 ° C for 6 h in an environmental chamber and thawing in water at 27 ± ° C for 18 h. After 42 days, compressive and flexural strength of all specimens were measured. Strength retention coefficient (SRC) was determined by the equation (E.g)-2:

$$SRC = S_{28}/S..................(2)$$

Where R28 is the strength of specimen immersing in distilled water for 28 days or the strength of specimen after 28 freeze-thaw cycles and S is the strength of specimen curing in air for 42 days.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Fluidity of Cement Pastes

The results of the fluidity tests are shown in Figure 1 indicated that the fluidity of MOC mortar increased as the rice husk ash content increased. This might be attributed to the decrease of water demand because of the amorphous silica of RHA that reduce the stickiness nature of MOC.

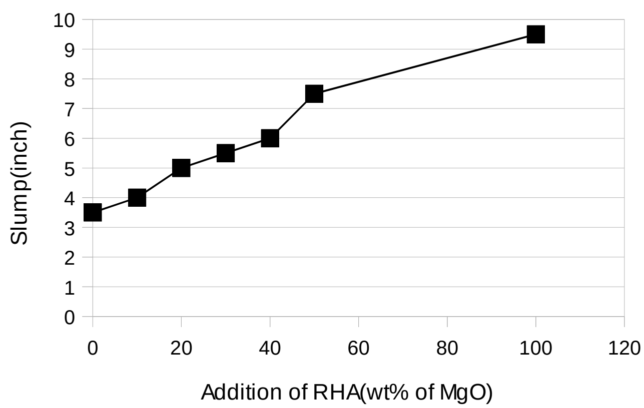


Fig 1 : Effect of dosages of RHA on fluidity of MOC and RiceStone pastes

### 3.2. Setting Time of Cement pastes

Figure 2 showed both the initial and final setting times of MOC and RiceStone cement pastes. A larger amount of RHA retarded the setting process. Since the initial set of MOC was characterized as formation of amorphous gel phases between magnesium oxide and magnesium chloride solutions, the utilization of fly ash may yield the retardation of the formation of amorphous gel of MOC through dilution effect.

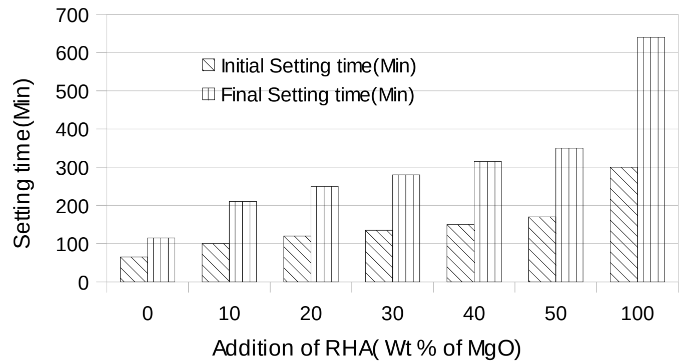


Fig 2 : Effect of dosages of RHA on setting times of MOC and RiceStone cement

### 3.3. Effect of RHA on the Strength of MOC cement

Figure 3 showed both the compressive and flexural strength of MOC and RiceStone cement specimens. It indicated that the both compressive and flexural strength of MOC and RiceStone cement specimens decreased as the rice husk ash content increased.

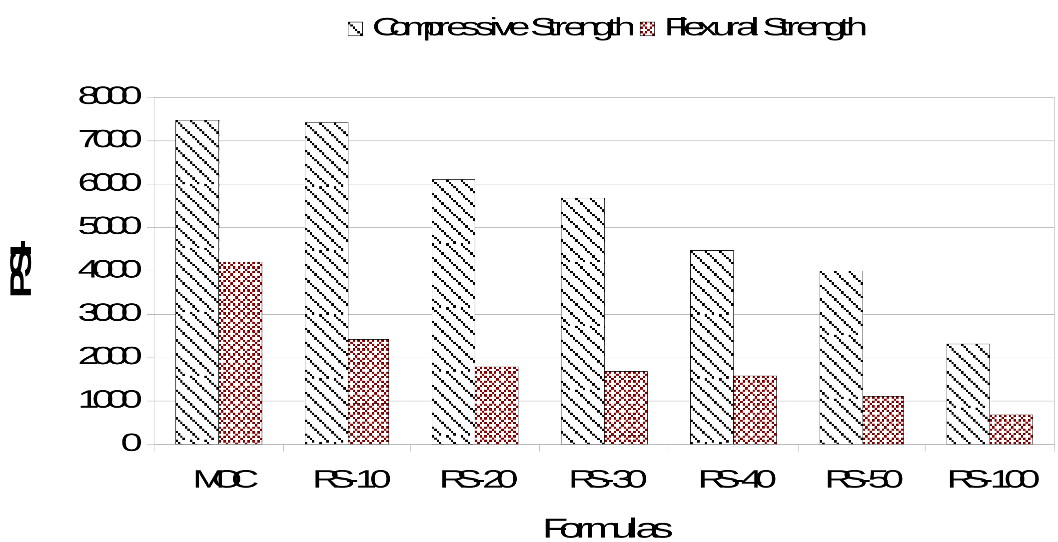


Fig 3 : Compressive and Flexural Strength of MOC and RiceStone

### 3.4. Water Resistance of Specimens

The results of water-resistance tests in Figure 4 revealed that the strength retention coefficients of the RiceStone were greatly increased with the increase of the RHA dosage both for compressive and flexural strength.

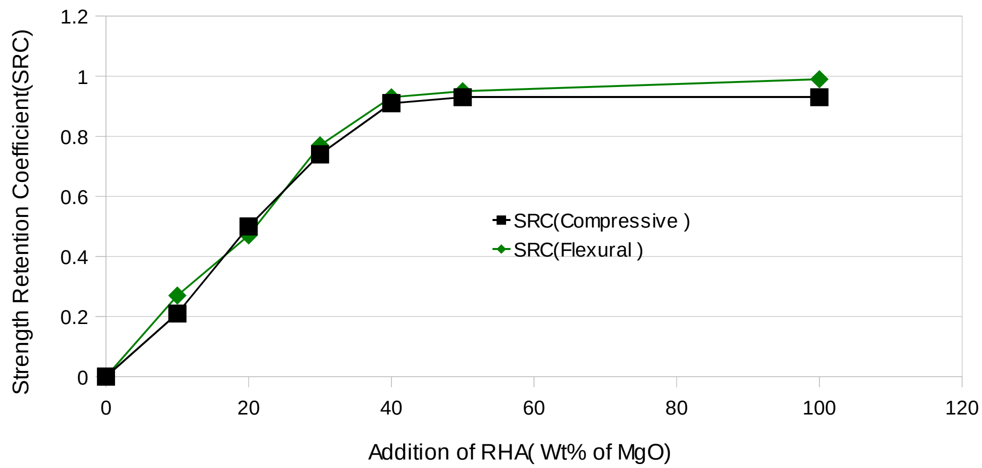


Fig 4:
SRC of MOC and RiceStone with different RHA Loading for water-resistance testing

### 3.5. Frost Resistance of Specimens

The results of frost resistance tests in Figure 5 revealed that the strength retention coefficients of the RiceStone were greatly increased with the increase of the RHA dosage both for compressive and flexural strength.

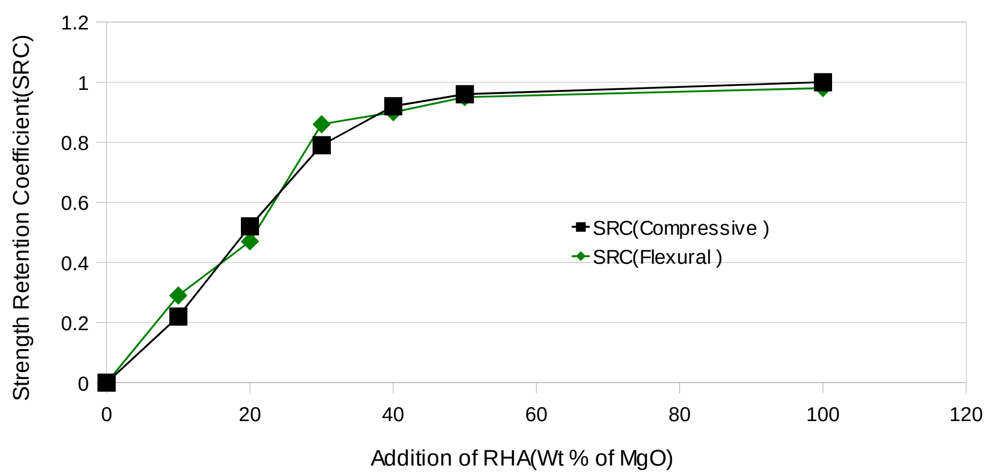


Fig 5: SRC of MOC and RiceStone with different RHA Loading for freeze-thaw testing

### 4. CONCLUSIONS

In a short term periods influence of RHA on the properties of MOC cement was impressive. RHA improved water-resistance, frost-resistance properties of MOC cement. It might be due to the change of dissolution rate of magnesium oxide and chemical reaction between MOC and rice husk ash. But future investigation is needed for long term testing. Determination of microstructure of MOC-RHA system is also essential in future investigation. Future investigation for production of MgO and $MgCl_2$ from sea water bittern is also essential for producing alternative green cement.

## 5. ACKNOWLEDGEMENT

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# PRODUCTION OF CEMENTITIOUS MATERIALS FROM SEA WATER BITTERNS: A FEASIBILITY STUDY

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## ABSTRACT

The technical feasibility of producing magnesium oxychloride cement, or Sorel cement, from salt farming bitterns has been shown with this work. Previous MCC work developed RiceStone, a magnesium oxychloride cement incorporating rice husk ash to improve water resistance, as a green alternative to ordinary Portland cement. To evaluate the feasibility of RiceStone as a locally produced, low $CO_2$-impact alternative, the magnesium oxide production process has been studied. Magnesium oxide, typically produced by roasting magnesium carbonate, is the main contributor to the energy and carbon dioxide footprint of Sorel cement or RiceStone.

The objective of this study was to develop a material and energy balance for the process to produce magnesium oxychloride cement starting with seawater bitterns. The experimental work at MCC Bangladesh's Sustainable Technology Research Center in Bogra used drum quantities of seawater bitterns from salt farming near Cox's Bazaar. The process involved three processing steps: (1) bitterns concentration and purification, (2) solidification and drying of concentrated magnesium chloride, and (3) high temperature roasting to produce the magnesium oxide product. Pilot scale equipment was custom designed and built to achieve the desired range of operating conditions for the experimental runs. Several kilograms of magnesium oxide were produced from bitterns for product property testing, but the main objective was to develop a material and energy balance. Essential to achieving these goals, and managing the process, was the use of ion chromatography (IC) to speciate both cations and anions. The complexities of high concentration (high ionic strength) precipitation and the role of crystallization kinetics required on-site analytical capability that the IC provided.

The material balance highlights the large unit ratio production of byproducts of potential economic value (magnesium sulfate, Epsom salts, and hydrochloric acid, 20% aqueous). An energy balance was calculated based on thermo-chemistry and engineering estimates of thermal efficiency of commercial equipment. Energy balance results indicate that the overall energy and $CO_2$ profile of the MCC process would depends greatly on the degree of energy recovery used. With a regenerative bed system for the calcining operation, the $CO_2$ emissions could be reduced to about half that of standard Portland cement production, but energy consumption would still be high.

**Key Words:** Sorel cement, RiceStone, Seawater Bitterns, Energy balance, Carbon dioxide

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## 1. INTRODUCTION

Worldwide production of ordinary Portland cement (OPC) is approximately 3,300 million metric tons (2010 estimate, [1]), and is increasing rapidly. It is evident that this continued growth of OPC production has a serious impact on energy, resources, and environmental pollution. While there is scope for incremental improvements in the production of OPC, much larger environmental gains could be achieved by alternative, environmentally friendly cement materials. One of the alternative cements that has been examined in this regard is magnesium oxychloride cement (MOC), also known as Sorel cement. MOC is a mixture of light burned magnesium oxide (MgO) with concentrated solution of magnesium chloride ($MgCl_2$) that was discovered by French engineer Stanislas Sorel in 1867 [2]. Compared to OPC, Sorel cement has many superior properties: no need wet curing, high fire resistance, low thermal conductivity, good resistance to abrasion, high surface hardness, frost resistance, fungi resistance, and low thermal shrinkage at high temperatures [3].

Analysis of the environmental impact of cements has focused on energy consumption and carbon dioxide emissions. When considering the energy consumption and $CO_2$ emissions of MOC as compared to OPC, it is the MgO component that dominates the analysis. Conventional production of MgO by calcining magnesium carbonate ($MgCO_3$) requires more energy than production of OPC. Production by the conventional calcining processes requires 7.1 MJ per kg MgO, and 5.3 MJ per kg OPC; the associated $CO_2$ emissions are 1.8 kg per kg MgO, and 1.0 kg per kg OPC [4]. Mining of $MgCO_3$ is also limited to a few countries, such as China, USA, and India. For MOC to be an environmentally friendly alternative to OPC, it is critical to have an alternative locally available, green source of MgO.

Seawater bitterns are a rich source of magnesium salt, especially $MgCl_2$. Recovery of $MgCl_2$ from sea water bitterns or brine is possible [5], as is production of MgO from $MgCl_2$. Dead Sea Periclase Ltd (Israel) utilizes the Aman process for producing high purity magnesium oxide from magnesium chloride obtaining from Dead Sea [6]. Many production processes are also developed for producing magnesium directly from seawater, bitterns, or brine. Among these, the Dow seawater process is the best known and most widely used [7]. So it is not impossible to produce these cementitious chemicals from sea water bitterns.

MCC Bangladesh has worked on developing a type of MOC cement, RiceStone, that includes an agricultural waste, rice husk ash, to improve its properties. In considering potential sources of MgO for RiceStone production, the above commercial processes were examined: however, the Aman process requires a very large energy input for pyrolysis of $MgCl_2$ into MgO, and the Dow seawater process requires lime for precipitation of $MgCl_2$ into $Mg(OH)_2$. U.S. Patent (4370422) proposes a process which comprises: (a) adding $Mg(OH)_2$ or calcined magnesite to a brine or bittern as a source of MgO, in such amount that the molar ratio of MgO to $MgCl_2$ is in the range of 0.66:1 to 0.066:1; (b) keeping the mixture at a temperature below 90ºC until a solid mass is formed; (c) drying the solid mass at temperature up to 200ºC; and (d) calcining the solid mass at maximum temperature. By this route a product of MgO was obtained and was analyzed to have purity minimum 98% MgO, but it was an energy intensive and time consuming process [8]. Seawater bitterns not only contain $MgCl_2$

but also $MgSO_2$ and decomposition of $MgSO_4$ into MgO requires higher temperature than decomposition of $MgCl_2$. The MCC process of producing magnesium oxide from seawater bittern tried to solve all these problems to produce environment friendly cementitious materials, and other chemicals as byproducts. This effort also involved calculating the energy and material and energy balance of the whole process, and determining optimum temperature for producing MgO by de-hydro-chlorination reaction.

## 2. BACKGROUND

The Aman spray pyrolysis, or roasting, process is practiced today recovering magnesium hydroxide from Dead Sea brine. The magnesium oxide product requires high purity and low levels of sodium chloride and iron. The primary products from this process are high purity magnesium oxide, industrial refractory, and magnesium hydroxide for nutritional additives.

Figure 1 shows a block diagram of the process, based on the Aman patent [9] and information available on the web. In this process, concentrated feed solution rich in magnesium chloride is added to the concentrator unit to further dehydrate and preheat with hot reactor exhaust gas. This unit operation increases the thermal efficiency of the unit and scrubs any entrained solids from the reactor. The scrubber liquid is highly concentrated magnesium chloride and contains dissolved hydrogen chloride, which results in an extremely corrosive solution. The gas from the concentrator passes to a hydrogen chloride absorber that recovers 10% hydrogen chloride in water. The reactor is a direct fired vessel with counter current flow of combustion gas and spray droplets which are fit at the top of the vessel (Figure 2). The reacted solid product exits the bottom of the reactor into a quench liquid where soluble salts (chlorides and sulfates) are dissolved and magnesium oxide reacts with water to form insoluble magnesium hydroxide. A gravity thickener concentrates the hydroxide. Filtration washing removes the last traces of soluble salts resulting in a solid magnesium hydroxide, which is calcined (500°C) to produce magnesium oxide.

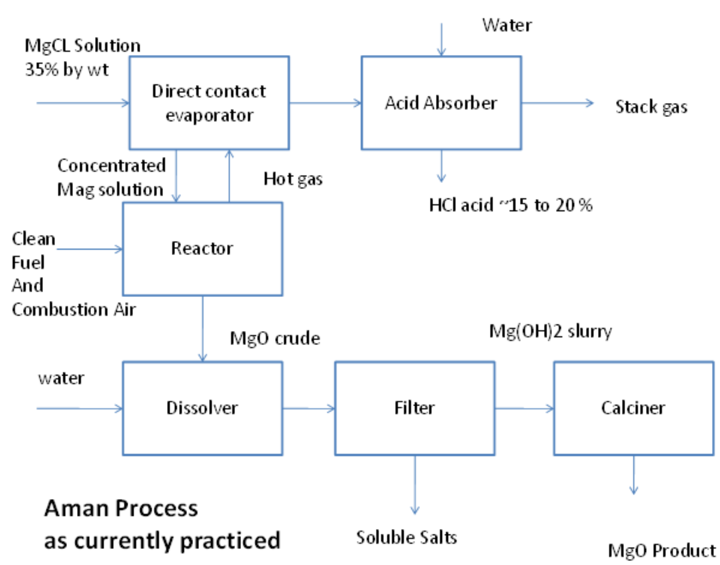


Figure 1. Block diagram of the Aman process.

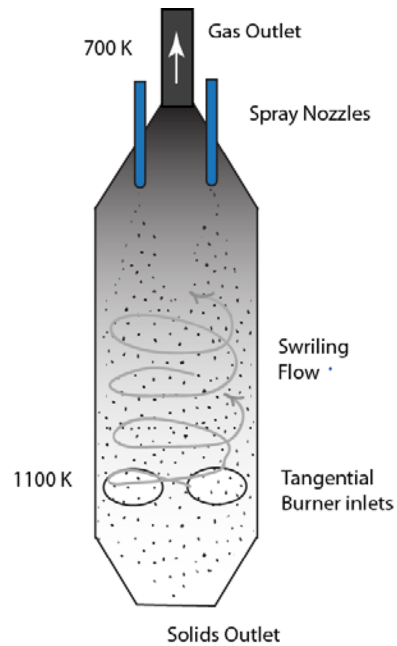


Figure 2. Schematic of Aman process reactor

The pre-feasibility analysis concluded this process had several major deficiencies and an alternative process requiring less corrosion resistant materials would be advantageous. The process concept that evolved is shown in Figure 3 as a block diagram. This includes the important concentration step. Commercial application of this technology was expected to utilize solar energy as the primary energy source for the brine concentration and solids drying steps. The key features of this process include using a small amount of magnesium oxide product to solidify the magnesium chloride concentrated solution and to conventional low-temperature drying to remove much of the water reducing the thermal load on the high temperature pyrolysis. The high temperature pyrolysis operation could be achieved in conventional furnaces. In addition, the dry solidified material could be readily stored and transported.

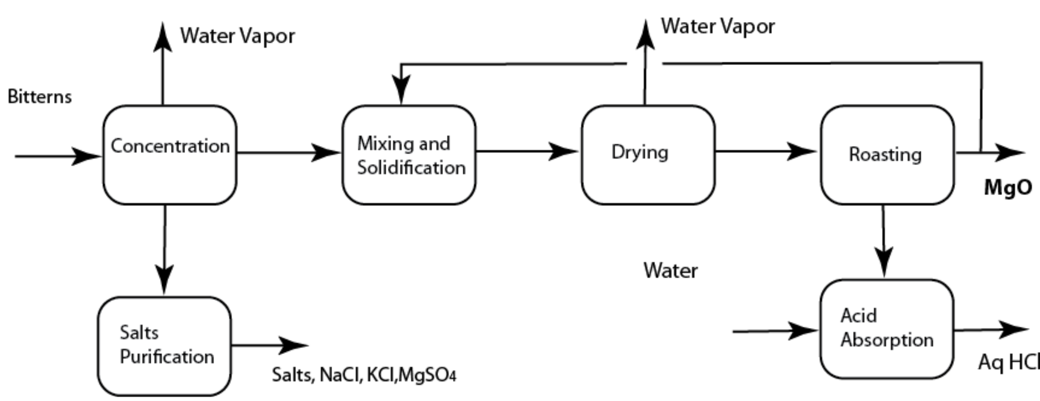


Figure 3. Block Diagram of MCC process

### 2.1 Chemistry

The overall chemistry of the de-chlorination process is shown in Equation 1; however this is an oversimplification [10]. Magnesium chloride forms several hydrated crystalline forms, for example dihydrate through hexahydrate. The thermo chemistry of the dehydration has been thoroughly studied [10], and begins at the modest temperature 60°C. Dehydration of the dihydrate form also dehydrochlorinates the $MgCl_2$; consequently, control of the solids drying temperature is critical.

$$MgCl_2 + H_2O \longrightarrow MgO + 2HCl \tag{1}$$

## 3. EXPERIMENTAL PROGRAM

The primary objectives of the feasibility pilot work was to identify the conditions necessary for the high temperature process, confirm the decision to eliminate the desulfating step, and demonstrate the overall feasibility of using commercial seawater bitterns from salt farming. The bitterns concentration portion of the program was only designed to obtain the concentrated material, not to optimise this portion of the process. It was designed to obtain sufficient information to develop a material and energy balance to allow evaluation of a commercial scale facility.

### 3.1 Analytical

Ion chromatography methodology was uses to determine both anions and cations in the process streams, including Na, K, Mg, Cl, and $SO_4$. A Dionex ion chromatograph [11] allows either anions or cations to the quantified with the use of a specialized micro sized ion exchange column and the appropriate aqueous solution, or eluent. Standard methodology for identifying peaks and using known reagent materials to calibrate the area response factors to quantify the plan. Because the samples are concentrated, high dilution factors are required to achieve effective analysis.

### 3.2 Process Equipment

The bitterns concentration was accomplished an open top 100-liter metal container with direct heat from a combustion gas burner below. Crystallized salt was removed by filtration with a fine mesh metal screen. Upon cooling, additional salts were moved in a similar manner. The solidification of the concentrated bitterns was accomplished using a mechanical agitator and a 100-liter vessel. The solids were dried in a direct heated low-temperature drying oven convection.

The batch high temperature roasting oven was heated with a fuel oil burner and equipped with a scrubber for the acid exhaust gases, as shown in Figure 4. The temperature in the oven was monitored with a sight port and a hand-held optical pyrometer. The hot gases were drawn through the quench and assess acid absorber by a blower at the exit of the acid absorber. This configuration provided a reduced pressure in the oven and column. The acid absorber was critical to capture HCl produced in the reaction.

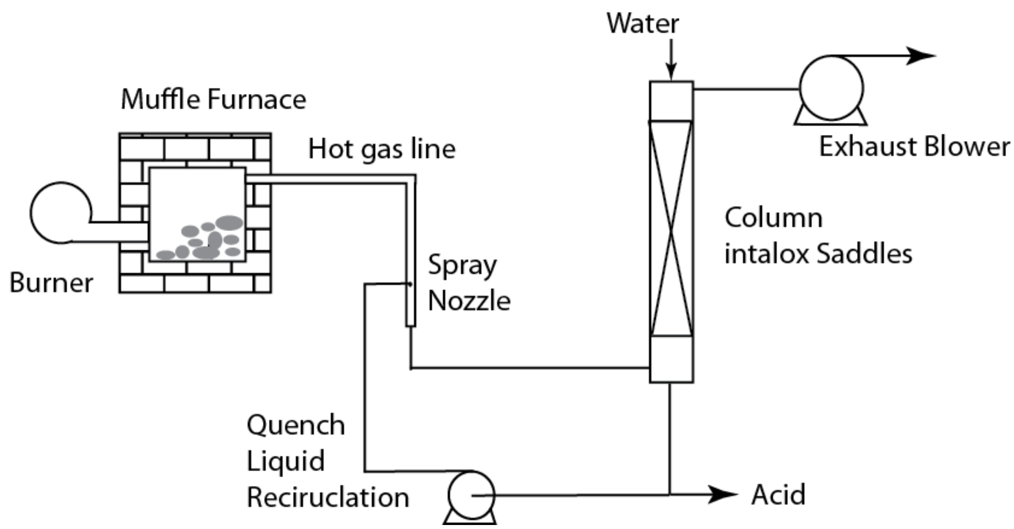


Figure 4. Schematic of reactor system

## 4. RESULTS

This narrative describes the qualitative results from three concentration runs and six roasting runs, which were completed in the 3-week experimental period. These experiments were the base for the following analysis, containing the material and energy balance which quantitatively describes the MCC process.

### 4.1 Bitterns Concentration

Boiling down the bitterns to concentrate by 50% resulted in significant amounts of salts precipitation in the hot solution. After settling this material, the clear liquid was collected and cooled to ambient temperature. Additional crystallization occurred, forming long needle-like crystals, which analysed to the magnesium sulfate (the hexahydrate form is Epsom salts). Some materials such as sodium chloride have solubility which is insensitive to temperature, while other materials such as magnesium sulfate are much more soluble at higher temperatures. This difference can be utilized to separate the sulfate and to recover a valuable by-product Epson salts.

### 4.2 Magnesium Chloride Solidification

Heated magnesium chloride solution was mixed with a small amount of MgO (0.1 molar ratio) and allowed to slowly solidify. The solid readily dispersed in the concentrated solution and the viscosity increased slowly over a period of 30 minutes with mild mixing. An addition hour is required for the setting to complete, but the solid was easily cut in to pieces for drying.

### 4.3 Solids Drying

The solids were dried in a gas heated convection oven with the temperature controlled to stay below 90°C. The drying time in the convention oven was approximately 12 hours, with trays used to allow air movement. The dried product was porous and slightly hygroscopic. Consequently, this material was stored in polyethylene bags to avoid water absorption.

### 4.4 Calcining

This is the pivotal step of the operation, requiring the greatest amount of energy and the most complex equipment design in the process. The objective was to determine the minimum temperature for a complete reaction. The initial lower temperature runs showed incomplete conversion of the layers of solid below the surface. In addition, the small furnace showed significant differences in heat flux in different portions. The higher temperature runs (850 - 900°C range) showed the best performance, as measured by the conversion of the chloride to oxide. The reaction time appeared to be limited by heat transfer, requiring several hours of residence time to complete the reaction.

### 4.5 Gas Quench

The circulated spray gas quench achieved the desired process results, only being limited by physical constraints of the operation.

### 4.6 Acid Absorption

The acid absorption system was designed to achieve high degrees of acid absorption. However the chloride material balance only accounted for 60% of the chloride in the acid stream and the product.

## 5. ANALYSIS OF EXPERIMENTS

The experimental work generated a significant amount of analytical and process information that was combined with thermodynamic information on the reaction and overall stoichiometry to produce the material and energy balance. The values for thermal efficiency of solar collection systems, from published guidelines [12], and high temperature furnaces, based on experience, were incorporated into the analysis. Reasonable thermal efficiencies provided significant guidance, especially on the high temperature reactor.

### 5.1 Unit Ratios

The overall material balance and chemical species balance resulted in the calculation of unit ratios for raw materials and by-products, Table 1. The unit ratio is defined as mass ratio of a raw material or by-product per mass of primary product. This analysis accounts, within the process bounds, for the recycle of magnesium oxide in the solidification process.

The unit ratios of the salt cake (composed of sodium chloride and potassium chloride) and hydrogen chloride are greater than 1, and the unit ratio of Epson salts is close to 1. This indicates large amounts of co-products will be produced, and these would need to be marketed to make the process cost-effective.

Table 1. Unit ratios

| Material | Unit ratio (kg/kg MgO) |
|---|---|
| Bitterns | 37.34 |
| Salt cake | 5.85 |
| Epson Salts | 0.8 |
| Hydrogen Chloride (pure) | 1.52 |
| Magnesium Oxide | 1.00 |

### 5.2 Energy Inputs

The overall energy requirements for the process, segmented by the temperature and suggested energy source, are described in Table 2. The use of solar energy especially for the bitterns concentration would require a significant amount of land area for solar concentrator collectors. This concentration step is at a lower temperature, 60°C, while the solids drying is at a higher temperature, 120°C. The furnace for calcining would be expected to operate at 900°C where the only cost-effective approach is to utilize fossil fuel in the form of natural gas. Even with the use of fossil fuel the energy requirement without stringent heat recovery results in extremely high energy cost.

The technology of choice for the calcining operation is a rotary multiple hearth furnace, which is the standard technology for calcining magnesium carbonate to produce magnesium oxide. This technology allows for control of the solids residence time and precise control of maximum temperature. The counter current gas flow makes good advantage of the thermal energy, yet without external heat recovery, the thermal efficiency would remain at 30% for large-scale commercial equipment. Using a regenerative bed system, this thermal energy profile could be increased to greater than 85%. The regenerative system also provides a system capable of handling slightly corrosive gas that may contain particulate matter. The added complexity is not desirable, but the added energy efficiency makes this effort essential for large scale operation.

Table 3 summarizes the energy requirements and carbon dioxide production for the MCC process, and compares it with analysis of commercial OPC production [13] and MOC by standard $MgCO_3$ calcination [4]. Without a regenerative process, this process has an adverse $CO_2$ footprint compared with OPC.

Table 2. Energy Requirements for process and sourcing

| Step | Temperature (°C) | Minimum energy (MJ/kg MgO) | Thermal efficiency | Solar efficiency | Energy requirements (MJ/kg) |
|---|---|---|---|---|---|
| Concentration | 65 | 72.5 | 90% | 60% | 134. 3 |
| Drying | 100 | 6.6 | 70% | 40% | 23.57 |
| Drying high temp | 130 | 23.6 | 70% | 35% | 96.3 |
| Calcining | 850 | 6.9 | 85% | NA | 8.12 |

Table 3. Summary of energy requirements and Carbon dioxide production

| Item | Energy Consumption (MJ/kg) | $CO_2$ production (kg/kg) |
|---|---|---|
| Ordinary Portland cement [13] | 5.2 | 1.04 |
| MgO from $MgCO_3$ [4] | 7.1 | 1.75 |
| MgO from bitterns | 87.1 | 3.04 |
| MgO from bitterns - with energy recovery | 9.88 | 0.45 |

## 6. CONCLUSIONS

The MCC process to recover magnesium oxide from seawater bitterns has been technically demonstrated and can compete effectively, from the energy and carbon dioxide emissions standpoint, with ordinary Portland cement. Identifying usage and markets for the co-products is critical to justify the land area requirement for bitterns concentration. The seawater bitterns are a valuable resource produced from salt farming. Optimizing and fine tuning the process will require construction of a demonstration and research facility.

## 7. ACKNOWLEDGEMENT

Larry Alderfer Fisher, former Mennonite Central Committee, Bangladesh Country Representative, provided guidance and support for this project. We also acknowledge the support of the Bogra office MCC staff for the work of building and acquiring the equipment required. We acknowledge technical support from Chris Christenson, Dennis Jewell, and Cliff Wilson, who provided significant guidance regarding the complex inorganic chemistry involved in this development activity. We acknowledge the generous contribution of the ion chromatograph by the Dow Chemical company.

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# SEISMIC VULNERABILITY ASSESSMENT OF EXISTING CRITICAL BUILDINGS IN RANGAMATI, KHAGRACHARI AND BANDARBAN MUNICIPALITY AREA

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## ABSTRACT

Chittagong Hill Tract (CHT) is consists of Rangamati, Bandarban and Khagrachari districts. According to the experts CHT area is under threat of a moderate to strong earthquake in near future. Structural vulnerability assessment in any earthquake porn city area is important to identify the risky buildings as well as to estimate the probable damage of the buildings in the area. In this study structural and non structural vulnerability of 152 selected critical buildings and structures have assessed to find the risk of damage of each building in Rangamati, Bandarban and Kharachari municipalities. The selection of the buildings and infrastructures were based on the type of building, occupancy of the building, importance of use, purpose of use, importance of existence during disaster i.e earthquake etc. The study concentrated on only Reinforced Cement (RC) type buildings because this type of building is more vulnerable and cause more losses than the others. As most of the RC type buildings are within the municipality area the study area was limited to three municipality area of CHT. Side walk and questionnaire survey was carried out using FEMA 310 checklist to identify the vulnerability of each 152 buildings separately. Various engineering and non engineering vulnerability factor and corresponding vulnerability weighted factor like soft storey, heavy overhang, short column, pounding possibility between adjacent buildings, visible ground settlement, plan irregularity, elevation irregularity, tall narrow content, URM parapet, cladding anchores etc have considered to find the damage risk of each individual buildings. It was found in the study that maximum buildings in Rangamati and Bandarban are 2 storey which is about 64% and 47% of the total building where as 50% of the total building in Khagarcahri are 3 storey. Study shows that 67%, 65% and 80% of the total building in Rangamati, Bandarban and Khagarcahri municipality had building on slope land, short column and heavy overhang vulnerability respectively. It was also found in the study that in Rangamati and Bandarban municipality around 21% and 7% buildings have severe/ collapse damage risk respectively and 5% building in Khagrachari municipality have high damage risk if a moderate to strong earthquake strike in this area. Increasing structural strength by retrofitting technique or demolition is the option for the buildings with severe and high risk of damage. Local municipality is the authority need take the necessary action through having dialogue with the building owner as soon as possible to reduce the probable damage of three municipalities.

**Keywords:** Reinforced Cement building, FEMA 310 checklist, Seismic Vulnerability, Risk

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## 1. INTRODUCTION

Experts and geologists say that Bangladesh is situated in the active plate collision zone and hence is very much vulnerable to large earthquakes. Over the last few years several number of moderate intensity earthquake have occurred in CHT area. The Bandarban earthquake of magnitude 6.1 on 21 Nov. 1997, the Borkal earthquake in Rangamati with magnitude of 4.8 on 26 July 2003, the Ruma earthquake in Banderban of magnitude 5.2 on 11 July 2007 and 3.2 magnitude earthquakes in Rangamati on August 23, 2008 are the most remarkable recent earthquake in the Chittagong Hill Tract region. According to GSHAP data, Bangladesh lies in a region with low to high seismic hazard that increases in the northern and eastern parts of the country. GSHAP Hazard map indicate the CHT area as highly earthquake hazard zone. A recent major earthquake in the CHT region has occurred near the Bangladesh – India border in Borkal upazilla of Rangamati district on 26$^{th}$ July, 2003 with a magnitude of 5.7 was felt at many places in south eastern part of Bangladesh at 05:18 AM caused damage to property and 3 notable deaths. The Union Parishad building collapsed in Borkal. 18 buildings were damaged in the Langadu area. The residential buildings of TNO (Thana Nirbahi Officer) and Upazila Chairman, upazila Krishi office, Krishi Bank, Post office, food godown, police station and a building of Rabeta Al Islami were among the structure that were damaged. Throughout the region nearly 500 buildings were damaged, 3 people were killed and 25 injured by this earthquake. Two women were killed when a mud house collapsed in the town of Rangamati. Chittagong Hill Tract area is consists of three district name Rangamati, Banderban and Khagarchari. As there's a huge possibility of happening a major earthquake within the CHT area in very near future, it is very much important to identify the seismic vulnerability of buildings in these area and to find the probable extent of damage. In this study an attempt has been taken to find the seismic vulnerability factors of the buildings in Rangamati, Bandarban and Khagrachari municipalities as well as to provide estimation on the risk of damage of these building if a moderate earthquake strikes the area. This study will give a pictorial view of the present seismic vulnerability and subsequent damage risk of the existing buildings which will help the authority i.e. municipality to prepare a better planning to face the disaster like earthquake.

## 2. OBJECTIVE OF THE STUDY

The prime objective of this study is to

1. Identify the seismic vulnerability factors of selected 152 major critical buildings of Rangamati, Khagrachari and Bandarban Municipality area.
2. Estimate the probability of damage of each selected building in each municipality.
3. Provide guidelines to municipality authority on the proper management of these vulnerable critical buildings to reduce the earthquake induced damages and losses.

## 3. METHODOLOGY OF THE STUDY

In this study 152 major critical buildings and infrastructure of Khagrachari, Rangamati and Banderban municipality of Chittagong Hill Tract were identified, surveyed and checked to asses the vulnerability of these structure to earthquake. The selection of the building and infrastructure were based on the type of building, occupancy of the building, importance of use, purpose of use, importance of existence during disaster i.e. earthquake etc. Much effort has been devoted in recent years to the problem of how to devise reliable estimates, given the large uncertainties that exist, (Sozen and Hassan 1997, Gulkan and Sozen 1999 and Yucemen et al. 2004) [1] [5] [6]. The procedures in FEMA 154 (1988), FEMA 310 (1998) Tier 1 and the procedure developed by Sucuoglu and Yazgan (2003) are examples of walkdown survey procedures [3] [4]. This study will give an overall idea on the present condition of the buildings in three municipalities and an idea on the management of this situation to reduce the losses during a disaster like earthquake. In this study survey was performed to gather the information of each of the 152 major critical structure and building throughout the three municipality area. During the survey FEMA 310 checklist was used to acquire the information of the each buildings [2]. Side walk and questionnaire survey was carried out for each 152 buildings separately. Various engineering and non engineering vulnerability factors like soft storey, heavy overhang, short column, pounding possibility between adjacent buildings, visible ground settlement, plan irregularity, elevation irregularity, tall narrow content, URM parapet, cladding anchores etc. have considered in the study. In his study different weighted factors have fixed for various engineering and non-engineering vulnerability of buildings. It was decided by the judgment and analysis of a group of expert engineers that the vulnerability factor for soft storey, heavy overhand, plan irregularity, elevation irregularity, pounding, slope land, visible ground settlement, short column, cladding anchor, parapet and tall narrow content would be 2, 0.5, 1.5, 1.5, 2, 2, 2, 2, 2, 2, 2 respectively. Finally the summation of these weighted vulnerability factor give a total vulnerability value of the corresponding building. A building with vulnerability factor grater than 8, more than 6, grater than 3 and less than or equal to 3 have severe/ collapse, high, moderate and none/ light damage risk respectively.

## 4. RESULT AND DISCUSSION

In this study all the building surveyed in Rangamati, Bandarban and Khagrachari municipalities were Reinforced Concrete (RC) type building. As all the three municipalities are comparatively newly developed, most of the critical buildings are reinforced concrete structure which have constructed within last two to three decades.

### 4.1 Building Height and Apparent Quality of the Building

In Rangamati and Bandarban, most of the surveyed buildings are 2 storied, whereas in Khagrachari most of the surveyed buildings are 3 storied. Because of the conflicting situation over the years, many of the buildings are not well maintained in the study area. As a result the apparent quality of buildings was not found good during this study. About 79% of the surveyed buildings in Rangamati appear to be average in quality assessment. About 21% of the bindings are in good condition since these were repaired time to time by the owners. In case of Bandarban, only 7% surveyed buildings were found to be good and 73% buildings were within average category whereas 20% of the surveyed buildings were found to be poor. In case of Khagrachari, about 53% buildings were found to be good, since the construction practice has been initiated here very recently. Around 47% of the buildings in Khagarcahri municipality were found in average quality.

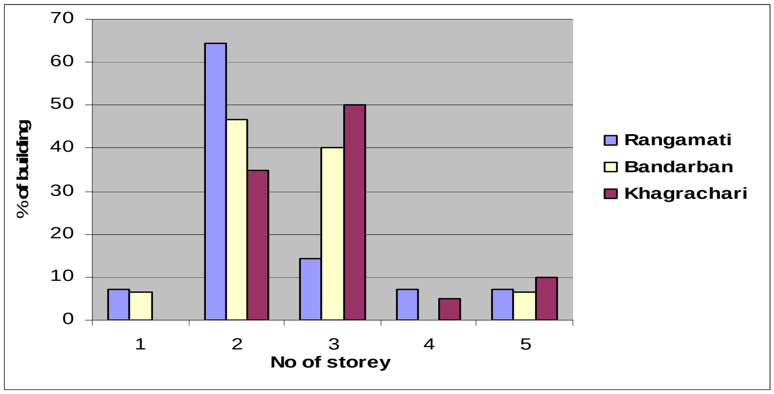


Fig 1: Percentage of building for different floor height.

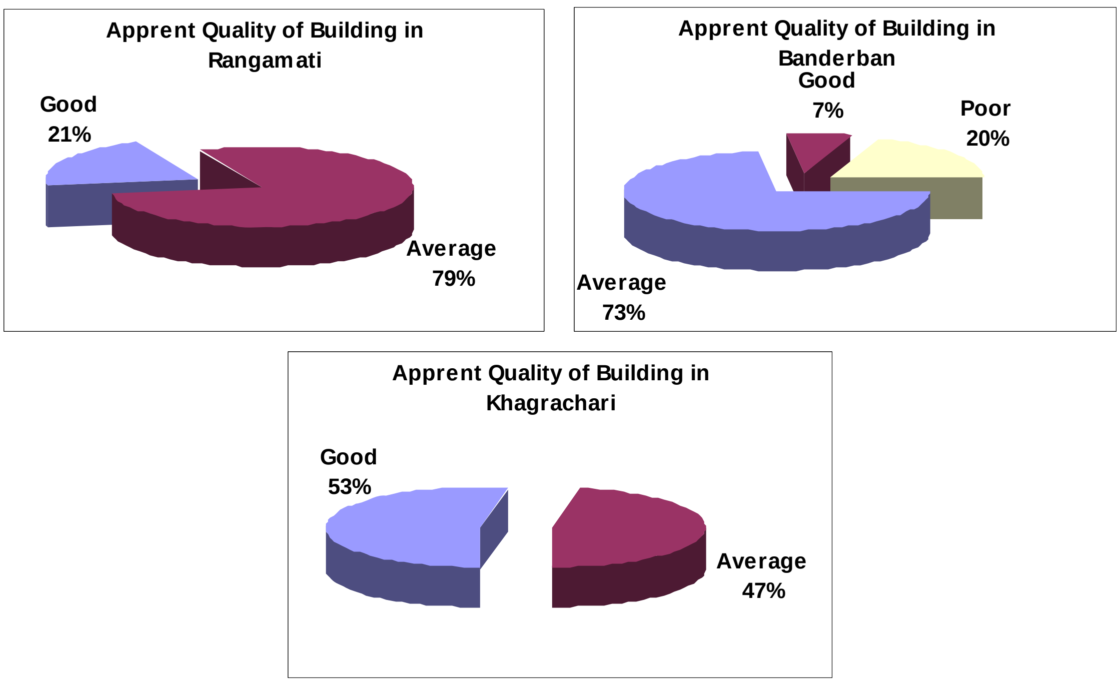


Fig 2: Apperent quality of the building in Rangamati, bandarban and Khagrachari Municipality.

### 4.2 Factors of Building Vulnerability

Several structural and non structural features were considered as the factor affecting the seismic vulnerability of the building.

#### 4.2.1 Structural Vulnerability Factor

In this study soft storey, heavy overhang, short column, pounding possibility between adjacent buildings, visible ground settlement, plan irregularity, elevation irregularity etc have considered as structural vulnerability factors. The study shows that in Rangamati about 70% of the surveyed buildings had short column vulnerability whereas only 7% building had pounding effect. Similarly in Bandarban 65% buildings had short column effect and 7% buildings had visible ground settlement. In case of Khagrachari heavy overhang problem was found in 85% of the buildings and only 5% building had pounding effect. No visible ground settlement was found in Khagrachari but it was 7% and 20% for Bandarban and Rangamati respectively.

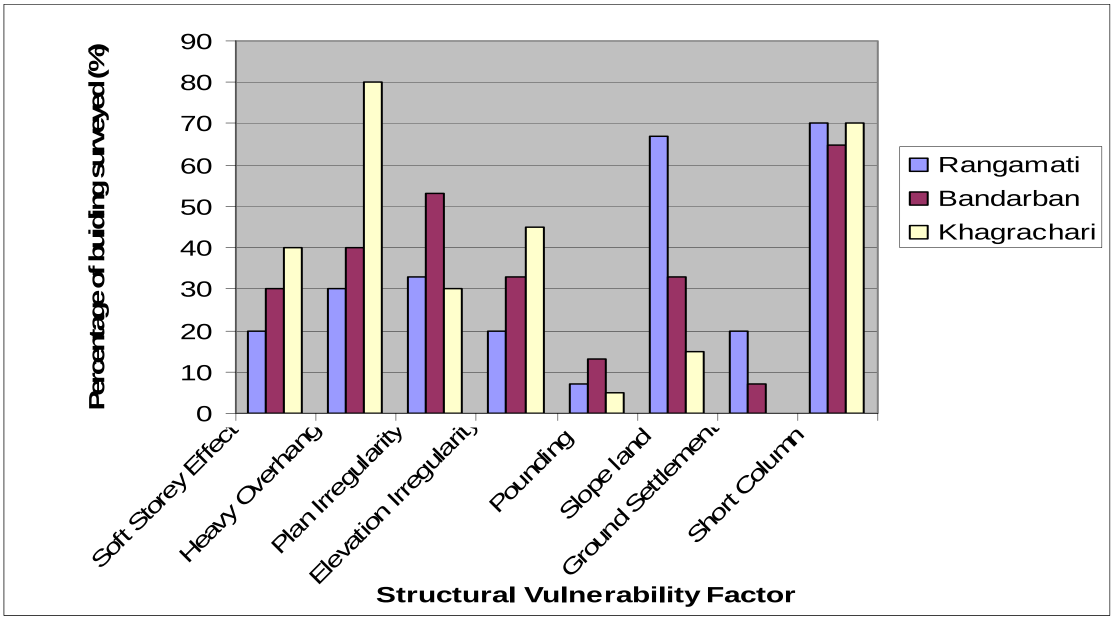


Fig 3: Percentage of building surveyed for various structural vulnerability factors

**Soft Storey**

Soft storey is one of the most important features of the building that increase the vulnerability of the building to earthquake. A soft story in a building happens when the ground story has less stiffness and strength compared to the other stories. Soft storey is generally found in the modern building where the ground floor of the building is used as parking or for any commercial purpose. Normally, this situation can be resulted from the building that locates along the side of the main street because the first story is used for a commercial space that has opening between the frame members for customer circulation. Besides, further irregularity can be caused by having taller clearances and different axis systems. Hence, the soft story buildings exhibit a less safe behavior than the similar regular structures during moderate and severe earthquake. Among the surveyed buildings in Rangamati, about 20% of the RC buildings were found with soft story. In Bandarban and Khagrachari soft storey were found in about 30% and 40% of the surveyed building respectively.

Fig 4: Soft storey found in surveyed building in Rangamati.

**Heavy Overhang**

Heavy overhang exist in any building make huge trouble during earthquake. Heavy overhanging floors in multistory buildings lead to irregularity in stiffness and mass distributions. From the view point of earthquake engineering, these irregular plan shapes are undesirable because they cause an inappropriate dynamic behavior when subjected to horizontal earthquake ground motion. For example, torsional moment in buildings can be increased during earthquakes due to non-symmetric distribution of mass and stiffness. Among the surveyed buildings in this study, about 30% of RC buildings in Rangamati were found with heavy overhangs. These buildings were found in both old and new. Significant portion of buildings with heavy overhangs were also found in Bandarban and Khagrachari as 40% and 80% respectively.

Fig 5: Heavy overhang found in Khagarcahri municipality.

**Short Column**

Short columns can be created by the arrangement of infill walls or other non-structural, architectural members. Sometimes, the infill walls are shorter than the columns and windows may be opened at the top of the periphery shear walls at the basement of the structures. In such cases, the column length becomes shorter and stiffer. Due to the increase in stiffness, the columns share more flexural moment and this causes the increase in shear forces. Therefore, these columns usually sustain heavy damage during strong earthquake. Earthquake damage in short columns is pretty common. For an example, it was observed after the August $17^{th}$, 1999 earthquake in Turkey (Mw=7.4) that a large number of buildings were damaged due to the presence of short columns. During this study, the presence of short columns was found in 70%, 65% and 70% of buildings in Rangamati, Bandarban and Khagrachari, respectively. There might be a substantial short column effect in this place as well, if a major earthquake event occurs.

Fig 6: Short column found in the surveyed building in Bandarban.

**Irregularity in Building Plan and Shape**

Building shape and elevation are major factors affecting buildings during an earthquake. From the experience of different earthquake, it is evident that the buildings with irregular shape are more damaging than the buildings are of regular shape. Similarly elevation of building is also another important factor responsible for damaging buildings during an earthquake. Narrow tall buildings are more vulnerable during an earthquake. About 20% & 33% of surveyed buildings in Rangamati have elevation & plan irregularity respectively, in case of Bandarban, the statistics is 33 & 53%, whereas for Khagrachari, elevation irregularity is about 45% and plan irregularity is about 30%.

**Pounding Possibility between Adjacent Buildings**

Damage due to pounding can be observed after almost every earthquake events. Different vibration periods and non-synchronized vibration amplitudes cause the close buildings to knock together. Buildings subjected to pounding receive heavier damage on higher stories. In Rangamati, Bandarban and Khagarchari pounding possibility was found in 7%, 13% and 5% of the surveyed RC building.

**4.2.2 Non structural Vulnerability Factor**

Different objects like furniture or goods of household use become dangerous during earthquake. Heavy furniture becomes threat since there are chances to fall on the people staying nearby. It is evident from earthquakes in different countries that non structural elements become a threat to life during an earthquake. During this study, non structural vulnerabilities like tall narrow content, URM parapet, cladding anchores etc were considered during survey of individual buildings. It was found in the study that almost all the surveyed building had high vulnerability of tall narrow content in Bandarban and Khagarchari municipality where as in Rangamati municipality it was around 60% of the surveyed buildings.

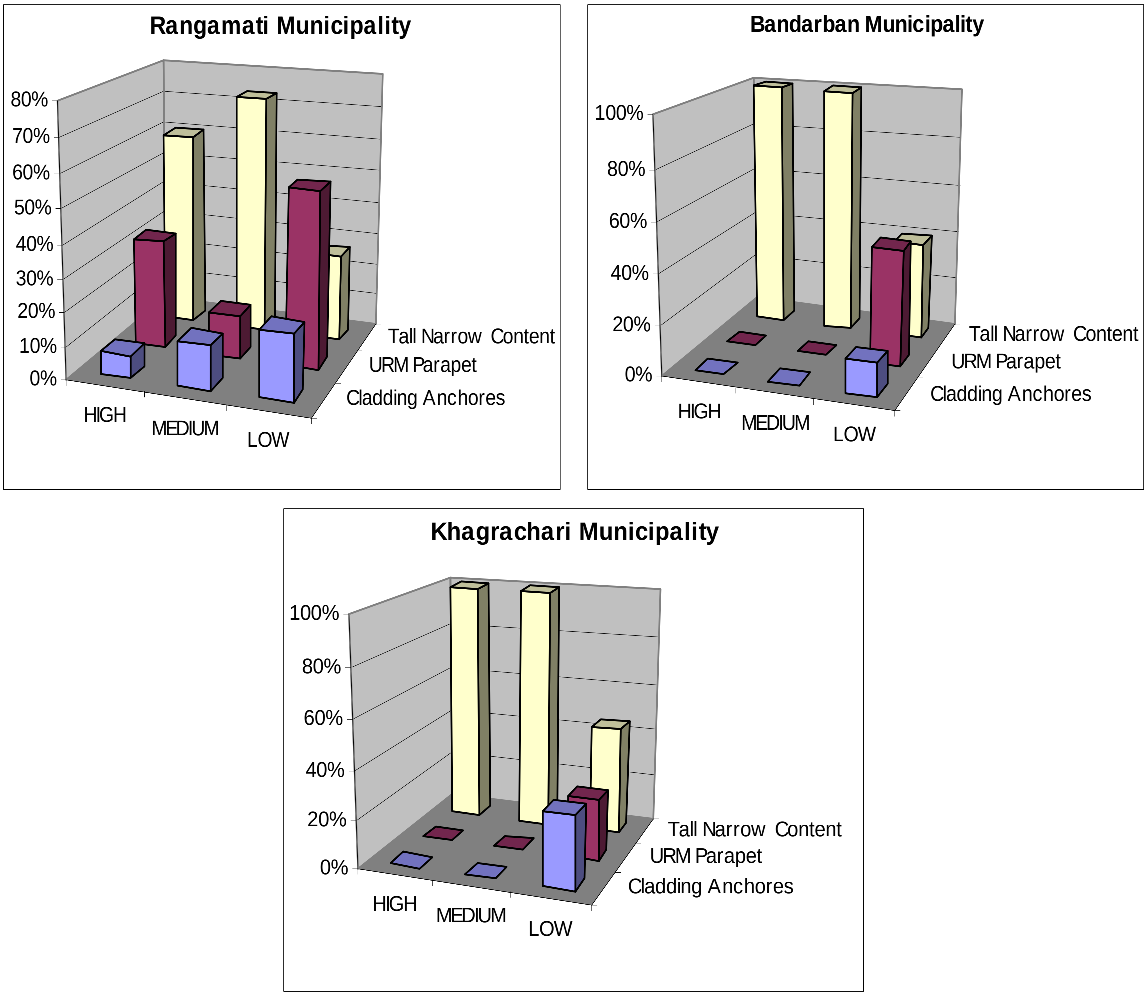


Fig 7: Non structural vulnerability of surveyed buildings in Rangamati, Bandarban and Khagarchari municipality.

### 4.3 Damage Risk Analysis of Existing Buildings

A risk analysis of the existing structures of Rangamati, Bandarban and Khagarchari municipalities have done to find the corresponding damage scenario of the existing buildings. The analysis has done based on the vulnerability factors identified during the survey. It was found in the study that in Rangamati municipality about 21% of the total buildings have severe and high risk of damage and 7% buildings have no damage risk. In Bandarban 7% buildings have severe damage probability and 20% buildings have no damage risk. Similarly in

Khagrachari municipality area no building has found in collapse/ severe damage risk but 75% of the surveyed buildings have moderate damage risk.

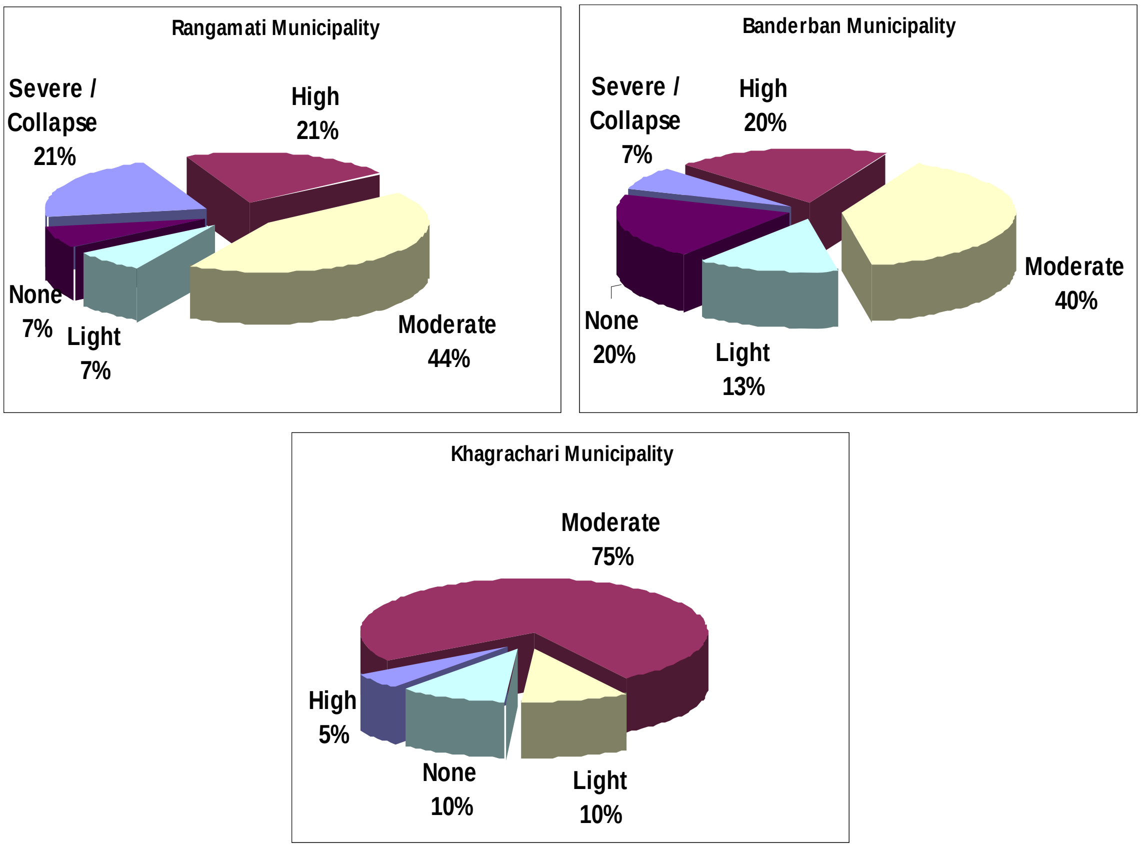


Fig 8: Damage scenario of buildings in Rangamati, Bandarban and Khagrachari municipality

## 5. LIMITATION OF THE STUDY

This study is limited to only the selected critical infrastructures within the municipalities. The study was constrained to only those buildings which will be operational during disaster period. There are number of installations in the municipality that are declared as restricted areas. Due to existing regulations in Bangladesh, it was not possible to conduct detail building and lifeline surveys in certain areas in the municipality area, which include Cantonment, BDR Area, Police Line, Police Thana, Installations like Radio station & power station etc.

## 6. CONCLUSION AND RECOMMENDATION

Various historical, scientific and statistical analyses prove that there's a huge possibility of occurring a moderate to strong earthquake in near future in CHT area. So it is very much important to check the structural strength and stability of the critical buildings and infrastructures of this area, which have done in this study. In this study it has found that the structural condition of the existing building in Rangamati, Bandarban and Khagrachari municipalities is in the alarming condition. It was estimated that if a moderate earthquake strike CHT area 21% and 7%

building of Rangamati and Bandarban municipality is under severe risk of damage eventually the structure will collapse. In this regards it is very much important that the municipality authority should take necessary action for these severe and high damage risk buildings in order to reduce the losses of life during an earthquake. Retrofitting is the one of the sustainable solution for these vulnerable buildings to increase the strength. If the strength of the building could not be increased by retrofitting need to be demolished as soon as possible to reduce the losses of lives during earthquake. The municipality authority should share the outcome of the structural assessment with the owner of building and encourage them for retrofitting otherwise demolition of building where retrofitting will not work.

## 7. ACKNOWLEDGEMENT

Khagarcahri, Bandarban and Rangamati Municipality; ERRP Project, UNDP-CHTDF

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# CHARACTERISTICS OF MICROTREMOR FOR A 110 MW POWER PLANT IN SOUTH WESTERN REGION OF BANGLADESH

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## ABSTRACT

It is relatively simple to obtain ground shaking characteristics, i.e. predominant period and amplification factor, from the microtremor observation in order to estimate the dynamic behaviour of structure for the damage assessment due to future earthquake. The characteristics of ground motion are amplified the most when the frequency content of the motion and the natural frequencies of structure are close to each other. Based on forced and ambient vibration test, the response of surroundings soil as well as structure can be monitored. This paper presents microtremor observations at free-field, concrete floor and on machine foundation in a 110MW power plant site in the south western part of Bangladesh.

**Key words:** Microtremor, power plant, vibration, time history, FFT

## 1. INTRODUCTION

In areas of low or moderate seismic activity, the effects of possible large earthquakes are usually explored through earthquake scenarios. One of the main parameters controlling the possible consequences of strong events is the ability of the structure to resist to the ground motion. Aim of this study is to obtain the characteristics of microtremor for the power plant at different conditions.

Microtremor is used to record the fundamental frequency and period of the structure and soil. The dynamic properties are the important factor for seismic design. Response of structure mainly depends on the characteristics of both excitation forces and dynamic properties of structures. This is why the natural frequency and period is taken on the basement, cement concrete floor to identify the dynamic properties of structures. The vibration characteristics in soil are different to structure. Hard soil gives high frequency and soft soil gives low frequency [4]. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral characteristics of horizontal component of the structure to that of ground.

First Fourier Transform (FFT) of foundation, concrete floor and free-field are similar during the full vibration of the machine load and zero vibration consideration for the power plant.

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## 2. STUDY AREA

The studied power plant has the capacity of 110 MW is situated near the bank of Padma River, south western part of Bangladesh. The plant was established in 2010. There have total 14 machines to generate the power. The study was considered during the full vibration (four machines running at a time) to compare the results with the machines at rest. Fig 1 shows the study area.


Fig 1: Study area of the microtremor.

## 3. MICROTREMOR OBSERVATION

Soil characteristics can be assessed by Microtremor measurement. Hard soil gives high frequency and soft soil gives low frequency. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ration of horizontal component of the structure to that of ground. Wave propagation mechanism of Microtremor and its relation with ground vibration characteristics were studied from the beginning of Microtremor studies [4], [6].

Basically there are two types of Microtremor observations to the number of observation points. These are point and array observations of microtremors [5]. From the array observation of Microtremor of period greater than 1 sec, Rayleigh-wave and Love-wave originating from natural sources, such as sea wave, variation of air and wind pressure can be recognized. On the other hand, short-period Microtremor of period less than 1 sec is thought to be generated by artificial noises such as traffic vehicles, industrial plants, household appliances, etc. Some researches [3], [2] have showed that microtremors are mainly composed of Rayleigh-wave and some researchers [7] have showed that short-period Microtremor bears resemblance to shear-wave characteristics. On the other hand, Microtremor can also be dominated by Love–wave [1]. Recently, Suzuki et al. (1995) have applied Microtremor measurements to the estimation of earthquake ground motions based on a hypothesis that the amplitude ratio defined by Nakamura can be regarded identical with half of the amplification factor from bedrock to the ground surface. However, the real generation and nature of microtremors have not yet been established.

In general, the approaches to the identification the dynamic properties of structure can be categorized into three main approaches: (1) empirical, (2) numerical analysis, and (3) direct measurement approaches. The empirical approach provides simplified formulas for estimating the fundamental periods of structures in terms of geometric dimensions of the structures. The second approach, the numerical analysis, is normally used during the design process. A finite model of the structure is first formulated. Dynamic properties such as natural frequencies and vibration mode shapes are obtained by the Eigen analysis. The third approach is the direct measurement approach, which first measures dynamic responses of existing structures, and then identifies their dynamic properties from the measured responses.

## 4. SOIL DATA

For this site, Standard Penetration Test was performed for 18 bore holes. These are obtained from subsoil investigation. Typical boreholes are shown in Fig 2. This 110 MW power plant is constructed on pile foundation.

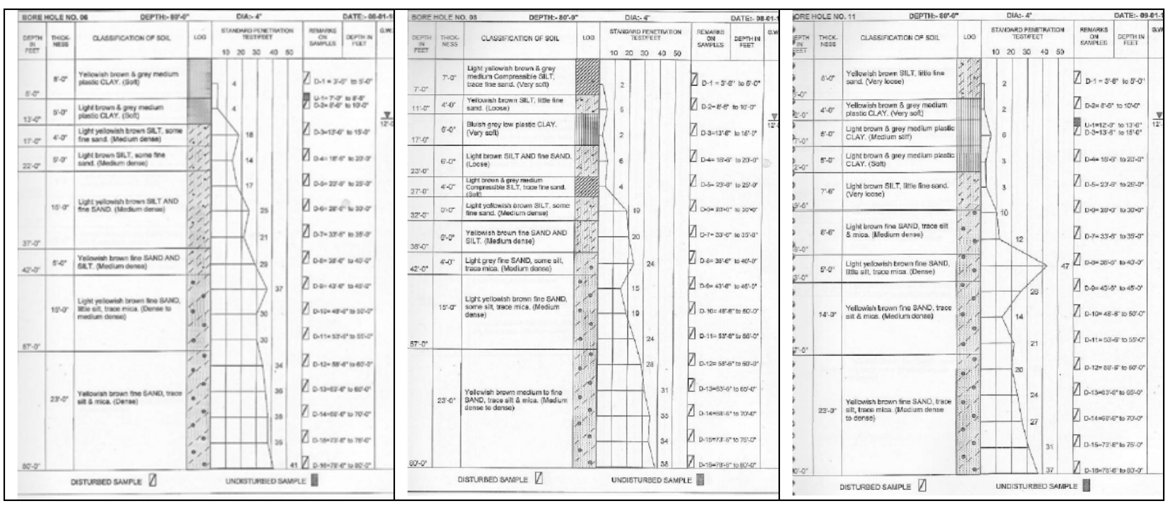


Fig 2: Measured subsoil SPT values for three bore holes.

In general, the top several feet of soil consists of yellowish brown silt with fine sand, the next layer contains medium plastic clay and the bottom layer consists of thick medium dense to dense yellowish brown fine sand.

## 5. DATA COLLECTION AND PROCESSING

For Microtremor observation at the power plant, initially the sensors are deployed. One sensor is fixed on the machine basement, one on the free field near the structure and another on concrete floor as shown in Fig 3. At first data was recorded during the machines running at full load, then data was recorded when all machines were in rest. After taking the observation with the help of microtremor program the time domain velocity data is converted to frequency domain data and find out the natural period of the structures were found. Microtremor measurement is shown below in Fig 4. Around the investigated structure three

3-dimensional accelerometers are assembled to measure the ground response of the ambient excitation.

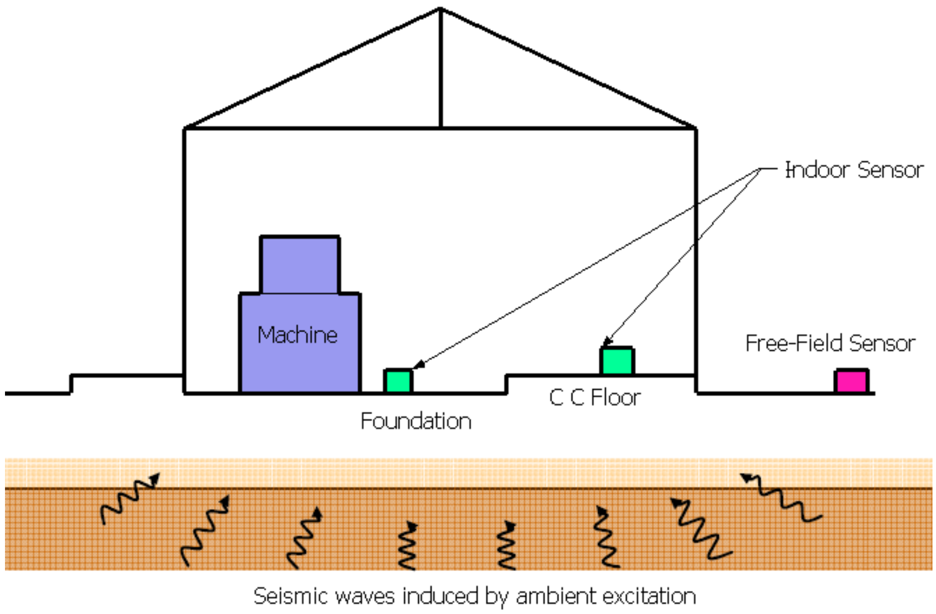



Fig 3: Instrument for ambient vibration measurement

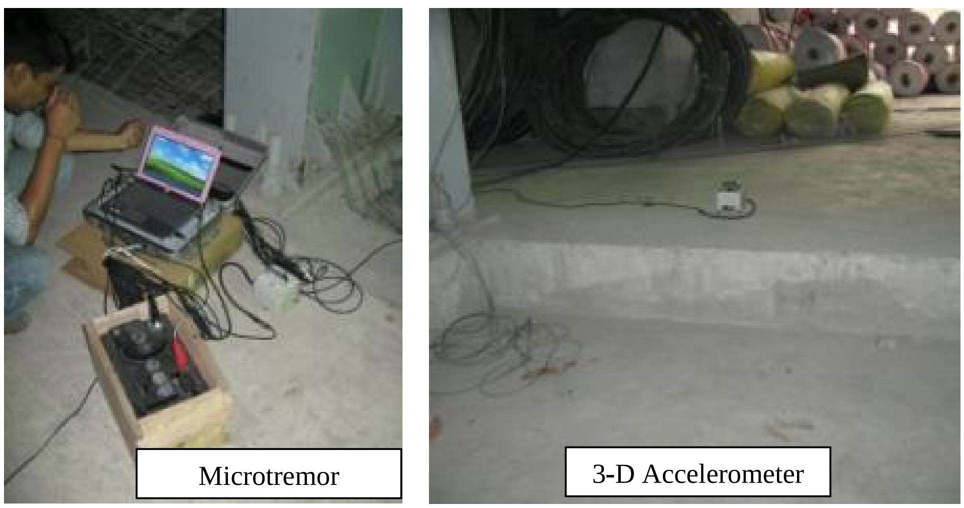



Fig 4: Microtremor data observation

The computation steps of the spectrum analysis is shown in Fig 5 and described as follows:

- Pre-Processing:

- 3-dimensional input (the accelerometer in northward direction to get North-South, East-West and vertical components)
- Windowing of the signal (in our case only the ambient parts are of interest, observe, in case of transient excitation only the transient parts of the time response are of interest)

- Main Data-Processing:

Hence the three different components of the signal were considered separately. The main data processing is repeated for every input-signal (n-Steps according to the numbers of preliminary separated windows).

- FFT is applied to obtain the several spectral amplitudes of the three components
- Smoothing of the three spectral amplitudes with a bandwidth factor of 15
- Afterwards the resulting horizontal component and vertical component are plotted to obtain the amplitude in frequency domain

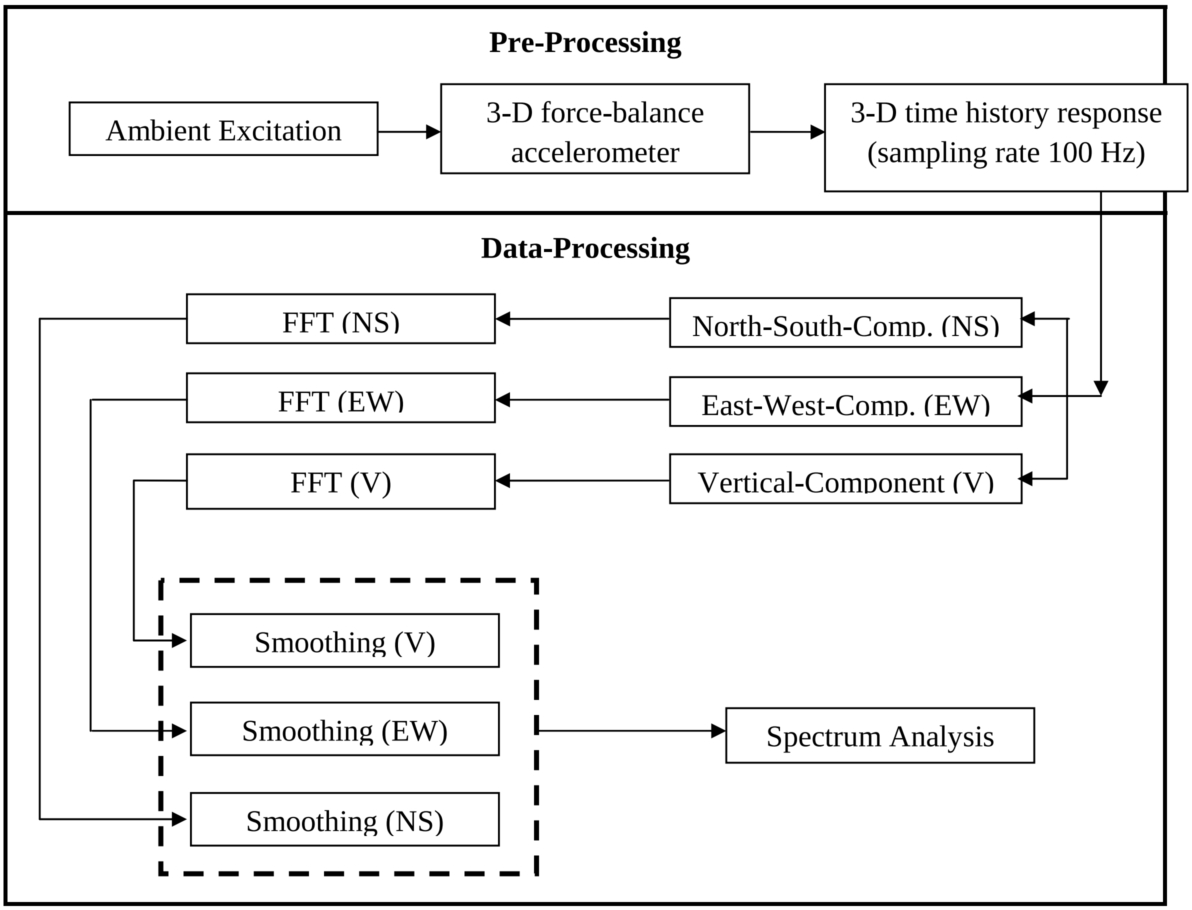
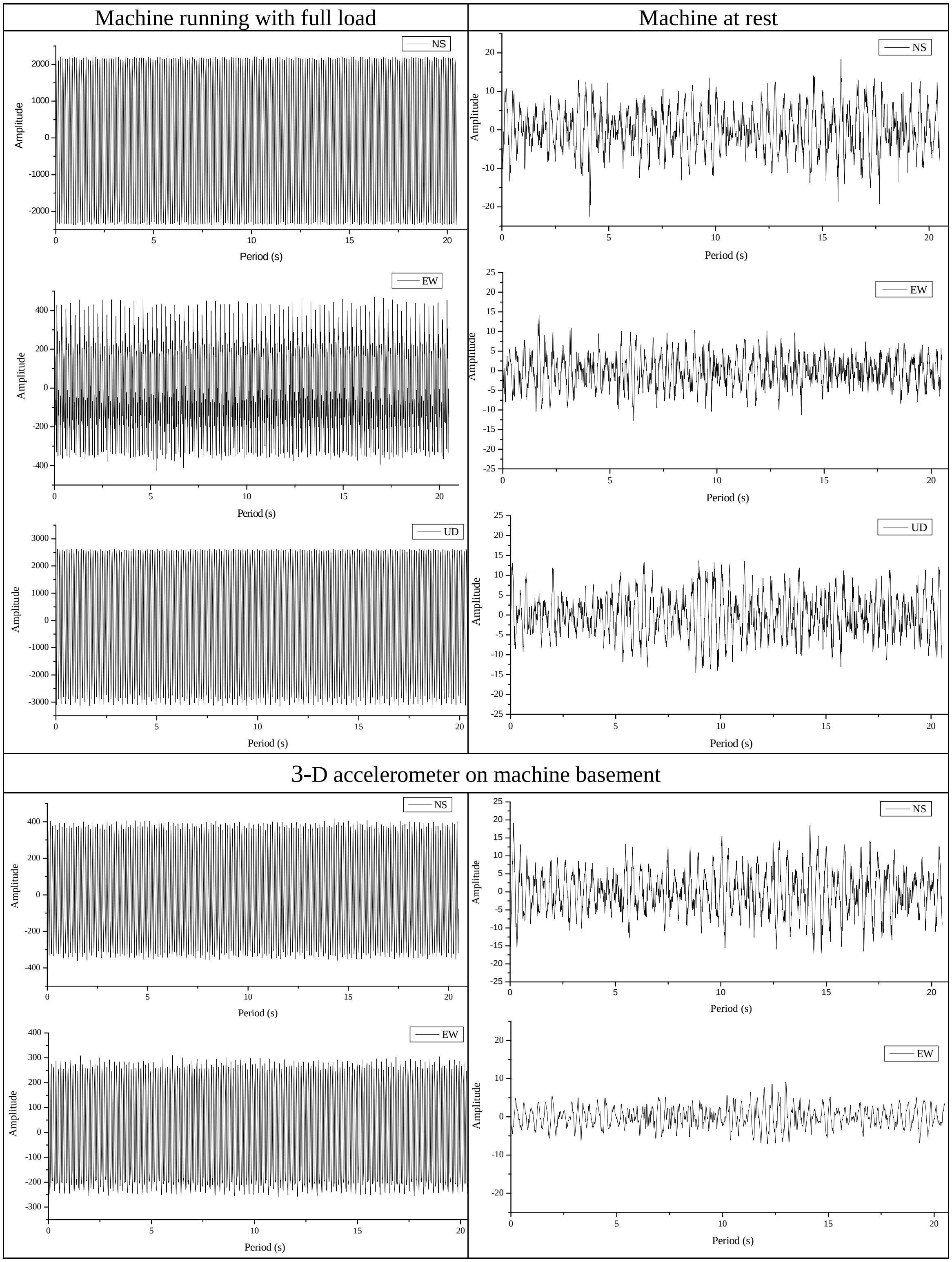



Fig 5: Flowchart of data processing

**6. RESULTS**

Fig 6 shows individual time histories for North-South, East-West and Up-Down components for free-field, concrete floor and machine foundation. Fig 7 shows FFT of those time histories. In this site, separation between machine foundation and surrounding soil is essential but no separation has been kept. This can be seen from Fig 7. As for fully loaded condition, predominant frequency is 8 Hz at all locations; Machine base has high amplitude, but on concrete floor and ground level amplitude decreased. With zero load, frequency is 3 Hz; but amplitude was 100 times lower than fully loaded condition. All amplitude is presented in micrometer.


Machine running with full load
Machine at rest
3-D accelerometer on machine basement
NS
EW
UD
Amplitude
Period (s)

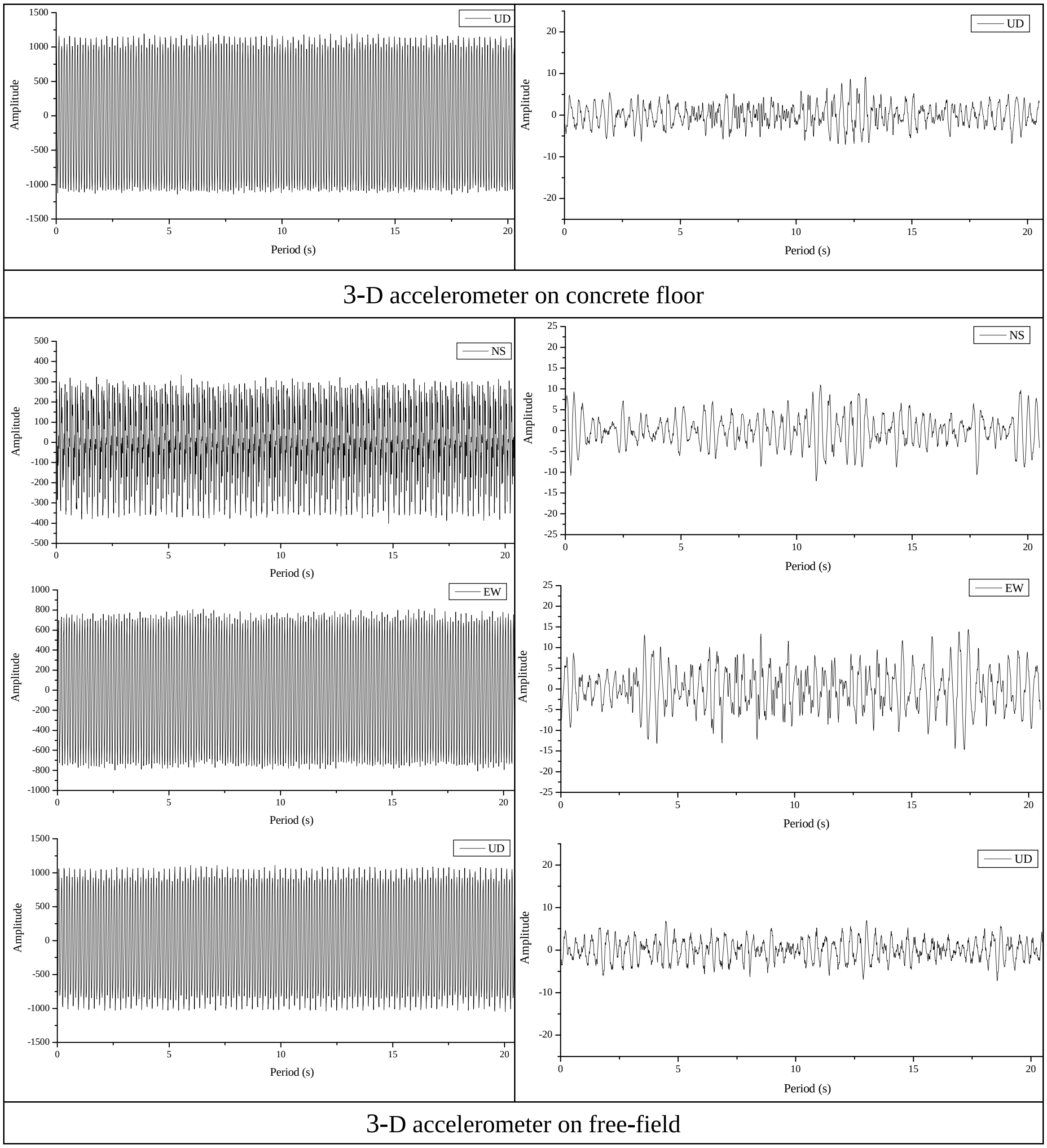



Fig 6: Time history data at different conditions and at different locations.

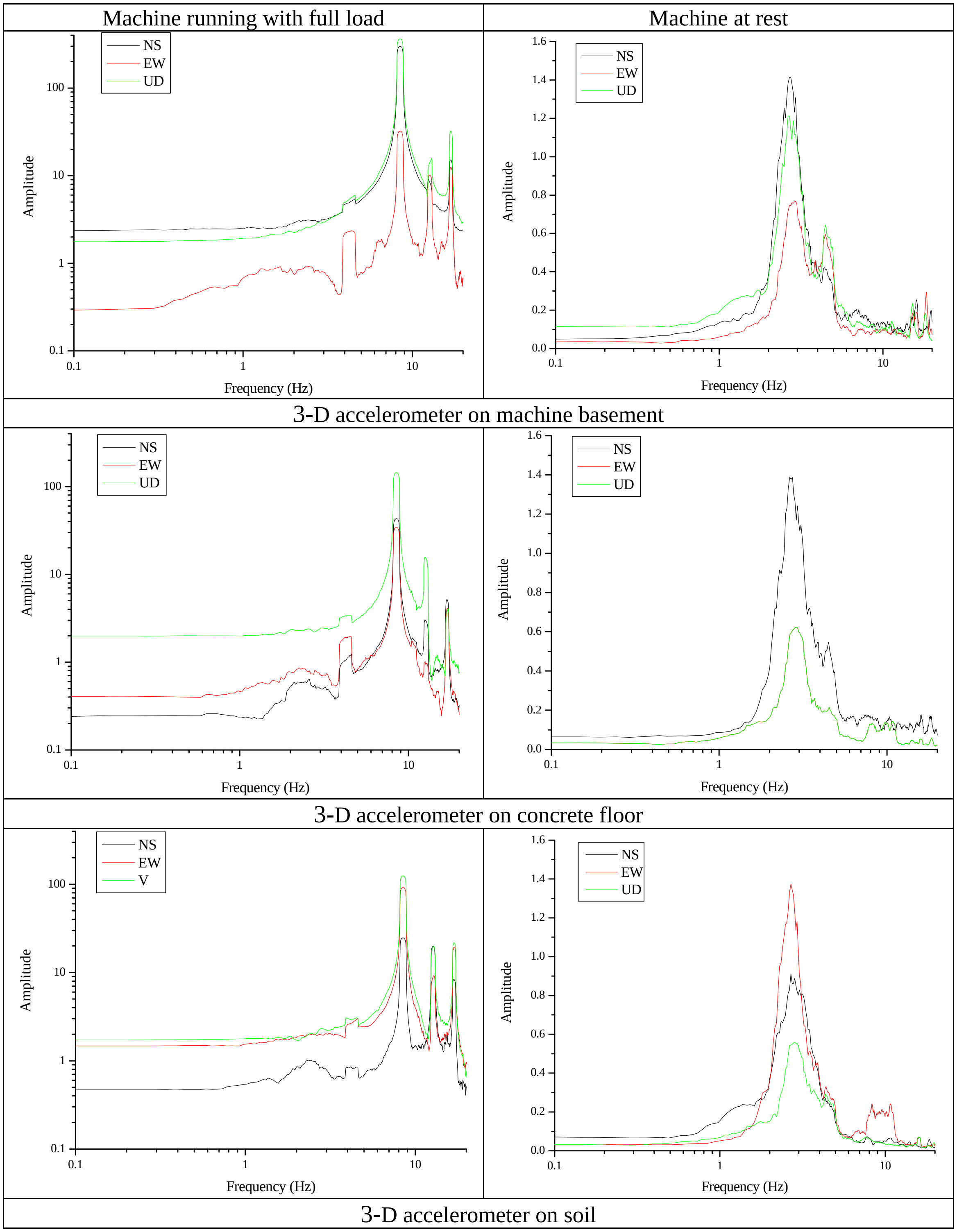



Fig 7: Smoothed data of horizontal and vertical Fourier spectra of microtremors.

## 7. CONCLUSION

This paper summarizes the microtremor observations at different locations of the power station. Microtremor observations have been made on machine foundation, concrete floor and free-field for 10 minute. The reading has been repeated for two times to check the stability of the acquired data. From observation, no separation has been found between machine foundation and surrounding soil. For fully loaded condition, predominant frequency is 8 Hz at all locations; Machine base has high amplitude, but on concrete floor and ground level amplitude decreased. For machine at rest, amplitude was 100 times lower than fully loaded condition with frequency 3 Hz.

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# LITHOLOGY IDENTIFICATION & POROSITY INTERPRETATION AT WELL #03 OF FENCHUGONJ GAS FIELD USING WIRELINE LOG

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## ABSTRACT

Porosity values can be obtained from sonic log, a formation density log and neutron log. In addition porosity these log are affected by other parameters such as lithology, nature of pore fluid and shaliness. For more accurate porosity obtained from combination of density-neutron log. The readings of these tools are determined by the properties of formation close to the borehole. The sonic log has the shallowest investigation. Neutron log and density log are affected by a little deeper region depending somewhat on the porosity, but generally within the flushed zone. Well-logging plays a very important role in the petroleum industry. It is an eye of oil or gas industry while it provides the detailed geological information including petrophysical properties of drilled holes. It enables quantitative estimation of hydrocarbon reserves through its open hole services. The geophysical well logging technique has also wide applications in subsurface mineral, geothermal and ground water exploration. The most established way to gather information about hydrocarbon-bearing reservoirs over the total length of the well is by means of wireline logging. The objectives of logging is to obtain information about the location, the amount and the producibility of hydrocarbons. Physical properties such as density, resistivity, magnetic resonance, natural gamma radiation are recorded as a function of depth. These physical properties have to be converted into petrophysical properties, which require interpretation models. These models can vary from one reservoir to the next because there are no known universal relationships between the physical parameters that are measured in the well and petrophysical rock properties. From this point of view the wireline well logging technique has been used in this research. Thus the aim of this research is to demonstrate the lithology identification and porosity interpretation at well #3 of Fenchugonj gas field. The result of the analyzed log data indicated that the sand and shale zone (zone A, zone B, zone C, zone D, zone E, zone F, zone G for sand only) exists at a depth from 1500m to 2700m (well#03). Then a collection of petrophysical parameter from a basic log data ( i.e. Gamma ray log, Density log, Neutron log and Sonic log.) are used to calculate porosity. The calculated average porosity of different zone are 18.622% which are responsible for having a potential reserve.

**Key Words:** Well Logging, Gamma Ray, Neutron, Density, Sonic, porosity and reservoir rock.

## 1. INTRODUCTION

The amount of hydrocarbon present in a reservoir is a function of its porosity and its hydrocarbon saturation. In addition, the efficiency with which the reservoir can be produced

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is function of its permeability. These parameters can be measured on core plugs, which are often considered as representing “ground truth.”However, core plug measurements are also affected by errors. In addition, coring is very expensive and there is never any guarantee that the target reservoir won’t be missed by the core, or that the full cored interval will be recovered. This is why wireline logs have become the primary source of data for petrophysical evaluation of reservoirs and are routinely recorded on every oil and gas well.Fenchugonj is an Upazila of Sylhet district on the north eastern corner of Bangladesh. Fenchugonj Gas Field is located at LAT: 24D 35M 59.83SEC N and LONG: 91D 57M 11.79SEC E. (source:[8]).The main objectives of this research are lithology (shale or sand) identification and porosity interpretation of at well # 03 of fenchugonj gas field. To know the application of several wire line log data e.g. gamma ray log, density log, neutron log and sonic log.

## 2. PETROPHYSICS AND RESERVOIR ROCK

### 2.1 Petrophysics

Petrophysics is the study of rock properties and their interactions with fluids (gases, liquid hydrocarbons and aqueous solutions). Because petroleum reservoir rocks must have porosity and permeability, we are most interested in the properties of porous and permeable rocks. The petrophysical properties that are the following: porosity, absolute permeability, effective and relative permeability, water saturation, hydrocarbon saturation. Source:[3]

### 2.2 Reservoir Rock

A rock capable of producing oil, gas and water is called a reservoir rock. In general, to be of commercial value, a reservoir rock must have sufficient thickness, areal extent and pore space to contain a large volume of hydrocarbons and must yield the contained fluids at a satisfactory rate when the reservoir is penetrated by a well. Any buried rock, be it sedimentary, igneous or metamorphic, that meets these conditions may be used as a reservoir rock by migrating hydrocarbons. Oil and gas fields are geological features that result from the coincident occurrence of four types of geologic features (Figure 1) such as oil and gas source rock, reservoir rock, seal and trap. Sandstones and carbonates (limestone’s and dolomites) are the most common reservoir rocks. Fenchugonj gas field’s reservoir rock is sandstone and trap is structural trap. The most probable structure is based on the structure identified with a mature source rock ,a migration path connecting source rock to reservoir rock ,a suitable reservoir rock (porous & permeable), a trap and an impermeable seal. After the identification of the structure, location is released for drilling. Once the well is drilled, the need arises for ascertaining the worthiness of the well. Till the time the well is being drilled it is not sure that the well drilled will bear hydrocarbon. To ascertain the potential of the well it is required to log the well.

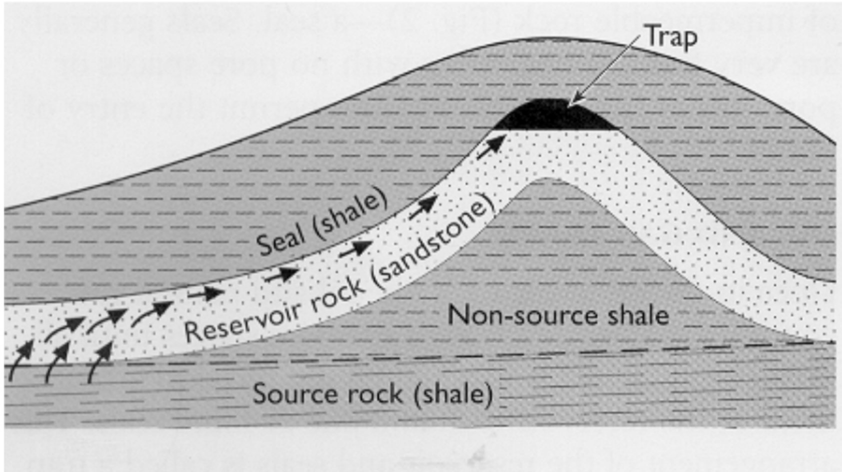


Figure 1: Reservoir rock (source: internet)

## 3. METHODOLOGY

### 3.1 Lithology Identification at well #03 of Fenchugonj Gas Field Using Gamma Ray Log

The Gamma Ray (GR) log measures the natural radioactivity of the formations in the borehole. The log is therefore, useful for identifying lithologies and for correlation purposes. Shale exhibit relatively high GR count rates due to presence of potassium ions in the lattice structure of clay mineral. On the other hand, Reservoir rock(calcite, dolomite, quartz) exhibit relatively low GR count rates due to absence of potassium ions in the lattice structure of minerals which shown in figure 1.(source 6)Based on above formula, identifying lithology of Fenchugonj gas field at well #03 which are shown table 1.

### 3.2 Porosity Determination from Density Log, Density-Neutron Log and Sonic Log

Density log : Gamma rays emitted from a chemical source (Ce137, Co60) interact with electrons of the elements in the formation. Two detectors count the number of returning gamma rays which are related to formation electron density.For most earth materials, electron density is related to formation density through a constant Returning gamma rays are measured at two different energy levels such as high energy gamma rays (Compton scattering) determine bulk density and therefore porosity and low energy gamma rays (due to photo electric effect) are used to determine formation lithology. Symbol for density: ρ(rho) (source: [5] )

Figure 2: Bulk density reading from density log

Porosity from density log,

$$\Phi_D = (\rho_{ma} - \rho_b)/(\rho_{ma} - \rho_f) \quad \ldots\ldots\ldots(2)$$

Which are shown in table 1.
Where $\rho_{ma}$= matrix of sand (2.65)
$\rho_b$ = Bulk density (from log data)
$\rho_f$ = Fluid density ( from chart , formation water, 1.1)
Neutron log: Neutron logs measure the hydrogen content in a formation.In clean, shale free formations, where the porosity is filled with water or oil, the neutron log measures liquid filled porosity. Symbol for neutron porosity : ($\Phi_N$) which are also shown in table 1.
Porosity from Density and Neutron log**:**The combination of density and neutron logs is now used commonly as a means to determine porosity that is largely free of lithology effects. Each individual log records an apparent porosity that is only true when the zone lithology matches that used by the logging engineer to scale the log. A limestone equivalent porosity is a good choice for both neutron and density logs, because calcite has properties that are intermediate between dolomite and quartz. By averaging the apparent neutron and density porosities of a zone, effects of dolomite and quartz tend to cancel out. The true porosity may be estimated either by taking an average of the two log readings or by applying the equation:

$\Phi_{D\text{-}N} = \sqrt{(\Phi_D 2 + \Phi_N 2)/2}$...........(3)

Which are shown in table 1.

Where $\Phi_D$ = from equation (2) and $\Phi_N$ from figure (3)

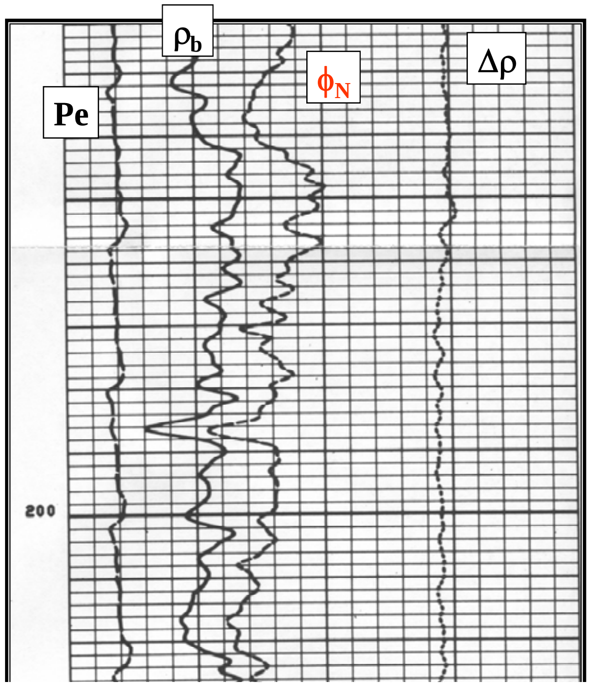


Figure 3: Porosity reading from neutron log

**Sonic log:** A log that measures interval transit time ($\Delta t$) of a compressional sound wave travelling through the formation along the axis of the borehole. The acoustic pulse from a transmitter s detected at two or more receivers. The time of the first detection of the transmitted pulse at each receiver is processed to produce $\Delta t$. The $\Delta t$ is the transit time of the wave front over one foot of formation and is the reciprocal of the velocity. Interval transit time is both dependent on lithology and porosity.Source

Porosity from Sonic log,

$\Phi_s = (T_{log} - T_{matrix})/(T_f - T_{matrix})$ ……..(4)

Which are shown in table 1.

Where $T_{log}$ =from sonic log

$T_{matrix}$= 55-51 micro second , for sand

$T_{fluid}$= 185 micro second , for salt base water

And 189 for fresh water

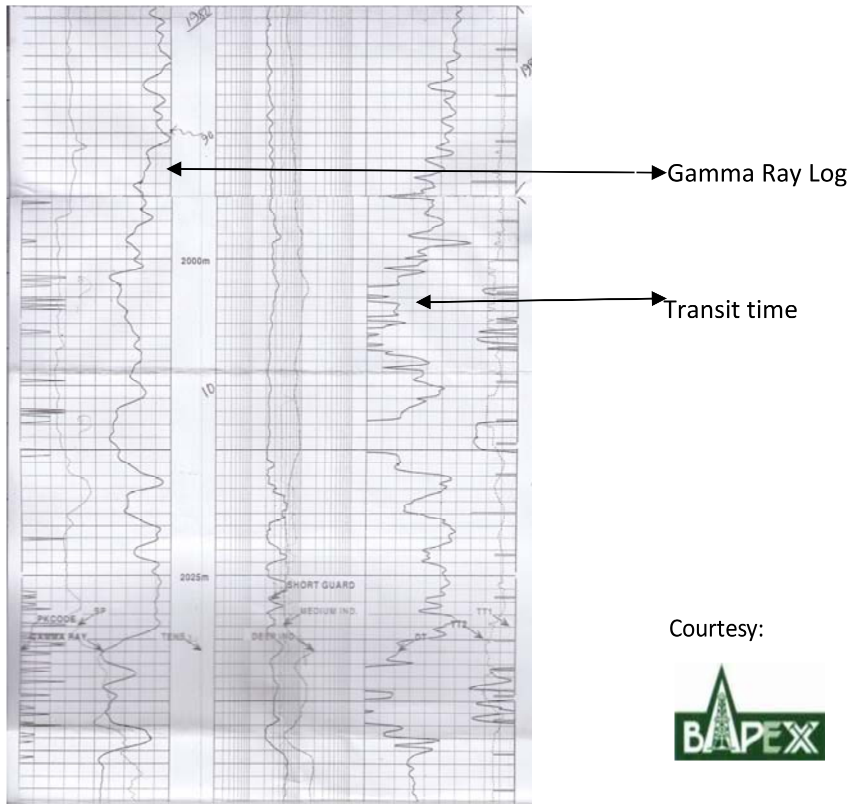


Figure 2 : Presentation of GR, SP, LL3, ILD, ILM, DENSITY & SONIC log at well #03 of Fenchugonj Gas Field (courtesy: BAPEX,30-March-04)

Table 1: Lithology Identification at well #03of Fenchugonj Gas Field using Gamma Ray Log. (courtesy: BAPEX)

| Depth (meter) | Lithology | Remark |
|---|---|---|
| 1500-1656 | Shale | |
| 1656-1680 | Sand | Zone A |
| 1680-1992 | Shale | |
| 1992-2017 | Sand | Zone B |
| 2017-2030 | Shale | |
| 2030-2086 | Sand | Zone C |
| 2086-2148 | Shale | |
| 2148-2154 | Sand | Zone D |
| 2154-2206 | Shale | |
| 2206-2260 | Sand | Zone E |
| 2260-2511 | Shale | |
| 2511-2526 | Sand | Zone F |
| 2526-2612 | Shale | |
| 2612-2627 | Sand | Zone G |
| 2627-2700 | Shale | |

Table 2 : Porosity interpretation of zone A , depth 1656m-1680m at well#3 of fenchugonj gas field

| Depth | Bulk density From Density log | Porosity from Density log,eq[2] | Porosity From Neutron log | Porosity from Density-Neutron log,eq[3] | Transit time from Sonic log | Porosity from Sonic log Eq[4] |
|---|---|---|---|---|---|---|
| (meter) | $\rho_b$ (gm/cc) | $\Phi_D$ (100%) | $\Phi_N$ (100% ) | $\Phi_{D-N}$ (100%) | T Log (µsec/ft) | $\Phi s$ ( 100%) |
| 1656-1658 | 2.25 | 0.258 | 0.36 | 0.31318 | 120 | 0.507576 |
| 1658-1660 | 2.25 | 0.2741 | 0.36 | 0.31995 | 148 | 0.719697 |
| 1660-1662 | 2.22 | 0.2741 | 0.195 | 0.237876 | 148 | 0.719697 |
| 1662-1664 | 2.35 | 0.1935 | 0.195 | 0.194251 | 120 | 0.507576 |
| 1664-1666 | 2.3 | 0.2257 | 0.195 | 0.210936 | 100 | 0.356061 |
| 1666-1668 | 2.35 | 0.1935 | 0.195 | 0.194251 | 95 | 0.318182 |
| 1668-1670 | 2.35 | 0.1935 | 0.195 | 0.194251 | 100 | 0.356061 |
| 1670-1672 | 2.32 | 0.2128 | 0.195 | 0.20412 | 98 | 0.340909 |
| 1672-1674 | 2.28 | 0.2386 | 0.195 | 0.217921 | 100 | 0.356061 |
| 1674-1676 | 2.3 | 0.2257 | 0.195 | 0.210936 | 100 | 0.356061 |
| 1676-1678 | 2.32 | 0.2128 | 0.195 | 0.20412 | 100 | 0.356061 |
| 1678-1680 | 2.33 | 0.2064 | 0.195 | 0.200781 | 90 | 0.280303 |
| Average | | 0.22575 | 0.2225 | 0.225215 | | 0.431187 |

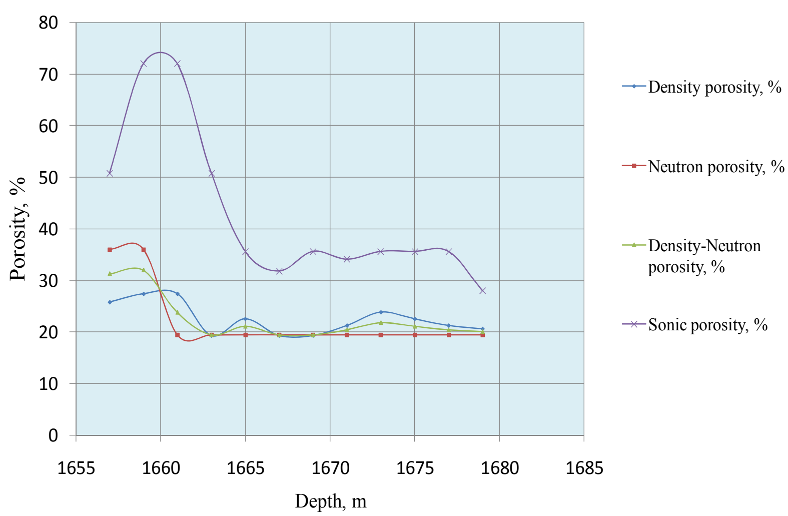


Figure 3: Porosity from several logs versus depth

Figure 3 shows that porosity from density log, neutron log, combination of density-neutron log and sonic log with respect to depth. In addition porosity from density log, neutron log and combination of density-neutron log approximately simil\ar but porosity from sonic log is far away from others.

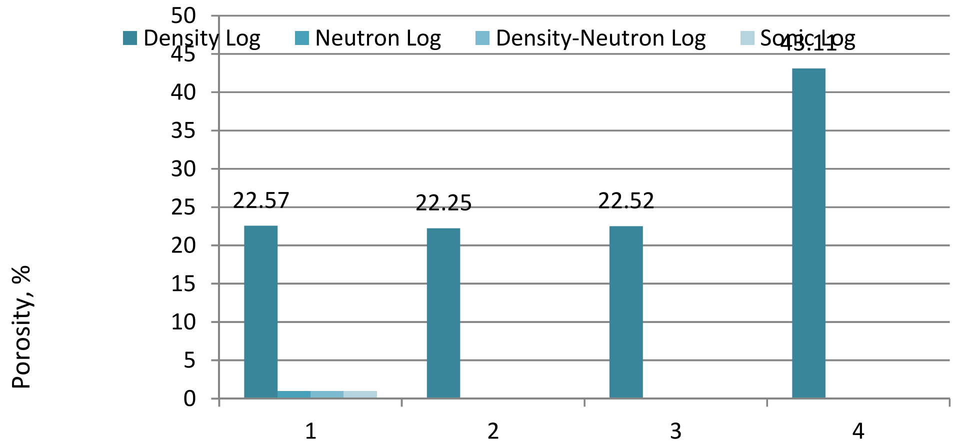


Figure 4: Average porosity from several logs

Figure 4 shows that quantitative values of porosity from density log, neutron log, density-neutron log and sonic log.

## 5. DISCUSSION & CONCLUSION

Average Porosity from Density log =22.575%, Neutron log =22.25%, Density- Neutron log =22.5215%, Sonic log =43.1187%.Similarly, average porosity interpreted for zone B, zone C, zone D, zone E, zone F and zone G. In the prediction of porosity, the best results were obtained from combination of density-neutron porosity. The average porosity from density-neutron log is 22.5215% but range of reference porosity is 18-20%. So interpreted porosity is approximately equal to reference porosity of Fenchugonj gas field. Likewise, porosity interpreted for zone B(1992-2018m), zone C (2030-2086m)zone D (2148-2154m),zone E(2206-2260m),zone F(2510-2526m),zone G(2612-2648m).The main contribution of this research is the understanding of the rock physics of sandstones reservoir and its use in reservoir characterization i.e. lithology identification and porosity interpretation. The results of this research show that lithology has a significant influence on reservoir characterization. Porosity are the key parameter determined from wire line logs that are used in the evaluation of a subsurface reservoir as a potential hydrocarbon producer. That are measures of reservoir content but not reservoir performance, and by themselves do not provide an actual indication of the hydrocarbon productivity of a reservoir. Finally we can claim that the density log is the primary log for porosity computation when lithology is known. The neutron porosity log is affected by borehole conditions and is seldom used alone for porosity estimation. It is routinely combined with the density log to help in lithology determination and identification of gas-bearing intervals. The sonic log is mostly used for seismic applications. It can be used for porosity determination if local transforms have been established.


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# PERFORMANCE OF EPOXY RESIN-BASED CONCRETE

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## ABSTRACT

In the present investigation, a series of polymer modified concrete specimens based on epoxy resin have been prepared using various compositions of epoxy resins with view to compare their performance with conventional Portland cement concrete. Compression strength and porosity of both polymer modified and unmodified concrete specimens have been measured and it is found that the compressive strength increase and the porosity decreases with the addition of polymer in the concrete composition. It is also found that the properties of concrete can be varied in a wide range with the variation of concentration of the polymer materials in the composition and this property makes the Polymer modified concrete very versatile in applications. This paper describes the failure pattern of both Polymer Concrete (PC), polymer cement concrete (PCC) and normal Portland cement concrete.

**Key Words:** Polymer, concrete, strength, Porosity

## 1. INTRODUCTION

Concrete is the most widely used construction material in the world because of its high strength, easy applicability and low cost. Portland cement-based concrete, however, has got high porosity which makes it easy susceptible to the penetration of moisture, chemical vapor and corrosive ions in the structure resulting in rapid physical and chemical deterioration. To overcome these shortcomings, in modern concrete construction, the role of polymers is increasing day by day. Polymer can be incorporated as a co-binder along with Portland cement or used as a single binder. The composites made up of aggregates bound jointly by polymer and cement as binders are called polymer cement concrete (PCC), while composites made up of aggregates bounded by polymer only are called polymer concrete (PC). The incorporation of polymers greatly improves strength, adhesion, impermeability, chemical resistance and durability properties of the concretes [1-3]. These properties make the PCC suitable materials for making various structural and non-structural pre-cast products [1][4]. Performance of PC is strongly dependent on types and mix proportion of aggregates and polymer. Several investigations [5-11] have been carried out to

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evaluate performance of PCs with various polymers such as furan based resin, polystyrene and some latex and various mix proportions.

Epoxy resin has attracted the attention of the investigators by virtue of its many valuable properties such as good adhesion to many materials, controllable setting time, high strength of the hardened product, impermeability to moisture, chemical resistance and so on. Many investigators have studied different aspects of epoxy resin- based concretes. Blaga and Beaudoin (1985) have studied the compressive strength, tensile strength, flexural strength, modulus of elasticity, poisson's ratio, coefficient of thermal expansion, water sorption properties and density of epoxy resin-based concrete with view to compare these properties with unmodified concrete and other polymer modified concrete [12]. It is found superior mechanical properties of epoxy polymer concrete based on mechanical strength and physical properties. Vipulanandan and Dharmarajan (1989) have prepared epoxy based polymer concrete and analyzed the fracture parameters of this material [13]. It was found that all fracture parameters of polymer concrete increased with the increase in polymer content. Vipulanandan and Paul (1990) studied the performance of epoxy and polyester based concretes under various curing conditions, temperatures and strain rates [14]. Influence of aggregate size and distribution on the mechanical properties of polymer concrete was also investigated in the study. Manjrekar (1992) used epoxy along with 40% dibutyl phthalate, furan, polyamide as binding materials in preparation of polymer concrete and evaluated the compressive strength, tensile strength, flexural strength and modulus of elasticity of the concretes [15]. The result shows higher mechanical strength of polymer modified concrete compared to conventional concrete. Seshadri and Ramanakumar (1992) discussed practical applications of PMC based on epoxy resin and other polymers and concluded that the use of polymers in concrete as repairing material was expanding due to the increasing demands from construction industry in recent years [16]. Abdel-Fattah and El-Howary (1999) studied the flexural behavior of epoxy and polyester polymer concretes [17]. It was found that modulus of rupture was 3 times higher than conventional concrete. Howary et al. (2005) studied the compressive strength, tensile strength, shear strength and flexural strength of epoxy and polyester polymer concretes and compared with that of conventional concrete [18]. It was reported that compared to conventional concrete, both polyester concrete and epoxy based concrete were found higher in compressive strength, tensile strength, flexural strength and shear strength at room temperature. Gokhale (2001) studied two cases of the use of epoxy resins for structural corrections and connections [19]. It was reported that due to various unforeseen reasons the provisions made in the design of a structure required major changes and in those cases epoxy could be used for structural corrections and connections. Sebok and Stranel (2004) studied wear resistance of mortar and concrete. It was found that wear resistance of concrete and mortar can be improved markedly by the impregnation of epoxy resin [20]. Addition to epoxy resin and aggregates, Golestaneh et. al. (2010) added silica powder as filler in the composition, and found that the compressive strength of the epoxy polymer concrete was enhanced four times with the addition silica powder in the composition [21].

From the literature survey, it appears that the replacement of Portland cement with polymers as a binding agent results in concrete with much improved quality with respect to various properties such as compressive strength, tensile strength, flexural strength, modulus of elasticity, poisson's ratio, coefficient of thermal expansion, water sorption properties and density etc. Among all other polymers (furan based resin, polystyrene, some latex, Polyester and other acrylic based polymer), epoxy based-polymer showed the best performances with respect to most of the parameters, although as Vipulanandian and Paul (1990) and Ribeiro et al. (2004) reported, thermal property of epoxy based concrete is bit inferior to those of polyester based concretes. Some of these parameters might further be improved with addition to silica fume [Golestaneh et. al. (2010)].

In case of Polymer cement concrete (PCC), Howary et al. (2005) reported that the use of polymer (Polyester, epoxy) resulted significant increase in compressive, tensile, shear and flexural strengths and epoxy shows superior mechanical strength compared to polyester. The ACI committee-548 (1995) reported improved tensile, compressive and flexural strength, and higher coefficient of thermal expansion, acid resistance and wear resistance of epoxy based polymer cement concrete compared to unmodified conventional concrete. This is also a vast division of concretes. In this type of concrete (PCC), both polymer and cement act simultaneously as binders. The properties of the PCC could be varied with variation in the binder ratio. For complete hydrolysis of the cement, adequate amount of water must be added to the mixture, and at the same time, the addition of epoxy, which is also a liquid, will contribute to the fluidity of the composition. This will limit the maximum concentration of epoxy to be added for a given cement concentration. Moreover, the epoxy resin being insoluble in water, and depending on the nature of the hardener, which may dissolve in either in epoxy, water or in both, the mixing procedure will play an important role in the formation of concrete structure, bonding among the components and the final properties.

The work is merely a preliminary step towards the optimization of the composition of the epoxy based PCC. The concretes were prepared with locally available aggregates. The properties under investigation were porosity, density and compressive strength. The purpose of the study was to acquire some knowledge about the maximum and minimum limit of the resin that could be added to the composition and the failure mode of the concretes under compressive stress.

## 2. EXPERIMENTAL

### 2.1 Materials

The components of the concretes are Portland cement, epoxy resin, hardener (for the resin), sand (fine aggregate) and coarse aggregates (stone chips). Fine aggregate and coarse aggregates used in the present investigation for concrete were collected from localities Sylhet and Madhapara (Bangladesh) respectively. Cement and epoxy resin used as binding materials, also the hardener for the epoxy resin was collected from local market. The cement used in this study was a commercial ASTM type I ordinary Portland cement.

#### 2.1.1 Characteristics of the Fine and coarse aggregates

The particle size distribution curve of the fine and coarse aggregate is shown in Fig.1 and Fig.2 respectively.

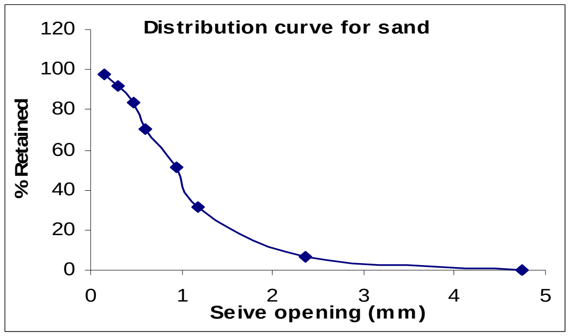


Fig.1 Particle size distribution curve for fine aggregate (sand)

The Figure 1 shows that the particle size of fine aggregate is in the range of 0.15-4.75 mm and about 50 % particles of fine aggregates are with sizes larger than 0.9 mm.

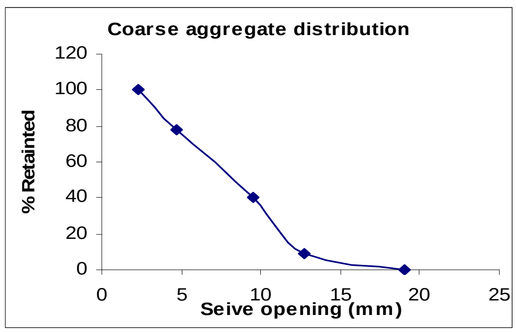


Fig.2 Particle size distribution curve for coarse aggregate

The Figure 2 shows that particle size of coarse aggregate is in the range of 4.75-19 mm and 50 % materials are presented in table-1. The chemical composition and some other characteristics (in weight percent) of the cement as follows: CaO-63.58, SiO2-20.44, Al2O3-5.34, Fe2O3-4.0, Loss on ignition-1.10, Insoluble residue-0.07 and Moisture content-0.5. The standard test-properties of the cement used as binder in the experiment is presented in Table 1

**Table 1** The standard test-properties of the used cement

| Test performed | Result |
|---|---|
| 1. Fineness test | 0.068% |
| 2. Setting time | |
| Initial | 2 hours |
| Final | 3 hours |
| Compressive strength | |
| 7 day | 14.92 MPa |
| 28 day | 19 MPa |

The setting time of Portland cement was determined by Vicat Niddle following ASTM standard method (C 191-82). The compressive strength and fineness of Portland cement also determined following ASTM standard method C109-80 and C 184-83 respectively.

The epoxy resin was used as collected from the market without further treatment/purification. As a commercial production exact chemical composition remained unknown. On laboratory test, the following property data was obtained at $30^0$C: Viscosity - 3600cps, Specific gravity-1.15 and pH= 7.70. Triethylene tetramine was used as a hardener of epoxy collected from market. It was in liquid phase and soluble to epoxy and water. It has specific Density 0.98gm/cm$^3$.

**2.2 Mixing, casting and curing procedure**

The samples were prepared using local Sylhet sand as a fine aggregate, Hard rock of Madhapara as a coarse aggregate, ordinary Portland cement and epoxy resin as a binder. The components (aggregates, binder and water) to prepare conventional concrete were mixed by a method and technique as prescribed by ASTM C 31-84. For the preparation of normal concrete specimens, the component ratio of cement-sand- stone chips was 1:2:4, and the water-cement ratio was maintained at 0.40.

A concrete mixer machine was used for concrete mixing. This had a moving bowl with a steel wall and mixing rod inside the bowl. To make the conventional normal concretes, cement, sand, coarse aggregate and water were mixed together for 2 minutes. To make the epoxy modified concrete (PCC), Portland cement, aggregates and water were mixed together for 2 minutes and then calculated amount of epoxy and hardener were fed into the mixer and was mixed with the pre-wetted compositions for 1 minute. In case of polymer concrete, sand, coarse aggregate were mixed together and then epoxy along with hardener mixture was added and mixed with the mixer machine for two minutes.

Through trial and error method, it is found that Polymer cement concrete can assimilate a maximum of 5 wt% epoxy content in its composition, and hence the study is made up to the concentration of 5 wt% (based on the total weight of concrete). More than 5 wt% polymers will cause extra liquidity of the mass leading to improper mixing. On the other hand, it is found that polymer concrete can assimilate a maximum 14 wt% epoxy content based on the total weight of concrete more than that will cause extra liquidity of the mass leading to improper mixing. It is also found that a minimum 10 wt% epoxy content required to bind aggregates properly to make polymer concrete.

The fresh concretes were cast into 152.4 mm cube molds with vibration following the procedure prescribed by ASTM, C 31-84 for compression testing. To examine the effect of epoxy on the workability (or flowability) of concrete, slump tests were done for the fresh concretes. The test procedure followed ASTM C 143-78 using a cone shape mold, 203 mm in bottom diameter and 102 mm in top diameter. Three slump tests were done for each mix and their average value was calculated. The concrete specimens were separated out from the mold after 24 hours of molding. Concretes with cement in its composition (conventional concrete, PCC) were kept in water for 7-28 days for curing and Polymer concrete was left to atmosphere for natural drying.

**2.3 Mechanical strength tests**

The compressive strength of 152.4 mm cube specimens of concrete were measured with a Universal Testing Machine (Model No.TIB/M.C; Capacity-300 Ton) equipped with data logger. Pace of loading was maintained at 0.5 N/mm$^2$/s three specimens of concrete were tested for each mix. The load was reported using a data acquisition system. Two hour before testing, the hardened specimens were taken out of water bath where they had been for 7 or 28 days for curing.

## 2.4 Determination of density and porosity

The samples were dried at room temperature $30^o$ C in atmosphere for 7 days until a constant weight $W_0$ of the specimen is confirmed. Then the dried sample was put under water in a water bath at room temperature. Initially at an interval of 1 hour and at the end at 6 hours, the samples were taken out, the water adhered to the surface were wiped by cloth and weighed. Then the sample is returned in the beaker. This process was repeated until the constant weight.
The parameters are determined by the following relations:

$$\rho_a = W_0 / V_0 \qquad (1)$$

$$\rho_T = \frac{W_0}{V_0 - (W_\infty - W_0)/\rho_w} \qquad (2)$$

and

$$\beta = 1 - \rho_a / \rho_T \qquad (3)$$

Where $\rho_a$, $\rho_T$ and $\beta$ are respectively apparent density, true density and porosity; $V_0$ is the bulk volume of the sample, $W_\infty$ is the weight at equilibrium and $\rho_w$ is the density of water.

# 3. RESULT AND DISCUSSION

## 3.1 Compression tests of concrete

The compressive strength of Polymer Concrete (PC) with different amount of epoxy content after 7 days and 28 days atmospheric curing is shown in the figure 3. The compressive strength of PC tended to increase sharply with the percentage of epoxy content. The strength gain rate is faster in first 7 days, about 81 MPa strength correspond to 92% of ultimate strength achieved in 7 days atmospheric curing which is very significant properties to consider this materials for repairing works. Maximum compressive strength of PC using 14 wt% epoxy based on total weight of the concrete at 28 days is 88.20 MPa.

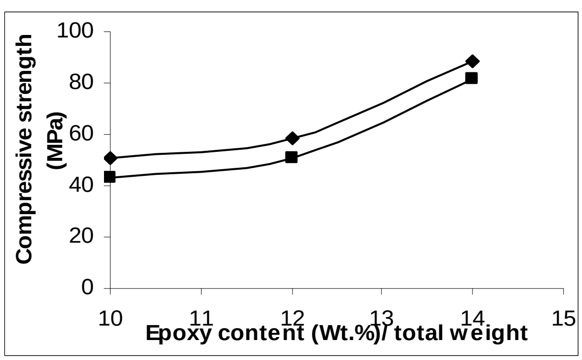


Fig. 3 Compressive Strength vs. epoxy content (wt.%)/total weight of the specimen curve for Polymer Concrete. . (♦) 28 days curing (■) 7 days curing

Through trial and error method, it is found that PC could assimilate a maximum of 14 wt% epoxy content in its composition. More than that causes surplus liquidity that result in lower strength of the concrete.

Golestaneh et. al. (2010) have reported highest compressive strength 75 MPa for PC with 10% epoxy, locally available aggregates and 100% waste silica powder and strength increased to 98 MPa with the addition of 15% epoxy with the filler composition remaining same. Blaga and Beaudoin reported maximum 50-150 MPa compressive strength for epoxy polymer concrete. Manjrekar has reported 65 MPa compressive strength for PC with 10% epoxy and filler (fine aggregate and coarse aggregates). To the contrary, Figure 3 shows maximum 88.20 MPa compressive strength for PC using 14% epoxy resin, locally available sylhet sand and coarse aggregates. Figure 4 shows that effect of epoxy composition on compressive strength of Polymer Cement Concrete (PCC). The strength gain rate of PCC is not as high as PC.

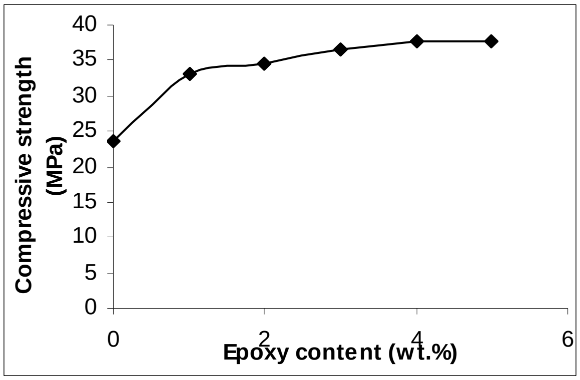


Fig. 4 Compressive Strength vs. epoxy content (wt.%)/total weight curve for Polymer cement concrete

Hawary et al. has reported about 38 MPa compressive strength of PCC with 60% epoxy (based on weight of cement). ACI committee (1995) has reported maximum 51 MPa compressive strength for PCC with 2.70 % epoxy ( based on total weight of the concrete) in Portland cement concrete. To the contrary, Figure 4 shows a compressive strength of as low as 35 MPa for epoxy polymer cement concrete with 3 % epoxy, locally available Sylhet sand and coarse aggregates. This justifies the experimentation with apparently known composition from the literature and to put effort to achieve improved concrete properties in our context.

### 3.2 Concrete failure pattern

Photographs of the fracture surface of normal Portland cement concretes showing unbroken coarse aggregate after compressive failure (fig 5a). It mentions that the most of the stone were easily de-bonded and can be explained by the poor bonding in normal concrete.

Fig-5 (a): Normal concrete after failure

But in case of polymer concrete, the failure behavior had changed from a de-bonding of the coarse aggregate from the matrix to cohesive fracture of the coarse aggregate due to the addition of epoxy resin. The fracture surfaces of polymer concrete specimens after compressive failure were very smooth shown in the fig.5 (b). That indicates all coarse aggregates were broken in a regular shape. It explains the strong bonding between coarse aggregates. Even after compressive failure, the structure was maintained in case of polymer concrete.

Fig-5 (b): Polymer concrete after failure

It is also observed that particle size of aggregates has great influence on mechanical behavior of PC and improve mechanical strength. According to experimental data, Polymer concrete using 12% epoxy provide 58.24 MPa compressive strength using 19 mm down coarse aggregate after 28 days curing but 64.50 MPa compressive strength was obtained using 12.7 mm down coarse aggregate at the same composition of epoxy. The result indicates that the particle size of aggregate has great influence on mechanical strength of the polymer concrete

Fig-5 (c): Polymer cement concrete after failure

Table-4: Physical properties of polymer modified and unmodified concrete

| Types of Concrete | Porosity (%) | Apparent density (gm/cc) | True density (gm/cc) |
|---|---|---|---|
| Normal Concrete | 2.90 | 2.67 | 2.75 |
| 1% Polymer cement Concrete | 2.20 | 2.56 | 2.62 |
| 4% Polymer cement Concrete | 1.21 | 2.44 | 2.47 |
| 12% Polymer Concrete | 1.30 | 2.27 | 2.30 |
| 14% Polymer Concrete | 0.42 | 2.33 | 2.34 |

The photograph of a fracture surface of polymer cement concrete specimen is shown in the figure 5©. The figure shows unbroken coarse aggregates after compressive failure that indicates weak bonding between coarse aggregates.

**3.3 Porosity, apparent density and true density of different types of Concrete**

Percentage of porosity, apparent density and true density determined for conventional concrete, polymer cement concrete and Polymer concrete (PC) is summarized in table-4.

The result indicates that the concrete modified with polymer shows lower porosity comparative to normal conventional concrete. It can be easily explained that the polymer formed film inside the concrete and fill up the voids. Porosity percentage decreases with increasing percentage of polymer application. In case of normal Portland cement concrete, water added to react with cement that occupied some space in concrete during casting. After casting extra water dried out, this creates voids. But in case of Polymer concrete, no Portland cement was added so there was not required to add any water. This is why in case of polymer concrete, porosity is very lower. The result shows the porosity of polymer concrete prepared with the addition of 14 wt% epoxy (based on total weight of the concrete) is 0.42% which is negligible compared to that of conventional concrete.

## 4. CONCLUSION

The addition of small amount of epoxy resin caused several changes in the microstructure and properties of concrete. For, Polymer concrete, The compressive strength after 28 days air curing were increased in three folds comparative to conventional Portland cement concrete and the increase was greater with greater epoxy content up to 14 wt% based on total weight of the concrete. The fracture behavior had changed from a de-bonding to cohesive failure of the coarse aggregate due to the addition of epoxy resin.

Polymer concrete shows their superior mechanical properties. This material can be used where higher compressive strength is required. It can provide early strength with quick setting. It has very lower porosity comparative to normal concrete so it can be the candidate material for damp proof. Due to high strength and light weight properties, PC would be highly effective and economically viable in the construction of structures with specific requirements such as in marine environment, for protection from flood and earthquake. In the seashore area of Bangladesh, hydraulic structures and constructional works could be done by Polymer modified materials.

Mixing procedure in case of polymer cement concrete is also important. In case of conventional concrete water must be added to react with cement. But polymer especially epoxy is not soluble in water so it forms a heterogeneous phase as a result polymer is not distributed properly through out the mixture which results lower strength. So recommended procedure is to mix the hardener with water properly and then added epoxy and stirred preferably mechanically, until uniformly mixed. Then cement, sand, coarse aggregates and half of the mixture should be loaded in to the concrete mixer and blended. The remaining mixture should be added in to the mixer machine and thoroughly mixed which usually takes maximum 5 minutes.

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# SAFETY, HEALTH AND ENVIRONMENT IN THE CONSTRUCTION SECTOR IN SYLHET REGION

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## ABSTRACT

Safety, Health and Environment in the construction sector are major requirements for the smooth conduct of construction work. The main purposes of this study are to evaluate safety, health and environmental condition in construction sites of Sylhet, the major city of the north- eastern region of Bangladesh, as well as to suggest ideal conditions for this. Some small and large construction sites were surveyed to identify hazards, health problems, measures that are taken for safety and health of workers, environmental conditions, training needs etc. In Sylhet city context it was found that in most of the building construction sites both contractor and laborers are reluctant to provide and use personal safety measures due to lack of knowledge and experience. Contractors are adopting their own means and standards. In most cases contractor are not willing to supply safety equipments. They want to save more money by procuring less safety equipments. It was also found that though safety equipments are available in any site, the workers did not use them because they are not used to using those. As labor is cheap, manual process is used here in many cases, often causing injury to many people, whereas in many develop countries mechanization has no other alternatives. There are also no standard for safety precautions that could legally be enacted by city management authority. There is no central authority to monitor and control the whole scenario, similar to that in developed countries. With the active presence of such a body frequency and severity of accidents could be reduced significantly. At this moment this construction sector in Sylhet region needs standardization and central coordinated control to develop more efficiency and safety.

**Key Words:** Construction, Safety, Health, Environment, Workers, Safety equipments, Hazard, Accident, Ideal/Standard Condition

## 1. INTRODUCTION

Construction is a high hazard occupation. It has the third highest rate of death by injury. Construction lost more workers to traumatic injury than any other major industrial sector during last several years. The leading causes of death among construction workers are fall from elevations, motor vehicles crashes, electrocution, machines, struck by falling objects and construction related diseases etc. Accidents and diseases can occur at any time, almost anywhere and to anybody. However, assurance of safety and health in our everyday life has become most desirable.

With the arrival of sophisticated technology people now-a-days choose to undertake ambitious projects in every facet of life. Building construction is one of such undertaking, which emerged appropriate as a new building typology in urban centers. High-rise buildings have to adopt more technical support such as elevators, fire escape, firefighting equipment, generator, etc. for its use in tight disciplined manner compared to a low-rise walkup building. Similarly, the construction process

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of a high-rise building also involves high technological and large-scale equipment and materials that require more and special precautions. Failure at any point in the process results in inconvenience, inefficiency and sometimes accidents that lead to physical injury and even death. In addition to this, lack of proper water supply, sanitation, waste management in construction sites may also lead to health hazard of the labors. Sylhet, the largest city in the north eastern region of Bangladesh is growing very fast, as a result of which construction activities are also increasing with a tremendous speed. But it is observed that in most of the building construction sites of the city both contractor and laborers are reluctant to provide and use personal safety measures due to lack of willingness, knowledge and experience. In order to help in identifying opportunities for improving workflow and productivity of individual activities and reduce construction accidents in construction sector of Sylhet the present study was undertaken. The main objectives of this study are to:

- To observe the present condition regarding health, safety and environment of construction sites
- To identify the most vulnerable situations
- To suggest way to mitigate the vulnerability
- To suggest ideal conditions for construction

## 2. METHODOLOGY

Several field surveys were conducted in residential as well as in commercial buildings which are 5 to15 storied and are under constructions, in different locations of Sylhet region. Careful observation of construction sites, working environment, safety conditions and accommodation systems etc. were performed. In every site, at first a questionnaire survey was conducted by asking each site engineer or responsible persons about the project, present working condition, their safety equipments, which type of safety equipments they are presently using, which type of equipments they should use but are not using and finally which type of accidents occurred during last 1 to 1.5 years due to reluctant of using safety equipment. Then a questionnaire survey was conducted by asking each worker if he faced any construction work related hazard or accidents and if he has been suffering from any health problems such as Skin diseases, Dermatitis, Hand-arm vibration, Masculo-Skeletal Disorder (MSD), Numbness in hand fingers etc. during last 1-1.5 years. Besides, a few number of professionals like architects, structural engineers, site engineers, contractors, supervisors, site in charge and laborers who are involved with the building construction and operation in Sylhet region, other than the surveyed sites, were also interviewed.

## 3. PREVIOUS STUDIES

From the study of M. Ashrafuzzaman and M. H. Rahman (2011) a comparison of using safety measures between Dhaka City and Sylhet City was found which is shown in table- 1. It is seen that Sylhet is lagging behind in this context.

P. C. Saha and M. J. Abedin (2005) observed that majority of the workers were not used to using safety equipments such as hand gloves, helmet, safety gloves, safety glass, safety boot, gum-boot, masks and hearing protection equipment etc. Some accidents were recorded which were related to electricity such as electrocution. In many construction operations such as painting, spraying and structure reinforcing with chemical compound and operations related with gas, oil, chemical etc, construction engineers and workers were exposed to chemically polluted air environment.

Recently Alam and Yadav (2011) collected some noise level from various construction sites of Dhaka and Sylhet Cities. They are tabulated and represented in a chart (Table-2). These results are almost similar with the findings of Sharmin (2009). It was found from the study that the energy equivalent continuous noise level, $L_{A\,eq}$ is observed started from 90 dB and ended on 100 dB. The maximum noise level is recorded for 106 dB while mosaic finishing is going on in a construction site.

**Table 1:** Comparison of safety practice between Sylhet City and Dhaka City

| SI no | Name of Safety measures | In Dhaka | In Sylhet |
|---|---|---|---|
| 1 | Security Fence | 93% | 33% |
| 2 | Regular Safety Inspection | 100% | 33% |
| 3 | Heavy Equipment Safety | 57% | 17% |
| 4 | Safety Sign Board | 93% | 53% |
| 5 | Illumination Practice | Medium | Bad |
| 6 | Fire Resisting Construction | 43% | 14% |
| 7 | Construction workers safety | Medium | Bad |
| 8 | Fall protection facilities | 93% | 20% |
| 9 | Safety for Engineers | Medium | Bad |
| 10 | First aid facilities | 28% | 14% |

.**Table-2**: Noise level in Construction Sites (Combined in Dhaka & Sylhet Cities)

| **Construction works** | $L_{A10}$ | $L_{A50}$ | $L_{A90}$ | $L_{A\,eq}$ | $L_{AE}$ | $L_{A\,max}$ |
|---|---|---|---|---|---|---|
| Brick Crushing (By machine) | 96 | 90 | 87 | 90 | 97 | 103 |
| Drilling | 90 | 88 | 84 | 89 | 93 | 90 |
| Framing Beams and Columns | 97 | 95 | 91 | 97 | 104 | 102 |
| Hammering | 93 | 91 | 69 | 96 | 97 | 99 |
| Iron bar straightening | 91 | 87 | 81 | 98 | 111 | 97 |
| Mixing aggregate | 95 | 90 | 87 | 91 | 102 | 100 |
| Mosaic Smoothening | 103 | 99 | 94 | 100 | 115 | 107 |
| Piling (Cast in Situ) | 86 | 84 | 80 | 84 | 112 | 93 |
| Tile Cutting | 104 | 97 | 94 | 99 | 112 | 106 |

## 4. DATA ANALYSIS AND RESULT OF SURVEY STUDY

### 4.1. Safety Measures

Safety means personal safety of the workers and other safety such as Security fence, Safety net or falling protection, Safety signboard etc. Efficiency and success of a construction site depends upon the using of safety measures. Among personal safety the most common are helmet, safety gloves, safety glass, gum-boot, safety-boot, safety belt etc.

#### 4.1.1. Personal Safety

The percentages of safety measures being used at present in Sylhet City are shown in table- 3. From the study it can be said that a large portion of labors are not using safety measures. According to the concerned persons sometimes labors do not want to use safety measures due to uneasiness, although they have the equipments.

**Table 3:** The percentage of personal safety measures being used at present in Sylhet City

| SI no | Item | At Present are in used (%) |
|---|---|---|
| 1 | Helmet | 50 |
| 2 | Hand gloves | 33 |
| 3 | Gum-boot | 50 |
| 4 | Safety boot | 50 |
| 5 | Safety belts | 66 |
| 6 | Safety glass | 16 |
| 7 | Ear Protection | 0 |
| 8 | Masks | 0 |

### 4.1.2. Safety Net

Safety nets are used to protect the falling of materials from top on the road, on foot path or on the people. In some construction sites the safety nets are not used or not properly used. In some areas it is provided with cement bags or jute bags. In figure- 1 a building under construction is shown, where inadequate safety net is used. Figure- 2 shows the overall scenario of using safety net in Sylhet City by pie chart. It is seen that 50% of the sites do not use safety net at all or do not use properly.

**Figure 1:** This is a figure of using inadequate safety net in a high-rise building at Zindabazar site

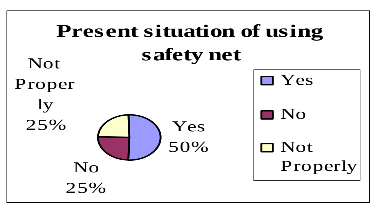


Figure 2: Present situation of using safety net in Sylhet City

### 4.1.3. Safety Fence

Safety fence or security fence are used to protect the outside vehicles and people from entering into the construction sites and also protect the people from falling into dangerous areas. Figure- 3 shows a 15 storied building under construction at Zindabazar which has not used safety fence.

**Fig-3:** Cavity in the stair room, there is no safety fence around it, so accident can take place any time.

The existing situation of using safety fence in Sylhet City is shown in the pie chart shown in figure- 4. It shows that most of the construction sites have no safety fence.

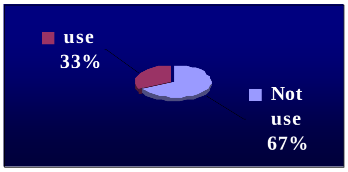


**Figure 3:** Existing situation of using safety fence in Sylhet.

#### 4.1.4. Safety Sign Board

Safety signboards are used for warning the people that the construction operation is going on or, the area is dangerous. The existing situation of using safety Sign Board in Sylhet City is shown in the pie chart (figure- 5). It shows that 80% of the construction sites do not have safety sign boards.

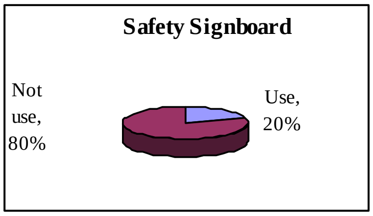


**Figure 4:** Existing situation of using safety sign board.

#### 4.1.5. Preliminary Treatment /First Aid

There is no preliminary treatment/ first aid box in any construction site.

#### 4.1.6. Regular Safety Inspection

Regular safety inspection is very rare. Chart in the figure- 6 shows in only 33% of sites arrange regular safety inspection.

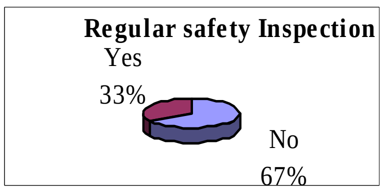


**Figure 5:** Regular Safety Inspection practice in Sylhet

### 4.2. Health Hazards, Injury and Death

In Construction sites many health hazards take place. Usually they are ignored. Only a few numbers of major hazards are recorded. During the field visit a questionnaire survey was conducted asking the workers about their health problems related to construction operation. From the bar diagram in figure-6 their health problems can be seen. Injuries of hand or finger, followed by skin disease are the main health problems in construction sites.

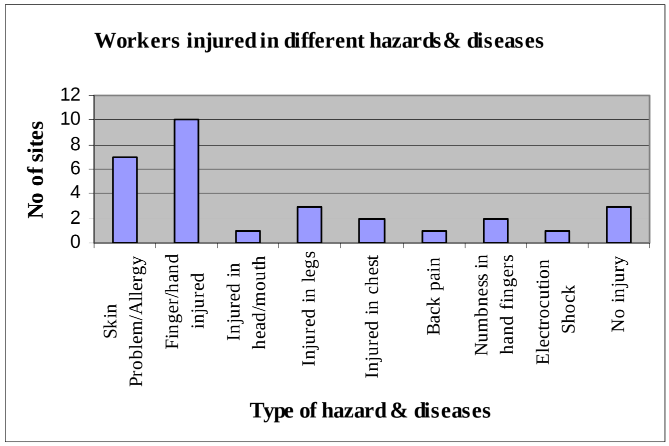


**Figure 6:** Different health problems workers suffer from during construction operation

During survey in construction sites some injury and death cases were shared with the workers. Some are as follows: (i) A worker aged 25/26 years fell down with scaffold during outside plastering due to loose fastening of scaffold and edge of a bamboo penetrated to the joint of his arm and shoulder and became invalid (ii) a woman worker (helper) fell down with a 50 kg cement bag on her head during lifting it from 7$^{th}$ floor to 8$^{th}$ floor and yet is suffering from pain in chest, legs and backbone (iii) A labor discussed that about 2 years ago a labor stroke his own head accidentally during cutting of M.S rod and instantly died (iv) another rod mason said that during cutting of rod by electrical machine with open hand (without gloves) he was shocked by electricity and seriously wounded.

### 4.3. Environmental Situation

Environmental Situation in the construction site is very bad. In maximum sites the workers make their living and dining areas with worn polythene or cement bags (Figure- 8), which are aesthetically and environmentally not friendly. Supply of drinking water is rare, maximum time they drink impure water which is supplied for construction work. Sanitary condition is also the same. There is no proper waste management; especially debris is not removed regularly.

**Figure 8:** Living and dining area of the workers of a site.

Construction sites create a great disturbance to the surrounding people, particularly in residential areas. If the site is shielded or have a high barrier, the residents get a little relief. It is a long process to build a house and the period of disturbance is also high. In construction area, air is polluted with $CO_2$, CO, $NO_x$, SPM, PT, VOC etc. Workers do not use masks and suffer from various health problems. The surrounding people also suffer from the same problems. There are also high noise problems due to operation of mechanical excavator, mixer machine, vibrator, welding machine, rod cutting machine, stone crasher etc. If sound protection wall or, devices or ear protection devices are used, the sound problems can be solved. But in the surveyed sites there is no measures of such type were found.

## 5. SUGGESTION FOR SAFETY MEASURES

Some suggestions are provided below in table- 4 for proper safety in the construction sites, which were collected from the safety measures format of Chevron Bangladesh.

**Table-4:** Proper safety measures in the construction sites.

| | | |
|---|---|---|
| **5.1.Earth excavation** | | |
| Excavation by Manually | Hit by spade and Stuck against, Cut, Soil collapse, Heat stress, Slip, Slip and Fall. | Maintain the safe distance, Use safety rubber Boot/Shoe and hand gloves, Maintain sloping and shoring, Stack the soil in a safe distance. Working sequence and drink of sufficient water. Address the slip and trip hazard, Area roped off. |
| Shoring | Cut, Slip, Trip, Heat stress. | Use safety rubber Boot/ Shoe, Working sequence and drink of sufficient water. |
| Leveling and Dressing | Hit by spade and stuck against cut, Slip, Trip and Fall | Maintain the safe distance. Use safety rubber boot/shoe. Address the slip, Trip hazard and Watch the step. |
| **5.1.Earth excavation** | | |
| Excavation by JCB | Stuck against, Cut, Soil collapse, Heat stress, Slip Trip & Fall, Electric under ground\cable, Damage, Insect bite, Eye contact, Personal accident. | Maintain the safe distance, Use safety rubber Boot/Shoe & Hand gloves, Maintain sloping & shoring. Stack the soil in a safe distance. Working Sequence & drink of sufficient water. Address the slip & trip hazard, Area roped off. Address the electric cable, Use eye Protection. Keep the viewers away from Excavator. |
| Stack Soil | Soil collapse, Slip, Trip & Fall | Stack the soil in safe distance. Address the slip trip hazard & watch the step. Area roped off |
| **5.2.Earth filling** | | |
| Place equipment in appropriate &safe location | Hit, Stuck, Ignition source | Maintain vehicle speed limit. Assign vehicle signaler. Don't place the equipment close to the process equipment. Barricaded area with caution tape, Stay in a firm and dry location, Keep fire extinguisher with vehicle |
| Ride on the truck | Pinch point | Recognized pinch point prior to start work & keep in mind during work. |
| Unloading local truck. | Hit by Eye contact, Sharp object. | Maintain safe distance, Use safety glass, Use cotton gloves. |
| Earth, back filling | Hit by spade & stuck against cut, Slip, Trip &Fall. | Maintain the safe distance, Use safety rubber boot/ shoe, Address the slip, Trip hazard & Watch the step |
| **5.3.Brick Work & plaster** | | |
| Brick cleaning | Dust/chips Scratch on hand | Use safety glass, Use rubber hand gloves |
| Carrying of Brick | Fall down on foot, Back injury, Slip-rip. | Use trolley / Don't carry more than 2 bricks together. Keep walk away clean. |
| Preparing & carrying sand-cement mixture | Dust, Slip, Trip, dust or any foreign materials can attack eyes. | Use dust mask, Keep walk away clean & Don't carry by head, Don't horseplay when carrying the load, Use safety glass. |

| | | |
|---|---|---|
| Chipping& plastering | Brick chips /mortar can attack eyes. Hammer can hit. | Use safety glass, Use cotton hand gloves, Hold the pan firmly, Keep the pan securely. |
| Manually Lifting Brick | Fall down, Back injury, Slip, Trip, Drop on Foot /head. | Lifting job should be done safely slowly & properly, Don't stay under lifting Brick, Tide the rope firmly. |
| Working at height | Fall down | Making scaffolding and bracing.<br>Use harness belt. |
| **5.4. Rod cutting & Binding** | | |
| Rod straightening | Hit by rod and hammer, Pinch point, Sharp edge, Trip, Flying Object | Pre inspection of hand tools, Hold the rod firmly. |
| Rod cutting | Sharp edge, Pinch. | Use hand glove |
| Rod binding | Sharp edge, Eye contact, Trip. | Use hand gloves, safety glasses, Keep working area clean, Address the slip and trip hazard. |
| **5.5. Concrete Pouring** | | |
| Start Mixture Machine | Hit by starting handle, Rotating wheel/belt | Area roped off, Use cotton gloves, Use ear plug, and Check wheel guard. |
| Loading and mixing of concrete into bucket and then transfer to funnel | Cut/Hit, Overload (Back injury), Slip, and Trip, Eye contact, Dust. | Maintain distance for one to another, Maintain safe distance from rotating parts, weighty materials to be carried by two men, Keep walkway clean, Use all basic PPE including rubber gloves and rubber safety boot |
| Manually carrying | Drop on Foot, Slip and Trip. | Hold the pan firmly, Clean walkway. |
| Lifting of concrete at height (No more then 6 ft so that no person need to work at height. | Bucket fall and Concrete fall, fall down from height. | Bucket to be firmly roped by shekel, pre-inspection of wire sling, Use new wire sling and tie up properly, Bucket lifting by winch , Tami pipe tied with funnel firmly, No more then 6 ft so that no person need to work at height . |
| **5.6.Door & Fan-light Fitting** | | |
| Door & Fan-light fitting. | Sharp edge, Eye contact, Trip. | Use hand gloves. Use safety glasses, Keep working area clean. Address the slip & trip hazard. |
| Lifting door & fan-light manually | Fall down, Back injury, Slip Trip. | Lifting job should be done safely slowly & properly, Don't stay under lifting door & fan-light. |
| **5.7. Welding** | | |
| Arc welding by generator | Bump, cut, Pinch point<br>Fire from sparks & flammable/combustible materials, Burns Radiation from welding arc Hit stress. | Wet condition or any raining welding activities, should stopped, Don't use welding holder for grounding a welding machine. Don't use any broken welding holder for any reason, Regularly inspect welding cable, extensions, junction box etc. |
| **5.8 Painting** | | |
| Surface preparation or | Dust, eye contact, cut, pinch point, fall down | Use dust musk, safety glass, cotton gloves, hard hat & harness belt. |

| | | |
|---|---|---|
| Thinner mixing | Splash out to eyes, Splash out to hand, Splash out to body | Use clear safety glass with side shield, Use cotton gloves, Use rubber apron. |
| Carry out the paint bucket | Fall, Trip or Slip. | Move carefully when carrying paint bucket. |
| Involve person | Lake of knowledge about paint. | Need to study MSDS and implement it. |

## 6. CONCLUSIONS

Safe work practices in small and big building construction play an important role in reducing injuries and fatalities in the construction sectors.

During survey it was found that in some cases the workers could not properly say about the accident or, injury or, they were not willing to express the actual condition of the accidents and injury. But in many cases workers were very enthusiastic in expressing their accidents and health hazards, as they thought that the survey was from government body and necessary steps would be taken from the central authority to reduce their health problems and hazards. Sometimes it was found that the contractors kept the true picture of the accidents and their nature obscure.

According to survey record it appears that major accidents happen very rarely or never in the whole process of a high rise building construction. Only minor accidents and injuries are commonly recorded which do not always involve the owner or the contractor with big amounts of financial loss or penalty and also followed by no legal procedure. The real situation of accidents in the high-rise building construction sites remains in dark. Contractors are not always found willing to provide personal safety materials like gloves, shoes, belts, helmets etc, while laborers are also found reluctant to use these safety materials during work. Another reason of supplying inadequate safety materials to the laborers by the contractors is that the contractors want to save more money by procuring less safety materials. In most cases many health diseases were also found among the workers which were work related. Their living areas were also not satisfactory. During survey it was found that the overall safety, health and environment condition in construction sector in Sylhet region is very poor. Absence of accountability in all aspects is also deteriorating the situation in construction sector. As high-rise construction sector is new in Sylhet region it is time to develop safety, health and environmental standard in construction sector.

The purpose of this study is to understand and to reduce the injuries, accidents, health diseases and it’s severity and to improve the working environment. Concerned persons may use this information to assess their workplace and create the safest and most productive worksite possible.

## 7. ACKNOWLEDGEMENT

The help of Next Plan Consultancy Firm is acknowledged for providing some field data. Also authors want to express gratitude to Md. Saiful Islam, Assistant Professor, CEE, SUST for providing necessary advices regarding the study.

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# STRATIGRAPHIC ANALYSIS OF FENCHUGONJ GAS FIELD, SYLHET

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## ABSTRACT

The Fenchugonj structure is located in the southern part of the Surma Basin which is potential for hydrocarbon accumulation in Bangladesh. As we know that the hydrocarbons are accumulated in a stratigraphic formation therefore the proper identification of such succession is greatly important. From this point of view, the present research analyzed the stratigraphic succession of the field based on different seismic sections interpretation which included the well data, wireline logs as well as laboratory analysis. The drilled section represents the Dupi Tila, Tipam, Bokabil, Bhuban and Barail Formation. The formation and age boundary are drawn with the help of Paleontological studies, Geo-chemical evaluation of detailed study of cores, ditch samples, log and drilling data. The sediments of this structure consist of the alternation of shale and sandstone of Oligocene to Recent age. The gas bearing sands of this structure are within Lower Bokabil to Upper Bhuban Formations of the Late Miocene age.

**Key words:** Fenchugonj structure, Surma Basin, Well data, Wireline log data, Stratigraphic Formation.

## 1. INTRODUCTION

The Fenchugonj Gas Field belongs to the Fenchugonj Upazila of Sylhet district at distance of about 40 km south of Sylhet town, bounded by Longitude $91^{0}53^{'}$ – $92^{0}$ E and Latitude N $24^{0}30^{'}$ – $24^{0}37^{'}$ N which is 30 km long and 8 km wide. It is a surface anticline (reverse faulted) in an area occupied by low hillocks and trending in a direction NNE-SSW. This field is a ‘producing’ one, after completion the drilling and well testing activities. This field is located near the western margin of the folded belt (Fig. 1) and lies in block 14 under PSC (Production Sharing Contract) (HCU/NPD, 2004) which was discovered by Petrobangla in 1988 and is operated by Bangladesh Petroleum Exploration & Production Company Limited (BAPEX) (Imam, 2005). At present, the gas field comprises of three wells. The Fenchugonj well #1 was drilled by PPL in 1960 to a depth of 2438 m and abandoned as a dry hole. Fenchugonj well #2 was drilled by Petrobangla in 1985 to a depth of 4977 m. The well was completed on 1986 and three gas bearing zones named as Upper Gas Sand, Middle Gas Sand and Lower Gas Sand were discovered. Fenchugonj well #3 is now on production stage and

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till now two gas bearing zones named as Upper Gas Sand and Lower Gas Sand are discovered (BAPEX, 1988).

The objective of this research is to analyze the lithology of this structure and define different formation by analyze seismic sections of different depth and finally interprete the analyzed results for understanding the Stratigraphic formation of the area.

### 1.1 Structure and Stratigraphy of the Studied Area

Fenchugonj structure is situated on the Sylhet trough, which has been formed due to continuous uplift of Shillong Massif with simultaneous subsidence. This trough is situated south of Shillong Massif and corresponds with the vast low lands of Surma valley. It is an oval shaped trough represents negative anomaly. In cross-section, it is sharply asymmetric with steep north flank and gentle south flank shown in Fig. 2 (Alam et al., 1990). The Fenchugonj structure appeared as a reversely faulted anticline with a NNE-SSW trending axis. The amount of dips in the eastern flank varies from $30^0$-$35^0$ and in the western flank is $20^0$-$25^0$ and the dips on the flanks increases with depth. The sediments of Fenchugonj structure consists of alternate shale and sandstone in varying proportion of Oligocene to Recent age. The stratigraphic succession of the Fenchugonj gas field is shown in Table-1.

## 2. METHODOLOGY

The research attempts to analysis the stratigraphy of the Fenchugonj Gas Field on the basis of reinterpreted seismic sections. Seismic prospecting is the best and most popular indirect method used for locating subsurface structures and stratigraphy that may contain hydrocarbons. The waves travel downward and outward, encounters the interface between rock layers with different seismic velocity characteristic. Geophones are placed on the surface to detect these reflections and connected to a recording truck for data storage. The basic seismic method consists of data acquisition, processing and interpretation of equipment. In this research, available seismic reflection and well data have been integrated and reviewed which were acquired by BAPEX. These data were interpreted to obtain information on the structure and stratigraphy of the area. The Geophysical wireline logs has been analyzed to interpret stratigraphic formation from well lines to seismic lines by putting the depth values into Time-Depth (T-Z) curve shown in Fig. 3 (Gadallah and Fisher, 2009).

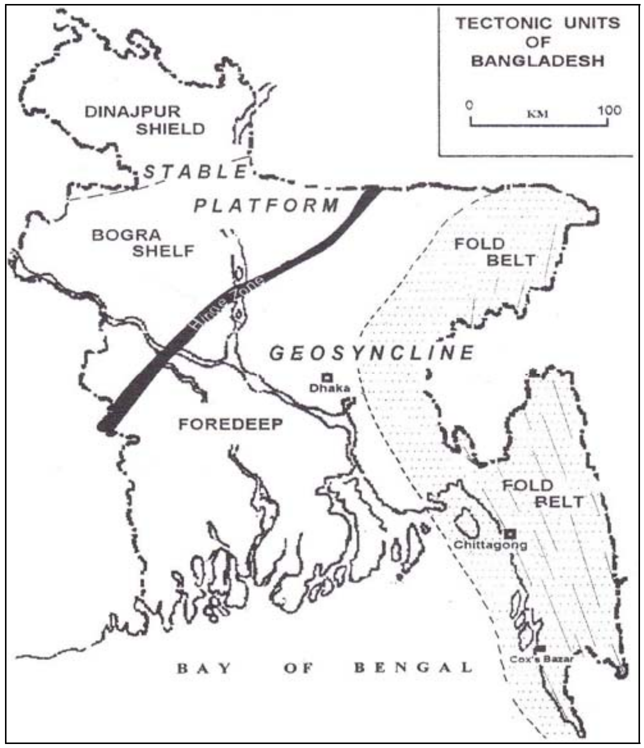


Fig. 1: Tectonic framework of Bangladesh (after Imam, 2005)

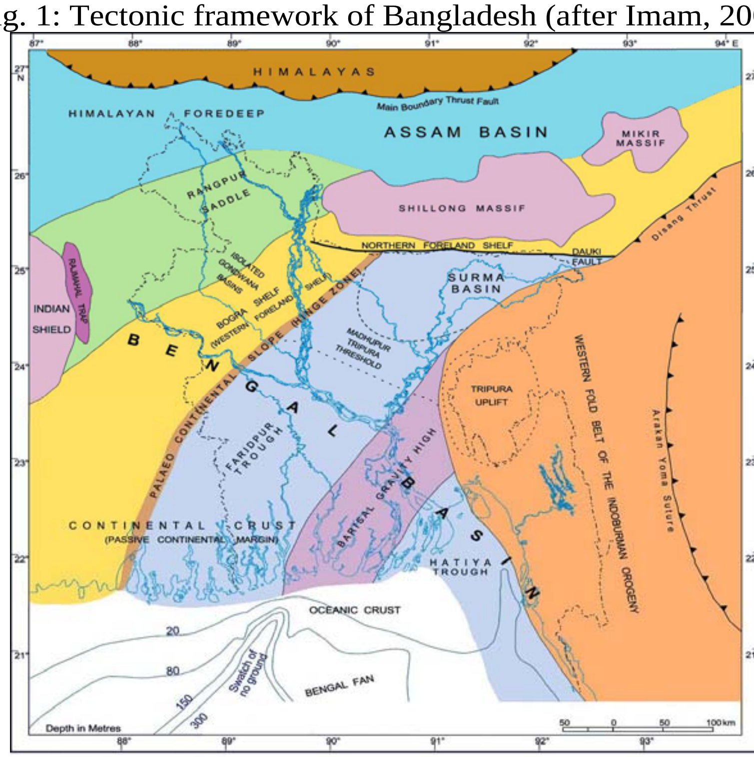


Fig. 2: Tectonic map of Bangladesh (after Alam et al., 1990)

Table 1: Stratigraphic Succession of Fenchugonj well (BAPEX, 1988)

| Age | Formation | Max. Thickness (m) | Member | Lithology |
|---|---|---|---|---|
| Recent | Alluvium | 30 | | Unconsolidated sand, silt and clay |
| Middle Pliocene | Dupi Tila | 290+ | | Coarse sandstones with soft clay |
| Early Pliocene | Tipam Sandstone | 890 | | Very coarse to medium sandstone with soft clay |
| Late Miocene | Upper Bokabil | 270 | | Medium sandstones with poorly laminated shale |
| | Middle Bokabil | 300 | | Medium to fine sandstone with well laminated shale |
| | Lower Bokabil | 470 | | Fine to very fine, sandstones and well laminated shale |
| Late Miocene | Upper Bhuban | 930 | Upper | Silty shale with fine grained sandstone |
| | | | Middle & Lower | Alternations of well laminated shale and well consolidated sandstone |
| Middle Miocene | Middle Bhuban | 1140 | | Minor sandstones with intercalated shale |
| Early Miocene | Lower Bhuban | 530 | | Laminated shale with coarse to very fine minor sandstone |
| Oligocene | Renji | 157+ | | Well laminated silty shale & fine sandstone |

## 3. RESULTS AND DISCUSSION

### 3.1 Stratigraphic Interpretation

Seismic reflections primarily depict time relationships. The lithological information conveyed by the reflection contributes. The stratigraphic succession of this field is based on well data, wireline logs as well as laboratory analysis. These successions are shown in Fig. 4-8. The drilled section represent by Bhuban, Bokabil, Tipam Sandstone, Renji and Dupi Tila Formation. The formation and age boundary are made with the help of Paleontological studies, Geo-chemical evaluation of the cores, ditch samples, log and drilling data. The core samples are taken from different formation, analyzed by Geo-chemical lab. Moreover, Gamma Ray log runs into the formation at depth column and disturbing at the depth of 2062-2081 m and 2768-2781 m for the presence of hydrocarbons. The gas sands were mainly identified from SP, RES, GR, CAL, DEV, FM and CBL logs (Bassiouni, 1994); although other suits of logs were analyzed during stratified formation and most of the time they are parallel with Gamma Ray log. Both of reflecting horizons produces continuous reflection all over the sections. Sometimes its may strong and sometimes its may light reflection. But the deviation is not more than $15^0$. Mostly, the alternations of Sandstone and Shale are found into the formations. Above this depth, the pay zones are named as Upper and Lower gas zone, respectively. Some of heavy minerals are also found at deeper depths which are not commercially viable. Each of the formation is now put into seismic lines to define the stratigraphic succession and identify individual lithologies.

From preceding analysis, taking time against depth of every formation from Time-Depth (T-Z) curve (VSP) (Fig. 3) and put on seismic line for defining the stratigraphic formation. Here, Middle and Lower Bhuban, and Barail Formation have no time value from T-Z curve. At this section, well #2 is developed at Shot Point (SP) -266 m (Fig. 9). Only faults can be clearly identified by stratigraphic interpretation shown in Fig. 9. Channel and other structural features could not be identified, due to limitations of the data.

### 3.2 Source and Reservoir Rocks of the Stratigraphic Analysis

For ensuring the hydrocarbon potential source, different geochemical analysis were carried out on ditch samples (51 samples, 5 to 10 m composites) and samples from conventional cores (13 samples) at geochemical lab of BAPEX. It appeared that the sediments from 1190-2400 m are immature for hydrocarbon generation, sediments from 2400-4200 m are early mature for oil generation but immature for gas generation and below 4200 m are middle mature for oil and gas generation (BAPEX, 1988).

### 3.3 Significance of Stratigraphic Analysis and Limitations

Hydrocarbons are always associated with thick sedimentary Basins and Bengal Basin provides excellent prospect for commercial accumulation of hydrocarbons. The presence of hydrocarbon in a reservoir often produces a detectable suite of responses in the seismic record.

Fenchugonj structure is situated in the transition zone between the central Surma Basin and the folded belt in the east and is closest to the eastern margin of the central Surma Basin. It is surrounded by different gas fields with Miocene reservoirs and also a comparatively young structure, so that the structural growth began after deposition of Upper Marine Shale and it is still continuing. It is situated on the unimpeded lateral migration path with respect to the eastern part of the Surma Basin and acts as a first trap for hydrocarbon emanating from Surma Basin to the east/south-east (BAPEX, 1988).

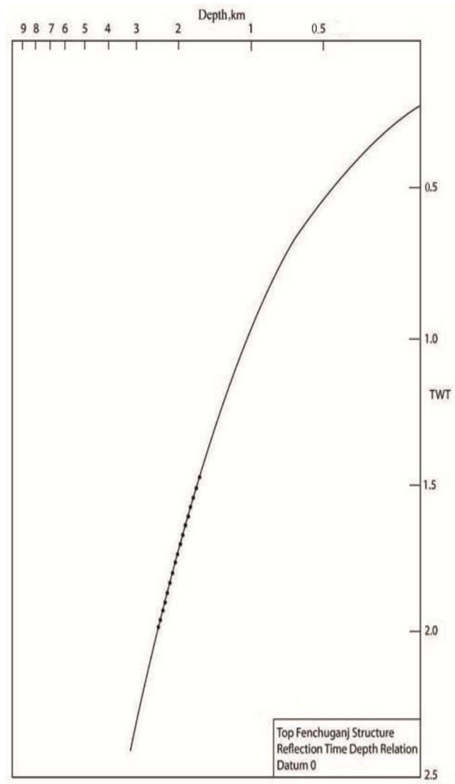


Fig. 3: T-Z Curve used in the research

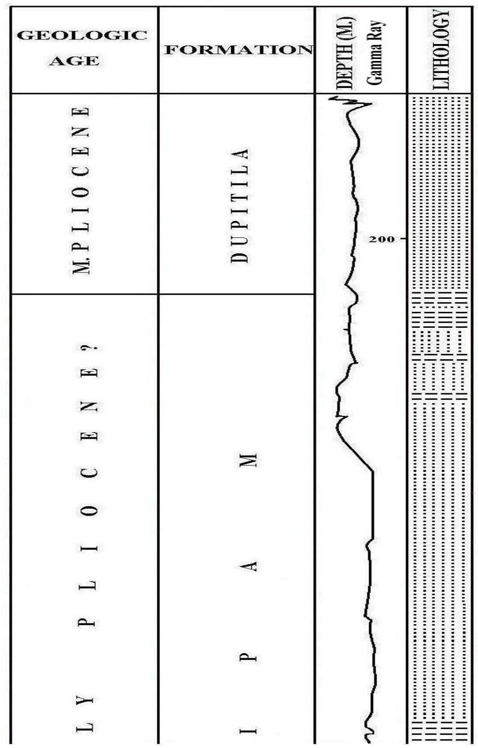


Fig. 4: Lithology of Fenchugonj well #2

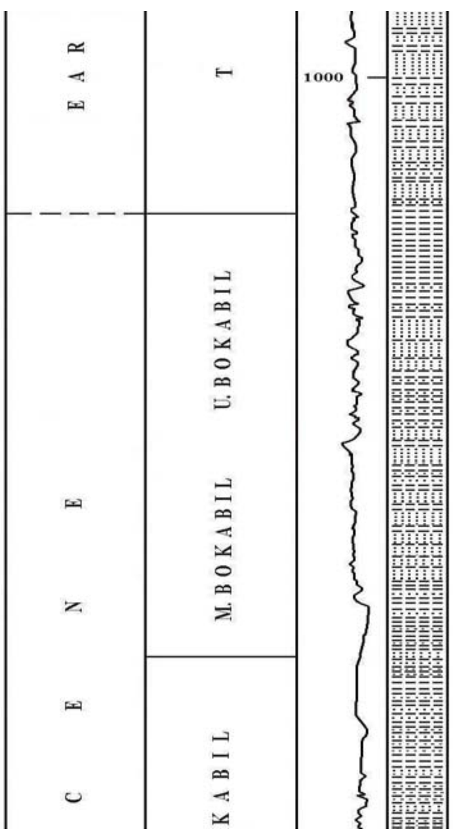


Fig. 5: Lithology of Fenchugonj well #2

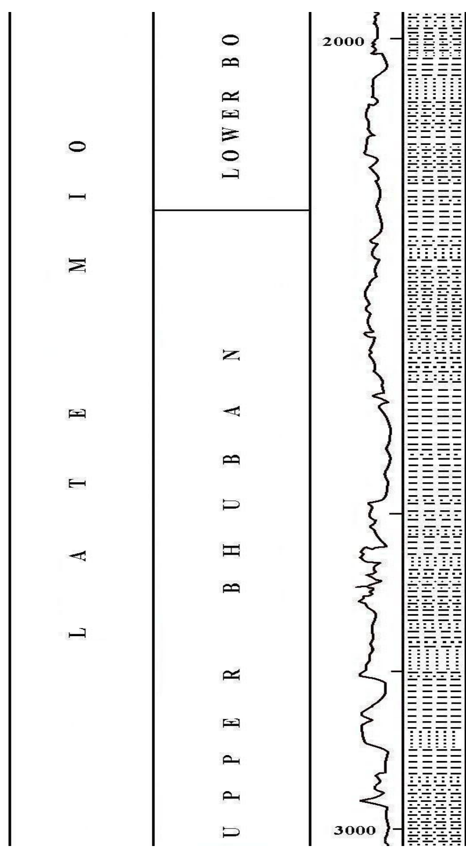


Fig. 6: Lithology of Fenchugonj well #2

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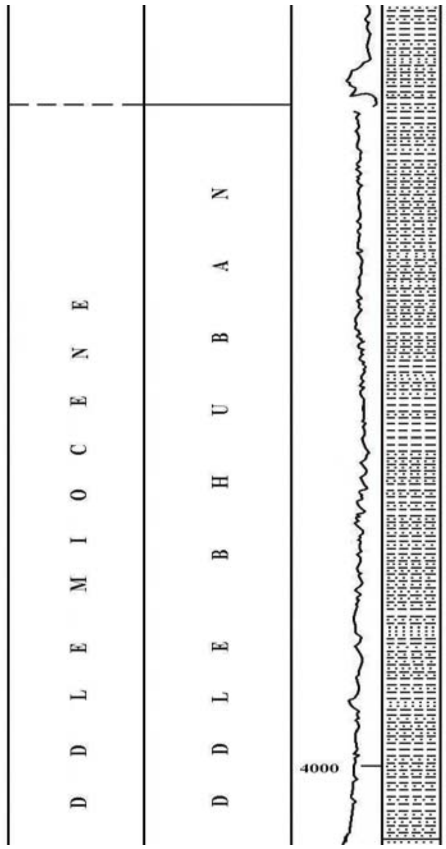


Fig. 7: Lithology of Fenchugonj well #2

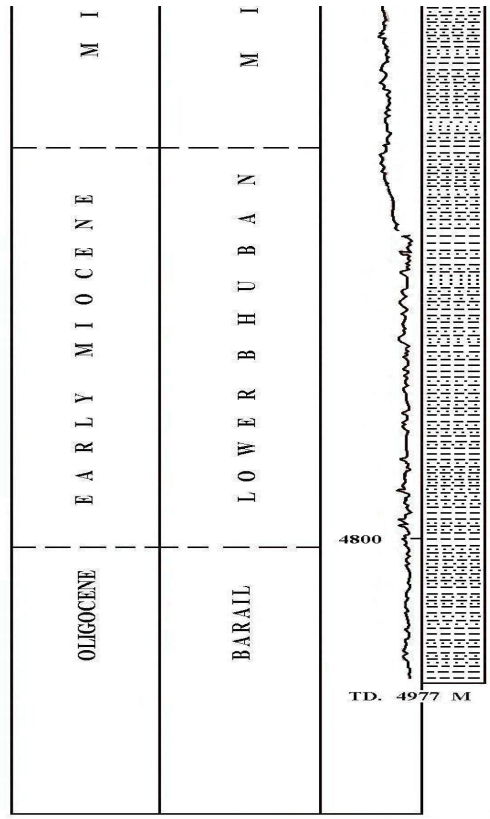


Fig. 8: Lithology of Fenchugonj well #2

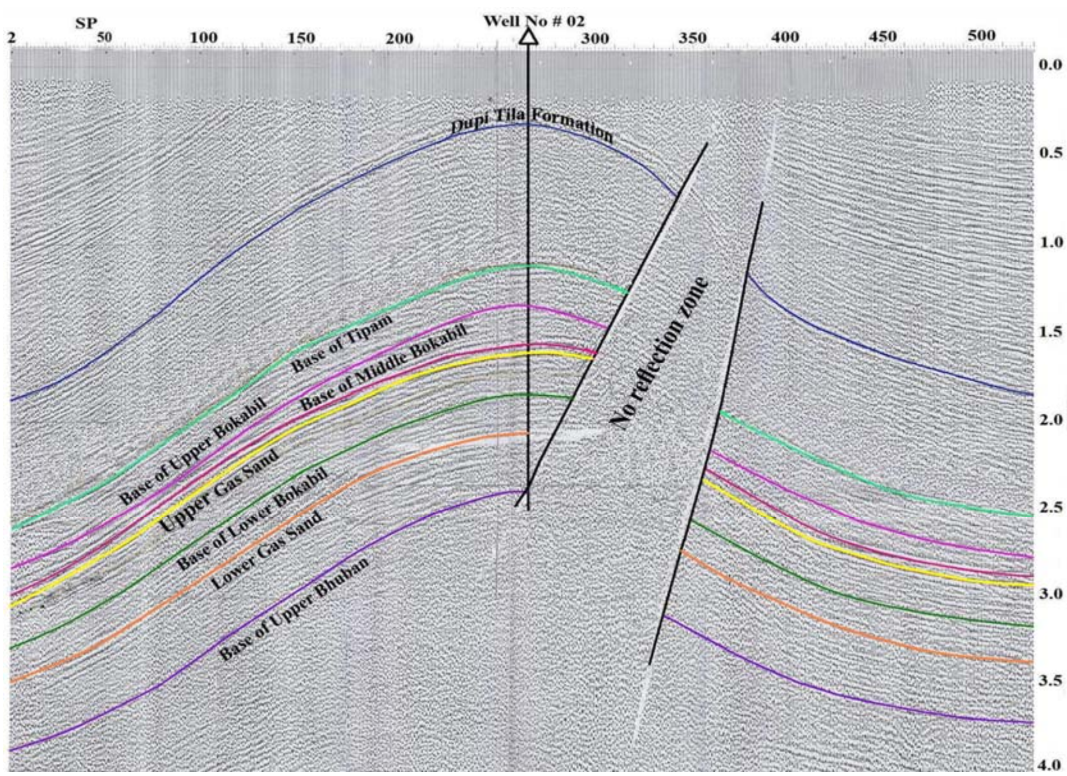


Fig. 9: Construction of Stratigraphic Formation

From lithological view, the sedimentary column consists mainly the alternation of Sandstones and Shales in Fenchugonj structure. These are necessary for hydrocarbon accumulation commercially and trapped properly. A high amplitude anticlinal fold with single reverse fault offers trapping (which is known as Structural traps) facility for hydrocarbon potentiality in this structure. This traps worked indirectly as a permeability barrier to hydrocarbon movement and, can be dominated by compression force and is closely related to the regional tectonic setting.

## 4. CONCLUSIONS

Fenchugonj Gas Field in Surma Basin located in the Structural Fold Belt in the East. This field is now in production stage and facing problems of stratigraphic formation. From this point of view, this research analysis deals the lithostratigraphy of this structure and defines the formation in the chronostratigraphic sequence to find the hydrocarbon potentiality. The stratigraphy of Fenchugonj well #2 could be analyzed which indicates the high amplitude folds with single fault exist. This anticlinal fold offers trapping (which is known as Structural traps) facility and indicates suitability for hydrocarbon potentiality in this structure. The gas sand belongs to the Lower Bokabil and Upper Bhuban Formations of Surma Group at depth of 2062-2081 m and 2768-2781 m, which is termed as Upper and Lower Gas zone respectively and these zones, is now more suitable for hydrocarbon accumulation.


## 5. ACKNOWLEDGEMENT

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# A REVIEW OF THE SUITABILITY OF MINING METHOD IN BANGLADESH COAL FIELDS

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## ABSTRACT

Bangladesh is blessed with coal-basins in the northwest and natural-gas fields are profuse in the eastern region. The current GDP growth of the country is proportionally related on its power generated from natural gas (82%), oil (9%), hydro (4%) and coal (5%) resources. The recoverable gas reserve (proven and probable) of discovered gas fields of the country is 20.63 TCF of which 7.42 TCF has been used so far leaving 13.21 TCF. Evidently, coal would be the only available alternative resource to meet the upcoming demand. Around 3 billion tones of high-grade coal were discovered at 5 coal-basins in northwest Bangladesh. Significant amount of coal mining has yet not been started, though first discovery of coal came in 1959. There are two coal mining methods: open pit and underground mining, are used in the world. Experts proposed both methods to extract the coal from Bangladesh-coal fields and also CBM (Coal Bed Methane) for deep 300-500m or more. Despite all well-meaning intentions, it appears that selection of mining method has been delaying the coal mining in Bangladesh. This critical review would provide rationales in favour of underground mining over open pit mining method in Bangladesh.

**Keywords:** Gondwana coal, Open pit mining, Underground mining, Northwest Bangladesh, Groundwater.

## 1. INTRODUCTION

The peoples of Republic of Bangladesh emerged 1971 from Pakistan. The country covers an area of 1, 44,000 sq km of onshore and 63,000 sq km offshore. Bangladesh extents from 20$^\circ$34’N to 20$^\circ$38’N and 88$^\circ$01’E to 92$^\circ$41’E. It is a densely populated developing country situated in the south-east Asia in the world (1099.3 percent per sq km) [18]. Bangladesh is undoubtedly heading towards a major energy crisis in the days to come. But with the reserve of coal, even if recovered even by open pit mining, will at best contribute a pond, if not a drop, in an ocean. So we must explore multiple options like undertaking massive search for oil, gas and coal, tapping wind energy in the coastal belt, generating small-scale hydro-electricity in the hilly terrains, solar energy, and coal extraction by underground mining only from the known deposits.

The primary objectives of this paper show the clear picture about the geological formation of the North-Western part of Bangladesh and Hydrological condition. Then different types of mining methods mainly underground mining and open pit mining. In finally in the discussion and conclusion emphasis is given which method is more applicable in Bangladesh.

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## 2. GEOLOGICAL STRUCTURE OF BANGLADESH

### 2.1 Plate Tectonics Evolution of Bangladesh

The Bengal basin has evolved from collision between Indian plate and the Asian plate. According to the plate tectonic theory, the north western part of Bangladesh (Bogra-Rangpur-Dinajpur area) was initially jointed along with Indian land mass with Antarctica, Australia and other forming a vast super continent named Gondwanaland far in the southern hemisphere. About 110 million year ago, during the Cretaceous time, the Gondwanaland super continent began to breakup and Indian began drifting toward north. The Bengal basin was initiated during this time with the rifting of the Indian plate from Antarctica. Then Indian plate collided with Asian plate and formed the Himalayan Mountain. The remaining landmass of Bangladesh formed from the sediment that coming from Himalayan Mountain. With the above outline the tectonic framework of Bangladesh may be broadly divide into two main units such as Stable platform in the northwest, Deep basin to the southeast and a third unit a narrow northeast, southwest trending zone called hinge zone separating these above two units (Figure 1).

Stable Platform unit occupies Rajshahi-Bogra-Rangpur-Dinajpur area which is characterized by limited to moderate thickness of sedimentary rock above a Precambrian igneous and metamorphic basement. Based on the thickness stable platform divided into two parts: (a) Rangpur saddle in the north with thin to limited (130m to 1000m) sedimentary cover above the Precambrian basement and (b) Bogra Shelf with moderate (1 to 6 km) sediment covers over the Precambrian basement. Deep (geosynclinals) Basin unit lies to the south and east of the stable platform which is characterized by huge thickness (maximum 22 km) of sedimentary rocks mostly sandstone and shale of Tertiary age. It occupies greater Dhaka-Faridpur-Noakhali-Sylhet-Comilla-Chittagong and Chittagong Hill tracts areas and Bay of Bengal. The third unit is called Hinge Zone unit which is about 25 km wide northeast-southwest zone that separates Precambrian platform from Deep basin to the southeast. There are no surface expressions of this unit [2, 4, 15, 16] From the tectonic evolution of Bengal Basin and structural framework of Bangladesh we see that the coal layers are situated in the stable platform.

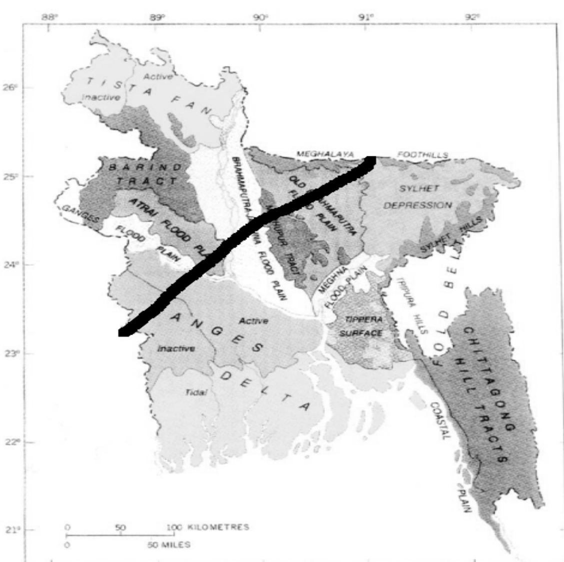


Fig. 1: Geological map of Bangladesh. (after Goggle Map)

### 2.2 Stratigraphy of the Bangladesh Coal Fields

Most of the coal fields are located in stable platforms in North-Western part of Bangladesh in Gondwana Coal Basin [3, 6, 5, and 13]. The major coal fields are Jamalganj coal field, Barapukuria coal field, Phulbari coal field, Dighipara coal field and Khalashpir coal field. General Stratigraphy of the North-western part is shown in Figure 2 and Table 1.

Table 1: Stratigraphy Succession of North Western in Bangladesh [15, 16, 17]

| Period | Formation | Lithology | Hydrogeology | Thickness (m) |
|---|---|---|---|---|
| Resent to sub resent (Holocene) | Alluvium | Silty clay | | 01-09 |
| Pleistocene | Barind Clay | Clay and sandy clay | | 10-20 |
| Pliocene | Dupi Tila | Sandstone, loosely compact sandstone | Unconfined Aquifer | 250-300 |
| Upper Oligocene to Miocene | Jamalganj Formation | Silty fine sand, clay, Shaly clay, sandstone, shaly coal | | 450-550 |
| Eocene | Kopili Shale Sylhet Limestone Tura sandstone | Sandstone, shale and small limestone | | 700-850 |
| Permian to Cretaceous | Shibganj Trapwash Rajmahal Trap Paharpur kuchma | Medium to very coarse grained off- white feldspathic sandstone frequently interbeded with conglomerate & coal layer with sandstone sequence | | 1200-1500 |
| Precambrian Crystalline Basement | | Igneous & metamorphic rocks | | |

### 2.3 General Characters of Coal Fields in Bangladesh

- The coal found in NW Bangladesh is high volatile bituminous coal. The quality of the coal is very good.
- The coal is Permian in age and occurs within fault bounded Gondwana basins.
- The coal seams occur at depth range from 118m to 1000m. Thick to very thick multiple coal layers are found in the coal fields of Bangladesh.
- The coal deposits are covered unconformable at the top by 100m to 200m thick loose to poorly consolidated water bearing sand layer.
- The coal basins are bounded by major normal fault forming half graben.
- Bangladesh’s coal is over 245-286 m.y. old.

## 3. FACTORS OF CONSIDERING THE SELECTION OF MINING METHODS

- Depth of the seam
- Thickness of the seam
- Seam configuration (in terms of horizontal or vertical dimension)

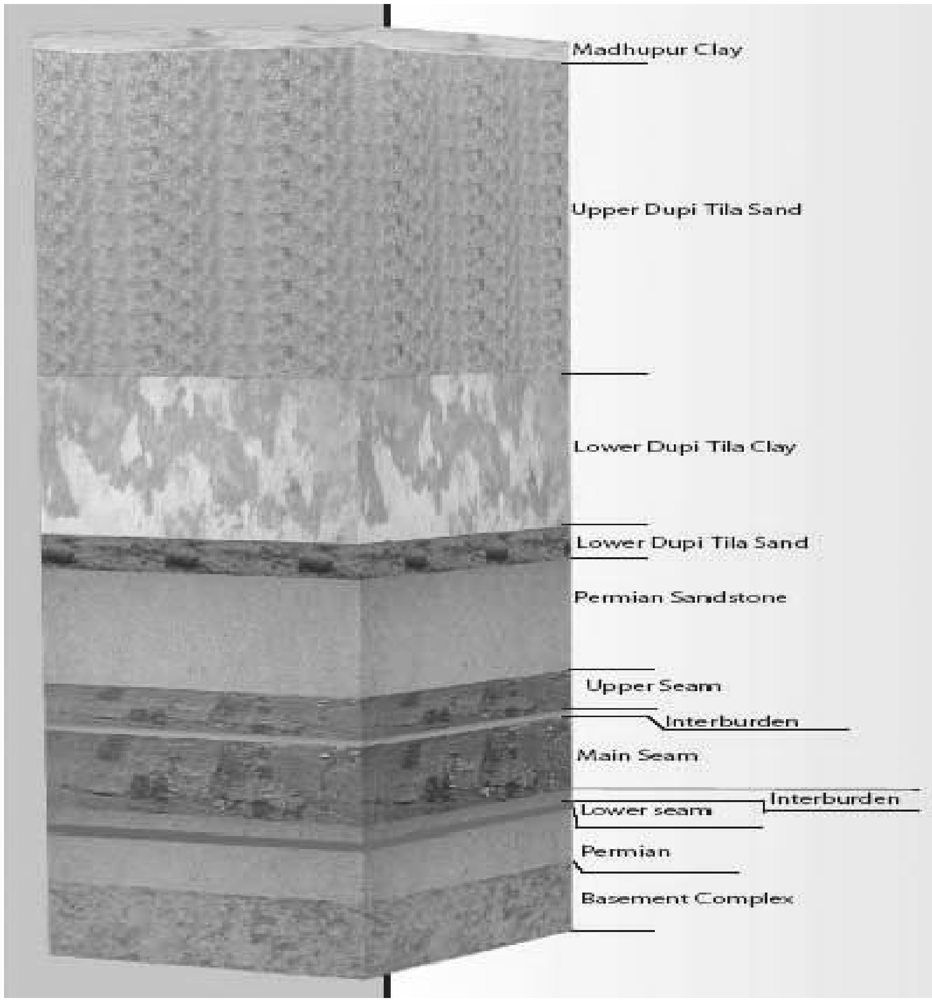


Fig. 2: Stratigraphy of stable platform in Bangladesh

- Lateral continuity of the seam
- The compositions of the overburden
- Overburden and seam hardness
- Proximity to surface water or an active ground water system
- Total deposit of coal
- Economical profitable

## 4. DIFFERENT MINING METHODS IN THE WORLD

Coal is commercially won by either of two basic methods: surface mining or Underground mining. The advantage and disadvantage of main two mining methods (open-pit mining and underground mining) are shown in Table 2. When an ore bed has been located relatively close to Earth's surface, it can be mined by surface techniques. Surface mining can be subdivided into two large categories: open-pit mining and strip mining. Open-pit mining is used when an ore bed covers a very large area in both distance and depth. Mining begins when scrapers remove any non-ore material (called overburden) on top of the ore. When an ore bed covers a wide area but is not very deep, strip mining is used. It begins the same as open-pit mining, with scrapers and other machines removing any overburden. This step involves the removal of two long parallel rows of material. Coal is normally extracted by underground mining techniques when the depth of the seam is greater than 300 feet. Other types of mining methods are proposed when depth is greater than 500m named CBM (Coal Bed Methane) [5].

## 5. PROBLEMS FACING IN UNDERGROUND AND OPEN PIT MINING METHODS

### 5.1 Hydro-geological Condition

Potential and major groundwater reservoir of Bangladesh lies in its north-western region covering greater Dinajpur and Rangpur districts. The groundwater resource of this region is the main aquifer of Bangladesh which is about 80-120 meters thick in the DupiTila formation and situated at about 10-12 meters below the surface. Extraction of coal adopting open-pit mining method can be disastrous for the north-western region in particular and Bangladesh in general due to dewatering of arsenic contamination free source of drinking and irrigation groundwater from DupiTila formation from a depth of 250 to 300 meters. Dewatering in the open pit mining area may not only disturb but also damage the aquifer, making the area a desert like place. [15] During monsoon, already mined out area will be filled up by rain water, which is required to be pumped out again. During rainy season mining will be difficult and may have to be postponed to facilitate pumping of water out of the mine. Thus 2-3 months in a year may be lost due to this. Thus uninterrupted supply of coal to the power station and other coal consumers may not be possible. There are lower Dupi Tila Formation which is impermeable for that underground mining is suitable than open pit mining [11, 15].

### 5.2 Subsidence/Landslide in the Mine Area

Subsidence in the context of underground mining is the lowering of the earth surface due to collapse of bed rock and unconsolidated material (sand, gravel, silt and clay) into mine area. This geological hazard is like an earthquake. The mine subsidence is controlled by many factors include mined out area, width of unsupported mine roof, thickness of overburden, competency (strength) of bed rock, hydrology and time. The area of mine subsidence increases proportionally with increasing width of unsupported roof rock. From the structural geology and stratigraphy of Bangladesh, rock strength is high [3] so the subsidence is low but DupiTila formation has high permeability and porosity so the quality of landslide high for the upper formation. In open pit there is landslide due to loose, incompact DupiTila formation.

Fig. 3: open pit coal mining

Table 2: Advantage & Disadvantage of Mining Methods [1, 5, 8, 14, 15]

| Parameter | Open-pit mining | Underground mining |
|---|---|---|
| Development work | Minimum development work | Needed major development work |
| Overburden | Need to excavate large volume of overburden to extract coal | Most excavation, apart from entry and tunneling, are made in saleable coal |
| Surface area loss | Large area of land temporarily lost | Only the area around pit-top is visibly disturbed |
| Environmental effect | Noise & coal dust pollution in and around mining area | No surface pollution; subsidence above workings may affect surface installation |
| Mine safety | Greater safety, no danger of explosion or fire; however danger includes landslides on excavation or spoils pile | Methane gas explosion, spontaneous combustion, roof collapse, water flooding pose danger to mine personnel |
| Affect of climate | Mining is affected by rigorous climate condition like heavy rain or snow | Climate do not affect the mining |
| Depth of mining | Maximum depth of mining limited by cost of overburden removal | Can work coal to greater depth; overburden to coal ratio not critical |
| Machinery | Simple machinery needed | More complex machinery needed |
| Recovery of coal | Almost all insitu coal may be recovered | Less than 60% of the in situ coal commonly recovered |
| Water discharge cost | High discharge cost | Less discharge cost than open pit mining |

Fig. 4: Underground coal mining

### 5.3 High Geothermal Gradient

The temperature rise will be caused by the heat dissipated from the human, and duct and pipe, the heat of blasting and etc. The temperature rise will worsen the underground environment, influence seriously the workers health and the laborer productivity, and finally become heat harm. According to the supplementary geological survey report, the temperature at the zone of invariable temperature of the mine is about 25.50℃; the depth is about 30m; ground temperature gradient in average is 3.51℃/100m [3]. According to above mentioned the comprehensive measured necessary for lowering the temperature should be taken. So for underground mining better ventilation system must be needed.

### 5.4 Air Pollution

Coal mining operations are sources of air pollution in the form of coal or rock dust from the mine itself. Gaseous air pollutants may also be generated by the transport operations within the mine area. The production of electric power used for in-mine ventilation, conveying, digging, loading, transfer, and other operations can contribute to air pollution indirectly. For most underground mines ventilation rates range from 5 to 40 cubic feet per minute per ton of coal per day, this translates to 10,000 to 200,000 cubic feet per minute for an average mine. Underground mines will release coal dust particles from blasting or loading operations, as well as gases such as hydrogen sulfide, sulfur dioxide, methane, and other hydrocarbons, although in relatively low concentrations. In open pit dust are mainly responsible for air pollution.

### 5.5 Gas Explosion

Gas is one of the main disasters to coal mine. It has large harmfulness. It cannot only suffocate the people but also burn and explode easily, also break down the middle and small size facilities seriously and thus stop the production. In the view of the whole mine, the main place with the gas build up are: working and heading face so the working place of the shearer and the tunneling machine coal falling place by mining, goaf, air sealed zone, airless zone, air supply stopping zone and the corner zone with poor ventilation. The gas explosion is less in open pit mining but environmental impact is relatively high.

### 5.6 Solid Wastes

Solid wastes are produced from both underground and surface mining operations in varying quantities. Wastes generated from underground mining are the waste rock from shaft tunneling, and refuse and coal fines removed during preparation. The solid wastes generated from surface mining include overburden from removal of the soil plus rock and impurities removed during preparation. The total solid wastes from underground mining are 0.06 to 0.10 Ib/ton of coal when waste removal is not required and 2.0 to 80 Ib/ton of coal when required because of the need to remove impurities, refuse, and "gob". These materials can be used as backfill for the mine shafts once the mining operation is completed to minimize the need for surface disposal. Solid wastes generated from surface mining operations are generally much greater when uncontrolled because of the large overburden soil washout. When careful land reclamation is practiced, the amount of overburden waste is greatly reduced. Much of the solid waste materials from coal preparation and waste water treatment can also be backfilled in the mined-out pits following mining before the land is reclaimed.

## 6. DISCUSSION

### 6.1 Views Favoring Underground Method in Bangladesh

The 100 to 200 meter thick unconsolidated and water bearing sandy layer (DupiTila formation) overlying the coal deposit is an active ground water aquifer. The amount of water that would be released in an open pit mining is not manageable and will create several problems. The monsoon rain may make the water problem even worst [15]. The presents of loose sandy water bearing aquifer above cold deposit is also responsible for large scale land sides in open pit mining. An open pit mining method would take up significant amount of agricultural land then underground mining method. For example an underground mine will take 0.96 sq. km. of land where an open pit mines would require 16 sq. km. of land. The coal fields are located very depth, which is not very encouraging for an open pit mine [5].

### 6.2 Views Favoring Open Pit Mining Method in Bangladesh

The loose water bearing 100 to 200 meter thick DupiTila sand layer above the coal deposit renders the shaft sinking for underground mine very difficult under normal circumstances. A time consuming and expensive freezing technique is required for the above purpose. This increase the project cost to a significant amount. The average stripping ratio is nearly 6:1 in $m^3$/ton (cubic meter of over burden per ton of coal). This ratio is suitable for open pit mining. The extraction ratio is very high in open pit mining [15]. The open pit mining is very safety. In Bangladesh the coal is overlying by younger sediment. The Permian sand stone also moderately fractured and jointed. It has low strength so it could not able to sustain the overburden stress / pressure [3].

## 7. CONCLUSION

Bangladesh is facing a serious challenge in terms of meeting the demands in the energy sector. Bangladesh needs to build national capability, formulate legal and organizational frameworks and mine coal so that she can retain and use the entire quantity to meet domestic energy needs. Finally, in such a national capability-based coal mining, Bangladesh needs to use coal mining methods that best suits the socio-economic, cultural, geologic, and environmental settings.

The government may undertake a detail hydro-geological study on major and potential aquifer in the north-western region of Bangladesh in the light of Asia Energy's proposal for open-pit coal mining in Bangladesh coal fields. At the same time Asia Energy may give a second thought to their proposal and examine underground mining prospects in the Bangladesh coal fields. The most pressing issue is the method to be used for coal mining in Bangladesh. Based on publicly available information on socio-economic and environmental feasibility studies done on the possibility of open-pit coal mining in Phulbari and other coal fields in Bangladesh, it is safe to conclude that open-pit coal mining will cause huge economic loss, social unrest and environmental degradation of unprecedented nature. There are several other viable alternatives to open-pit coal mining that are being practiced in various countries in the world. Given the socio-economic, cultural, and environmental settings, Bangladesh should consider a combination of underground coal mining, extraction of coal bed methane (CBM) and underground coal gasification (UCG) projects.

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# COMPARATIVE ANALYSIS OF PHYSICAL PROPERTIES OF SAND FROM DIFFERENT QUARRIES OF BANGLADESH

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## ABSTRACT

The main objective of this study is to determine the physical properties of sand from different quarries and comparative analysis to overview the quality of sand. Compressive strength and durability of concrete are depend on the properties of sand. So, it is important to find out properties of sand to get maximum benefits. In order to conduct this study, steps like field observation, sample collection, analysis and laboratory test measures were considered. As the properties of sand vary from sources, sand collected from river, stream and underground. After sample preparation, Sieve analysis, Strength, Bulk Density, Specific Gravity test were performed in accordance with ASTM standard test method. The data developed by sieve analysis indicate that, sand of Jaflong and Jointapur are well graded and best for concrete work. Volagonj, Sunamgonj and Rajnagar sand are suitable for mortar and plastering work. This study serves as useful information to recommend sand for their best possible uses.

**Key Words:** Sand; Sieve analysis; Fineness modulus; Specific gravity; Absorption, Bulk density; Compressive strength.

## 1. INTRODUCTION

Sand should be pure silica ($SiO_2$). It should be free from clay and silt, shells, salts and organic matter. The inert materials used in concrete are termed as aggregate. Since approximately three quarter of the volume of concrete is occupied by aggregate. So, its quality is considerable importance. The aggregates properties limit the strength of the concrete, as weak aggregates cannot produce a strong concrete and greatly affect the structural performance of the concrete. It is preferable that sand should be washed before all engineering works. [1]

Sand is formed by the process of weathering and abrasion, or by artificial crushing a larger parent mass. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or $SiO_2$). In concrete work, it is usually termed as fine aggregate. It is used for making concrete, mortar and plaster. It is also used for glass manufacturing, filling under floor, basement, etc. Thus many properties of the aggregate depend on the properties of the parent rock, e.g. physical and chemical stability, chemical mechanical composition, specific gravity, hardness, pore structure, color etc. in addition, there are other properties of aggregate which are absent in the parent rock: particle shape and

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size, surface texture and absorption. All these properties may have a considerable influence on the quality of fresh and hardened concrete. [4]

## 2. SITE AND SAMPLE INFORMATION

As the properties of sand vary depending on the source, sand was collected from different sources. In this study, sample was collected from north-eastern regions of Bangladesh (Sylhet) and central part of Bangladesh (Narsingdi). General information of site and sample, are shown in Table 1:

Table 1: General information of site and samples

| Symbol in Fig 1: | Site name | Upazila | District | Sand type |
|---|---|---|---|---|
| | Jaintiapur | Jaintiapur | Sylhet | River |
| | Alibahar | Sylhet | Sylhet | Stream |
| | Volagonj | Companiganj | Sylhet | River |
| | Jaflong | Gowainghat | Sylhet | River |
| | Rajnagar | Rajnagar | Maulvibazar | Stream |
| | Sreemangal | Sreemangal | Maulvibazar | Stream |
| | Sunamganj | Derai | Sunamganj | River |
| | Habigonj | Shastaganj | Habigonj | River |
| | Monohardi | Monohardi | Narsingdi | Underground |
| | Raipura | Raipura | Narsingdi | Underground |

## 3. AGGREGATE PROPERTIES, TEST METHODS AND RESULTS

### 3.1. Sieve analysis and gradation

Grading refers to the distribution of particle sizes present in an aggregate. Gradation affects many properties of an aggregate. It affects bulk density, physical stability and permeability. With careful selection of the gradation, it is possible to achieve high bulk density, high physical stability, and low permeability. For performing sieve analysis test, mother sample was taken which pass through #4 sieve and retain on #200 sieve. The grading is determined in accordance with ASTM C 136, “Sieve or Screen Analysis of Fine and Coarse Aggregates.” Portion of an aggregate passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75 µm (No. 200) sieve is called “fine aggregate” or “sand,” ASTM C 33 (“Standard Specifications for Concrete Aggregates”) lists several such size groups using the simplified practice recommendation (SPR) number designation. [2] Results of sieve analysis of our study are shown in Table 2.

#### *3.1.1. Fineness modulus*

Using the sieve analysis results, a numerical index of fineness called the fineness modulus (FM) is computed. FM is a parameter for checking the uniformity of grading. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1 as called for in ASTM C 33. [2] The concept of being able to describe particle-size distributions by an index number remains useful for many purposes. Fineness modulus variation is being used as a convenient means of keeping quality history data on uniformity of particle-size distribution of aggregate production, delivery, and use.

FM = (Percentage retain in standard sieves / 100) ………. (1)

Sands with a value of Uniformity Coefficient (Cu) equal to 3.0 or more and Coefficient of gradation (Cg) more than 1.0 are well-graded. If both of these criteria are met, the sand is classified as well graded. If both of these criteria are not met, the sand is classified as poorly graded.


Fig 1: Samples location in map.

Table 2: Test results of sieve analysis

| Sample name | Fineness Modulus (FM) | Uniformity Coefficient (Cu) | Coefficient of gradation (Cg) |
|---|---|---|---|
| Jaintiapur | 2.67 | 3.2 | 1.01 |
| Alipahar | 3.336 | 2.25 | 0.89 |
| Monohardi | 3.336 | 1.89 | 0.79 |
| Rajnagar | 1.843 | 2.22 | 0.87 |
| Raipura | 1.36 | 1.76 | 0.78 |
| Sunamganj | 2.05 | 2.94 | 0.84 |
| Volagonj | 2.22 | 2.54 | 0.99 |
| Jaflong | 3.0445 | 3.19 | 1.05 |
| Habigonj | 1.35 | 1.69 | 0.84 |
| Sreemangal | 1.476 | 2.215 | 0.81 |

Table 2 shows that,

- Jaintapur and Jaflong sand are well graded. For containing too much small particles, Habigonj, Sreemangal and Raipura sand are open graded.

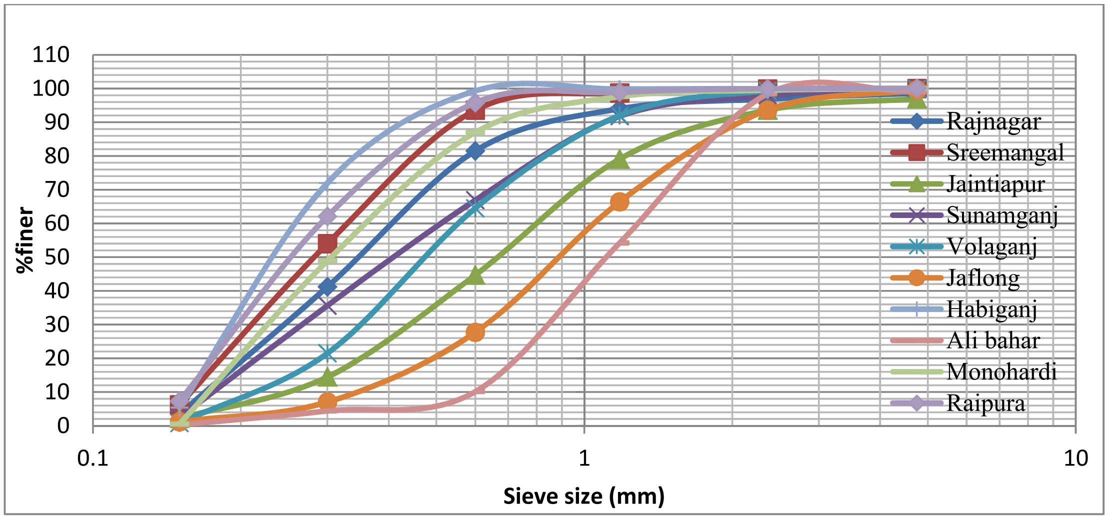


Fig 2: Grading curve of all sand samples

Grading curve is used to show the results of a sieve analysis graphically. The percent passing is usually plotted on the vertical axis, while the sieve sizes are plotted on the horizontal axis. Upper and lower limits specified for the allowable percentage of material passing each sieve may also be included on the grading chart. Figure 2 shows grading curve for all samples.
Figure 2 shows that,

- Curves of Habiganj, Sreemangal, Rajnagar, Raipura indicate earlier sieve size, so this type of sand are open graded.
- Curves of Jaintapur, Volaganj and Jaflong contain the particle of different size in good proportion and like S curve. Such sand is known as well graded.
- Curves of Habiganj and Monohardi indicate sand containing the particles of almost the same size. Such sand is known as uniform. Alibahar sand is coarse graded.

**3.2 Specific gravity (relative density)**

The specific gravity of an aggregate is the mass of the aggregate in air divided by the mass of an equal volume of water. An aggregate with a specific gravity of 2.50 would thus be two and one-half times as heavy as water. Each aggregate particle is made up of solid matter and voids that may or may not contain water. Specific gravity is determined at fixed moisture content.
Test methods for finding specific gravity of aggregates are described in ASTM C 128, "Specific Gravity and absorption of Fine Aggregate." [2]

***3.2.1 Significance of specific gravity***

The specific gravity of an aggregate is used in mixture proportioning calculations to find the absolute volume that a given mass of material will occupy in the mixture. Absolute volume of an aggregate refers to the space occupied by the aggregate particles alone; that is, the volume of solid matter and internal aggregate pores, excluding the voids between particles. In a given concrete mixture, substituting one aggregate with another of a different specific gravity will cause the volume of concrete (yield) to change for the same batch mass. Changes in the aggregate specific gravity also cause the concrete density to change. This is undesirable if a minimum density is specified. While the specific gravity of an aggregate is not a measure of aggregate quality, a variation in the specific gravity may indicate a change in the aggregate characteristics. [2]

The volume of the aggregate particle is usually assumed to be the volume of solid matter and internal pores. Two different values of specific gravity may be calculated depending on whether the mass used is an oven-dry or a saturated surface dry mass.

### *3.2.2 Bulk specific gravity (oven dry)*

Bulk specific gravity is the oven-dry mass divided by the mass of a volume of water equal to the saturated surface dry (SSD) aggregate volume. Aggregate that contains no water in the pores or on the surface.

Specific gravity has been determined by Pycnometer method. The specific gravity (Oven dry) values are calculated as follows:

Bulk Specific Gravity (Oven dry), $S_d = A / (B+S-C)$ ………. (2)

Where, $A$ = the mass of oven-dry sample in air; $S$ = the mass of saturated surface-dry sample in air; $B$ = the mass of flask filled with water; and $C$ = the mass of flask with specimen and water to the calibration or filling mark. Results of specific gravity (oven dry) are shown in Table 3.

### *3.2.3 Bulk specific gravity (saturated surface dry)*

Saturated surface dry (SSD) bulk specific gravity is the saturated surface-dry mass divided by the mass of a volume of water equal to the SSD aggregate volume. Most normal weight aggregates have a bulk specific gravity (SSD) between 2.30 and 2.90. Aggregate in which the pores connected to the surface are filled with water but with no free water on the surface. [2]

The specific gravity (SSD) values are calculated as follows:

Bulk Specific Gravity (SSD), $Ss = S / (B+S-C)$ ………. (3)

Where, S = the mass of saturated surface-dry sample in air; B = the mass of flask filled with water; and C = the mass of flask with specimen and water to the calibration or filling mark. Results of specific gravity (SSD) are shown in Table 4.

Table 3: Bulk Specific Gravity of all Sand Samples (Oven dry Basis)

| Name of the sample | A (in gm) | S (in gm) | B (in gm) | C (in gm) | $S_d$ |
|---|---|---|---|---|---|
| Jaintiapur | 300 | 300 | 1263.5 | 1449 | 2.62 |
| Alibahar | 299 | 300 | 1263.5 | 1447 | 2.57 |
| Monohardi | 299.5 | 300 | 1263.5 | 1450.5 | 2.65 |
| Rajnagar | 298 | 300 | 1263.5 | 1447.5 | 2.57 |
| Raipura | 297.5 | 300 | 1247 | 1434 | 2.63 |
| Sunamganj | 300 | 308 | 1247 | 1432 | 2.44 |
| Volagonj | 300 | 307.5 | 1247 | 1435 | 2.51 |

| | | | | | |
|---|---|---|---|---|---|
| Jaflong | 300 | 310 | 1247 | 1438 | 2.52 |
| Habigonj | 300 | 312.5 | 1264.5 | 1435 | 2.11 |
| Sreemangal | 290 | 300.5 | 1247 | 1430.5 | 2.47 |

Table 4: Bulk Specific Gravity of all of Sand Samples (Surface dry Basis)

| Name of the Sample | S (gm) | B (gm) | C (gm) | $S_S$ |
|---|---|---|---|---|
| Jaintiapur | 300 | 1263.5 | 1449 | 2.62 |
| Alibahar | 300 | 1263.5 | 1447 | 2.58 |
| Monohardi | 300 | 1263.5 | 1450.5 | 2.91 |
| Rajnagar | 300 | 1263.5 | 1447.5 | 2.59 |
| Raipura | 300 | 1247 | 1434 | 2.65 |
| Sunamganj | 308 | 1247 | 1432 | 2.5 |
| Volagonj | 307.5 | 1247 | 1435 | 2.57 |
| Jaflong | 310 | 1247 | 1438 | 2.61 |
| Habigonj | 312.5 | 1264.5 | 1435 | 2.20 |
| Sreemangal | 300.5 | 1247 | 1430.5 | 2.569 |

Table 3 & 4 show that,

- Jaintiapur, Alibahar, Rajnagar, Raipura, Sunamganj, Volagonj, Jaflong and Srimangal sand is good and within the typical range required for normal weight concrete.
- Bulk Specific Gravity of Habigonj and Monohardi sand is not within the typical range required for normal weight concrete.

### 3.3 Absorption

The mixing water in a batch of concrete is all the water present in the concrete, with the exception of absorbed water within aggregate particles. Absorption of aggregate may affect on the effective water cement ratio in concrete mixing. Absorption values are used to calculate the change in the weight of an aggregate due to water absorbed, compared to dry condition. [2] Absorption test results are shown in Table 5. The Absorption values are calculated as follows:

$$\text{Absorption, \%} = (S-A) / A \times 100 \quad \text{……….} \ (4)$$

Where, A = Weight of oven dry specimen in air, S = Weight of the saturated surface dry specimen. Absorption is a measure of the total pore volume accessible to water, and is usually calculated using the results from a specific gravity determination (ASTM C 127 and C 128).

Table 5: Absorption Test of All Sand Samples

| Name of the Sample | A gm | S gm | Absorption % |
|---|---|---|---|
| Jaintiapur | 300 | 300 | 0.09 |
| Alibahar | 299 | 300 | 0.33 |
| Monohardi | 299.5 | 300 | 0.17 |
| Rajnagar | 298 | 300 | 0.67 |
| Raipura | 297.5 | 300 | 0.84 |
| Sunamganj | 300 | 308 | 2.67 |

| | | | |
|---|---|---|---|
| Volagonj | 300 | 307.5 | 2.5 |
| Jaflong | 300 | 310 | 3.33 |
| Habigonj | 300 | 312.5 | 4.17 |
| Sreemangal | 290 | 300.5 | 3.62 |

Table 5 shows that,

- Only Habiganj sand is not in the range of absorption required for normal weight concrete.
- Jaintapur sand is best for concrete work and it is preferable to use Alibahar, Monohardi, Rajnarar, Raipura sand for concrete work.

### 3.4 Bulk density

The bulk density of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles. Bulk density of sand indicates the type of particle properties. The bulk density of aggregates ranges from 1200-1800 Kg $m^{-3}$ for normal weight aggregate and 500-1000 Kg $m^{-3}$ for light- weight aggregates.[5] Methods for determining bulk density are given in ASTM C 29/C 29M. [2]

#### *3.4.1Factors affecting bulk density*

Bulk density depends on the moisture content of the aggregate. For fine aggregate, increasing moisture content beyond the saturated surface-dry condition can decrease the bulk density. The resulting increase in volume decreases the bulk density. This phenomenon, called "bulking," is of little importance if the aggregates for a concrete mixture are batched by mass. Other properties that affect the bulk density of an aggregate include grading, specific gravity, surface texture, shape, and angularity of particles. Higher specific gravity of the particles results in higher bulk density. [2] Bulk density test results are shown in Table 5. The Bulk density values are calculated as follows:

Bulk density, $M = (G-T) / V$ ………. (5)

Where, M = Unit weight of the aggregate in Kg $m^{-3}$

G = Mass of aggregate & the measure in Kg

T = Mass of the measure in Kg; V = Volume of the measure in $m^3$

Table 6: Bulk Density Test results of All Sand Samples

| Name of the Sample | G (in gm) | T(in gm) | V(in $m^3$) | M ($Kgm^{-3}$) |
|---|---|---|---|---|
| Jaintiapur | 2033 | 515 | .001 | 1518 |
| Alibahar | 2037.5 | 515 | .001 | 1522.5 |
| Monohardi | 1961 | 515 | .001 | 1446 |
| Rajnagar | 2027.5 | 515 | .001 | 1512.5 |
| Raipura | 1717 | 515 | .001 | 1202 |
| Sunamganj | 2045 | 514.5 | .001 | 1530.5 |
| Volagonj | 2083 | 514.5 | .001 | 1568.5 |
| Jaflong | 2166.5 | 514.5 | .001 | 1652 |
| Habigonj | 2067 | 514.5 | .001 | 1552.2 |
| Sreemangal | 2035 | 514.5 | .001 | 1520.5 |

Table 6 shows that,

- Highest Bulk Density in Habigonj sand and lowest Bulk Density in Raipura sand.
- All types of sand within the typical range required for normal weight concrete and light-weight concrete.

## 3.5 Strength test

### *3.5.1 Compressive strength of mortar*

Mortar is a pest generally made by the mixing of fine aggregate (sand) and cement with water. Sand in mortar prevents shrinkage and cracking of mortar in setting. It is also claimed that some chemical reactions take place between silica ($SiO_2$) of sand grains and the constituting cementing materials to form a hardened mass. Sand in mortar should be free from salt and other impurities. [1]

For making mortar, the ratios are water: cement: sand = 0.486: 1: 2.75 as a standard value. Test method conforms to the ASTM requirements of specification BS1881. In mortar work Compressive strength should be more than 5 MPa. Compressive strength test results of mortar are shown in Table 7.

### *3.5.2 Compressive strength of concrete*

Strength of concrete is considered most vulnerable property. To determine the compressive strength of concrete cylinder test were performed. Cylinder test are performed according to ASTM C 470-93a test method. [4]

For making Cylinder, the ratios are cement: sand: stone = 1 : 2 : 4 as a standard value and water: cement ratio 0.486. After preparation of cylinders are stored undisturbed for 24 hours at a temperature of 58° to 66° and a relative humidity of not less than 90 percent. After 24 hours the moulds are stripped of and the cubes and cylinder are further cured in water at 58° to 66°F A time period of 28 days was selected by specification writing authorities as the age that all concrete should be tested. [4] In structural analysis the compressive strength of concrete are vary 30 MPa (4000 psi) to 40 MPa (60000 psi) but in practical it may 18 MPa (2500 psi). Compressive strength test results of concrete are shown in Table 7.

Table 7: Compressive strength test results of mortar and concrete

| Name of the Sample | Mortar | | Concrete |
|---|---|---|---|
| | 7 days strength MPa | 28 days strength MPa | 28 days strength MPa |
| Raipura | 15.14 | 22.80 | 21.44 |
| Monohardi | 26.46 | 19.20 | 19.93 |
| Alibahar | 25.63 | 27.53 | 27.85 |
| Habiganj | 2.84 | 4.01 | 13.25 |
| Volaganj | 7.47 | 14.85 | 21.45 |
| Jaflong | 8.50 | 13.30 | 21.47 |
| Jaintiapur | 23.43 | 37.53 | 24.57 |
| Rajnagar | 13.96 | 19.69 | 19.23 |
| Sreemangal | 5.34 | 8.80 | 16.08 |
| Sunamganj | 10.03 | 14.45 | 20.20 |

Table 7 shows that,

- Except Habiganj all types of sand within the range of normal weight concrete strength and suitable for concrete work. ( >15 MPa )
- Highest compressive strength in Alibahar sand (27.85 MPa) and lowest compressive strength in Habiganj sand (13.25 MPa).
- Except Habiganj all type of sand are suitable for mortar work. (> 5 MPa )

### 3.6 Test for silt and clay

Silt and clay in sand should not be present in large quantity, because, owing to their fineness and large surface area, they increase necessary to wet the particle in the concrete mix. [4] The amount of silt and clay present in sand affect on the effect water cement ration in concrete mix. The fines content (percentage or silt and clay content) should not be higher than 5 %. [3] Except Raipura sand all types of sand within the range. Results of silt and clay content shown in Table 8.

### 3.7 Test for organic impurities

Hydraulic cements set and harden, not by drying, but through a chemical reaction between the cement grain and water. Organic impurities weaken the bond with cement pest and no chemical reaction take place between organic matter and cement.

The presence of organic matter is determined by stirring a sample of sand with 3% solution of sodium hydroxide or caustic soda in a closed bottle. The sample is left for 24 hours. The color of the solution turns brown if any organic matter is present. The amount of organic matter is determined from the intensity of darkness of the solution. [1] Except Habigonj and Monohardi all type of sand contain organic matter. Results of organic impurities represent in Table 9.

Table 8: Test for silt and clay of all types of sand samples

| Name of the Sample | Volume in cc | Bicker weight in gm | Bicker + Sample weight in gm | Wt of silt & clay in gm | % weight |
|---|---|---|---|---|---|
| Jaintiapur | 25 | 29.641 | 29.645 | 0.004 | 0.4 |
| Alibahar | 25 | 36.319 | 36.364 | 0.045 | 4.5 |
| Monohardi | 25 | 48.760 | 48.8 | 0.04 | 4 |
| Rajnagar | 25 | 40.159 | 40.2 | 0.041 | 4.1 |
| Raipura | 25 | 30.1383 | 30.201 | 0.0627 | 6.27 |
| Sunamganj | 20 | 46.944 | 46.946 | 0.002 | 0.02 |
| Volagonj | 10 | 39.9813 | 40.0147 | 0.0334 | 0.334 |
| Jaflong | 10 | 46.3418 | 46.3634 | 0.0216 | 0.216 |
| Habigonj | 20 | 37.95 | 37.9722 | 0.0222 | 0.222 |
| Sreemangal | 10 | 32.5994 | 32.6338 | 0.0344 | 0.344 |

Table 9: Test for organic matter of all types of sand samples

| Name of the Sample | **Color** | **Decisions** |
|---|---|---|
| Jaintiapur | Reddish dark | Organic matter present |
| Alibahar | Reddish dark | Organic matter present |
| Monohardi | No colour | Organic matter absent |

| | | |
|---|---|---|
| Rajnagar | Reddish dark | Organic matter present |
| Raipura | Reddish Light | Organic matter present |
| Sunamganj | Reddish dark | Organic matter present |
| Volagonj | Reddish dark | Organic matter present |
| Jaflong | Reddish dark | Organic matter present |
| Habigonj | No colour | Organic matter absent |
| Sreemangal | Reddish dark | Organic matter present |

| Properties | Typical ranges | Minimum value | | |
|---|---|---|---|---|
| | Normal weight concrete | Mortar | plaster | Filter media |
| FM | 2.3 to 3.3 | 1.5 | 0.8 | |
| Absorption | 0 to 4 % | | | |
| Bulk specific gravity | 2.30 to 2.90 | | | 2.65 |
| Compressive strength | >15 MPa | >5MPa | | |
| Silt and clay content | <5% | | | |
| Bulk density | 1200 to 1800 Kg $m^{-3}$ | | | |
| Uniformity coefficient | | | | <1.65 |

Table 10: Standard values of sand for different wroks

## 4. CONCLUSION

Considering physical properties of sand, it should be used for different engineering work. Sand type which is not appropriate for construction work can be used for other works. Proper utilization of sand must be ensured by knowing its quality. In our study, based on standard values of sand it can be recommended that, Jaintiapur, Alibahar and Jaflong sand is best for concrete work. Volagonj, Sunamgonj, Sreemangal and Rajnagar sand are suitable for mortar and plastering work. Raipura and Monohardi sand can be used as filter media. Habiganj sand is suitable for sand filling.

Same sand are used in different purpose which is locally available due to reduce cost or any other reason, but sand of different places is suitable for different work such as Jaintiapur and Jaflong sand are suitable for concrete work.Due to the limitation of sand quarries in Bangladesh, it is necessary to ensure proper use of sand in different field which is better for that purpose.

So, Ministry of Mineral Resource can take appropriate legislative steps for proper use of sand and sustainability of this field.

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# DESIGN AND APPLICATION OF A MULTI REACTOR HEADSPACE GAS RESPIROMETER IN WASTEWATER BIOASSAY

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## ABSTRACT

A volumetric respirometer suitable for studies of oxygen uptake rate of wastewater is described. The respirometer is facilitated with multi reactor chambers for the bioassay of five wastewater samples simultaneously. Magnetic stirrers are provided for the continuous agitation of the test samples. Temperature can be controlled over a range of $18^0$C to $32^0$C. The volumetric manometers provide direct readings of the oxygen consumption value. The amount of oxygen consumed by a typical wastewater sample within 19 hrs of duration has been found to be approximately 2.88 ml/L.

**Key Words:** Headspace gas respirometer, Manometer, Wastewater, Bioassay, Oxygen uptake.

## 1. INTRODUCTION

Bioassay allows for a quantitative measurement of the effect of a substance on a biological system. Oxygen uptake, in this regard, reflects the ability of the biomass to metabolize wastewater components. By measuring the oxygen uptake response of the biomass to various environmental conditions, plant operators can “listen” for symptoms and diagnose potential operating problems. Timely response to such problems can mitigate or eliminate their impact on the treatment plant [1]. Respirometry is a widely used technique for the characterization of wastewater and activated sludge and constitutes a well-established procedure to assess the state of microbial activity and for the calibration of microbial kinetic models [2]. Commercially available or user-built respirometer systems fall into two major categories namely 1) headspace gas respirometer and 2) dissolve oxygen depletion respirometer [3]. The BIOSCAN multi reactor manometric respirometer (Model no-MMR1003) is a specially designed device based on the principle of headspace gas respirometry.

## 2. DESCRIPTION OF THE APPARATUS

The construction details of the respirometer can be seen in fig. 1 to fig. 3 while table 1 represents some technical specifications. The BIOSCAN multi reactor respirometer consists of two major parts i.e. 1) Reactor unit and 2) Manometer unit.

### 2.1. Reactor unit

The body structure of this unit is made of a rectangular box of 18 gauge metal sheet with a plain white coating surface. A 5mm thick glass reservoir is placed within the unit with an

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automatic aquarium water heater of 50 watt to serve as a temperature control unit for the respiration cells. Magnetic stirrer made of six small cooling fans of 12 volt and powerful magnets are placed on the bottom part of the unit. A power adaptor is connected to the back outer surface of the unit to supply DC current to the magnetic stirrer from a 220 AC source. Six conical flasks fitted with air tight rubber stoppers and $CO_2$ scrubbers are used as experimental reaction cell.

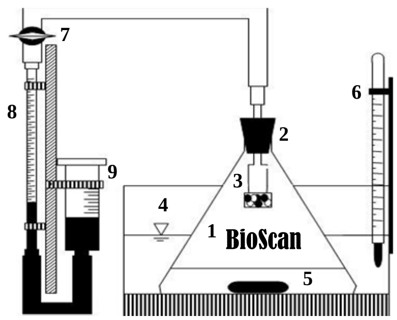


Fig. 1: Schematic diagram of the Bioscan multi reactor respirometer (1.Reaction cell, 2.Rubber stopper, 3.$CO_2$ absorber, 4.Water bath, 5.Magnetic stirrer with stir bar, 6.Thermometer, 7.Control valve, 8.Manometer and 9. Manometric liquid reservoir)

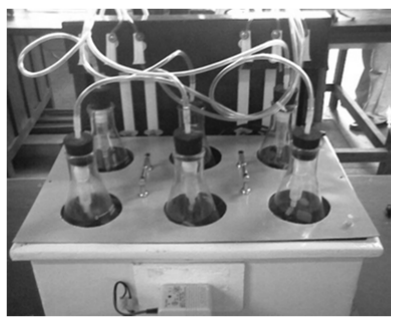

Fig. 2: Photographic view of the reactor unit.

**2.2. Manometer unit**

This unit is integrated with six liquid manometers to observe the oxygen uptake value of the wastewater sample in the reaction vessels. The manometer is constructed with a 2mm laboratory pipette connected with a 5 ml plastic syringe as manometric liquid reservoir. The open end of the volumetric pipette is attached to the rubber stopper of the reaction flask through a 5mm rubber tube. The manometers are placed on the outer surface of the manometer casing in a vertical orientation.

Table 1: Technical specifications

| | |
|---|---|
| Measuring principle | Respirometric (manometric) |
| Volume range | Approx. 1.5 ml |
| Manometric liquid | Water solution (yellow colour) |
| Temperature range | 18-32°C ±1°C |
| Power supply | Input: 230 V AC, Output: 18 V D |
| Dimensions | 38cm*33cm*32cm |
| Weight | Approx. 10 kg |


Fig. 3: Photographic view of the manometer unit.

## 3. APPLICATION OF THE APPARATUS

The respirometric analyses were performed in a 500 ml conical flask with a special synthetic sample prepared from 100 ml municipal wastewater mixed with 1 gm sugar (glucose) and 200 ml distilled water. A blank sample was also run which was composed of 300 ml distilled water with 1 gm sugar. The blank provides the manometer reading corresponds to slight temperature or pressure changes in the water bath. The experimental values of the sample were adjusted to correct for the blank reading.

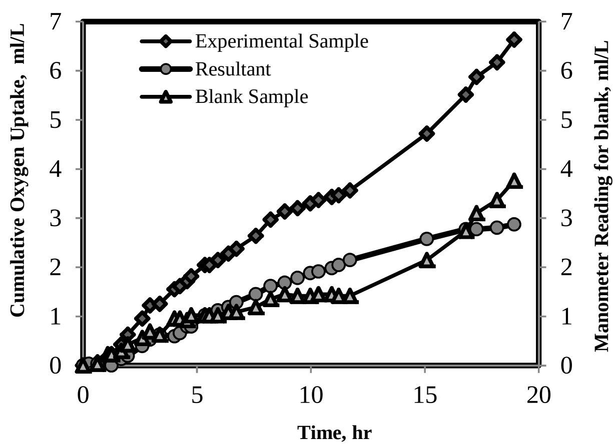


Fig. 4: Respirogram represents the cumulative oxygen uptake by the test sample.

All the experiments were conducted at a temperature of $22\pm1^0C$. Results of the oxygen consumption of the test sample as expressed on a cumulative basis over a 19 hr period are illustrated in Fig. 4. The resultant line symbolizes the actual oxygen consumption pattern of the test sample which represents the biological activity of the wastewater. The amount of oxygen consumed by the sample within 19 hrs of observation was approximately 2.88 ml/L. Fig. 5 represents the oxygen uptake rate of the test sample. Here the first peak was observed at 15 min of contact which was 0.66 ml/L-hr. A second group of readily biodegradable constituents caused a second high OUR peak at 1.25 hrs. Another three peaks of 0.40, 0.42 and 0.39 ml/L-hr were observed at 2.93, 4.57 and 5.35 hrs consecutively. The oxidation of readily biodegradable organic constituents was followed by a long tail of slowly degrading constituents. This indicates that microorganisms would require several more hours of contact time to allow complete oxidation of the organic constituents of the wastewater. But due to the constraint of measuring limit, the experiment was ended up after 20 hrs duration.

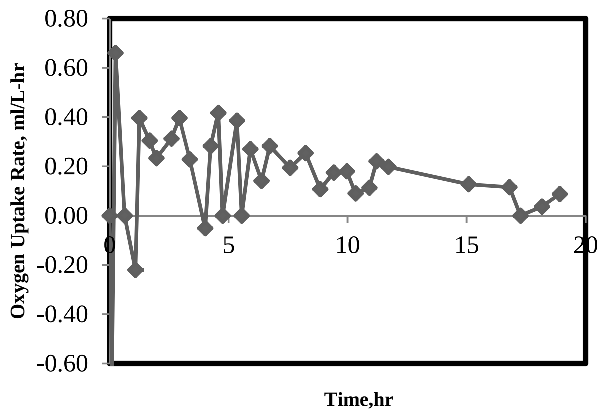


Fig. 5: Respirogram represents the oxygen uptake rate of the test sample.

## 4. CONCLUSIONS

Headspace gas respirometry offers a great advantage in compare to the conventional analytical method of BOD determination [6]. However thermobarometric change and extent of sample agitation during the experiment exert a profound effect on the test result. As future research, we are building mathematical models and we will try to undertake a program of extensive data collection and analysis based on this respirometric bioassay.

## 5. ACKNOWLEDGEMENT

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# PATTERN OF SALT TRANSFER THROUGH BRICK SAMPLES

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## ABSTRACT

Salinity is one of the most striking problems in coastal areas where a significant amount of water, used for both drinking and daily purposes is salty. Not only in coastal belt but also in those areas where rivers come in vicinity of the sea; salinity in water causes serious damages to the structures of that area. The pores entrapped in the brick, works as the transferring media of the saline water by capillary action. Eventually the efflorescence [1] occurs and causes manifold harms to the structural masonry elements like bricks and plaster overlaid onto it. The study focuses on the pattern of salinity transport through brick samples. For ease in study; one dimensional flow was considered for determining transport pattern. The brick samples were sliced off into different segments to find out whether there exists any stratification in accumulation of salt entrapped into the pores or there exists any affinity of accumulation at any specific zone in brick. Two experimental set-ups are still under observation as representatives of multidirectional flow with or without plaster.

**Key Words**: Efflorescence, capillary action, evaporation, salinity, brick, coastal area.

## 1. INTRODUCTION

Bricks are one of the essential materials used mostly in building construction in Bangladesh. Almost all residential structures as well as industrial and commercial complexes use bricks in their construction processes. Although in some cases concrete is used merely in their construction, brick gives it a volume. In ancient ages when the concept of bricks was not established; stones were used in construction purposes for specific areas. Later brick's advent as a surrogate to stone made a revolutionary change in construction works as it is lighter, workable where stone is not available and economic but sufficiently stiff to withstand superimposed loads. The trend of using bricks increased day by day despite the availability of stone. Brick's lightweight as well as hauling and construction economy put it at a pinnacle of demand. But the reason behind its lesser weight is the presence of entrapped pore spaces inside. Despite acquiring thriving demand; it is not beyond perfection. It can not resist saline water to intrude in. As a result intrusion of saline water from ground or other possible sources happens through capillary action.

Structures are affected by the salt present in water or salt present in water those are used for construction purposes. Progressive urbanization is resulting in massive industries, Buildings

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etc. Most of the cases these structures are built near to the watercourses for lesser transportation cost. When these bricks are exposed to salinity; it does not illustrate a satisfactory thing. White crust over the brick surface occurs as a result which causes subsequent deterioration of the structural elements. Brick contains numerous pores resulting from escaping of the entrapped air, water, organic particles during burning [2]. These pores serve as transferring media for salinity. Salt from underground water or from the soil in vicinity of brick walls keep passing through these pores and proceeds further. Saline water leakages from plumbing works may also partake in it. When this saline water comes on the surface *i.e.* in exposure of sunlight; evaporation occurs. As a result salt gets accumulated onto the brick in the form of white crusty matter. If this phenomenon is allowed to occur furthermore then salt increases more & forms white crust. The source of salinity may also be various food items, fertilizers containing salt, soaps, detergents etc. Structures situated in industrial area may also be affected by salinity. Efflorescence causes distressed brick and plaster materials. The co-existence of other potential distressing mechanisms-such as the acid rain typically present in the industrial area can overlap and mask the effect produce by the salts raised by seawater capillary rise [3]. Therefore it is worthy to look the quantity and pattern of salt transport through brick samples under controlled laboratory condition.

## 2. METHODOLOGY

The goal of the study was to determine the amount of salinity flow through brick samples installed for one directional flow as well as multidirectional flow of saline water of different concentrations. Two experimental set ups were made. One was as the representative of typical coastal water and another was as the representative of normal tap-water. Other 6 (six) experimental set-ups are still under observation with multidirectional flow of saline water.

In general cases structures are exposed to salinity of different concentrations. Bricks may face to withstand against almost 35000 mg/L of NaCl (Sodium chloride). In coastal areas it appears as 1000 mg/L of NaCl. In some cases, Intrusion of saline water from leakages of plumbing works embedded in the wall. Although seawater contains salinity of different forms, only sodium chloride has been taken into consideration for experimental purpose as it constitutes the major part of the dissolved solids of seawater. Moreover efflorescence is merely a white crust formed by crystallization of dissolved NaCl due to capillary action and subsequent evaporation from the surface of bricks.

Two kinds of saline water were prepared for imitating the practical cases as stated above. First class bricks were split along its longitudinal axis to form test specimen into two equal parts. Split halves were normally identical in terms of size and shape. Their sizes varied slightly in decimal places and shapes were mostly uniform to look at. So the volumes of all three split bricks were normally identical. The sizes are as follows

A- 9.75” ×2.126” ×2.358”
B-9.75” ×2.191” ×2.142”

For ensuring one dimensional flow of saline water; split bricks were wrapped peripherally. Paraffin wax was used for wrapping the bricks. Almost 1mm thick wax layer was maintained over the brick surface to seal the pores on the peripheral surface. Later a coating of packaging tapes were used for restricting air & sunlight which accelerate the efflorescence process. The degree of efflorescence is highly susceptible to the sun's position in the sky and it is evident that the east and west facing sides of a structure will receive more sunlight in sunrise and sunset respectively. So peripheral wrapping was a must to ensure the one directional flow *i.e.* flowing aloft. Another 6 set ups were with plaster (1:5) and without plaster bared bricks

The experimental set ups were installed near to the window inside a room at the north-west corner. Northern attachment ensured the wind flowing over the surface.

The three experimental brick samples were installed as column on the 15$^{th}$ July of 2010 and were undergone close observation how and what quantity of water they suck from saline waters of specific concentrations for each specimen. Water was pushed almost daily upon the requirement to maintain a certain water depth. Later a very interesting outcome was found which will be discussed in the result and discussion section thoroughly.

2.2 cm of their bottom were kept sunk for 190 days. Then they were taken out of the bowl (saline water container) for further salinity determination. They were cut into different segments representing different height levels. Each level was considered as the representative of brine water contained by that level. Then the slices were pulverized into granules and kept sunken in distilled water for 24 hours. Later they were tested for Chloride content and interesting results regarding the flow pattern of salinity through bricks was revealed.

## 3. RESULT & DISCUSSIONS

Different significant findings have been made after the observation of the brick samples and testing for $Cl^-$ content. Here are some data.

**Table 1: Percentage of Chloride at different levels for Sample ID: A (1000mg/L)**

| LEVEL | MASS OF DRY BRICK SAMPLE (mg) | % OF CHLORIDE CONTENT |
|---|---|---|
| 11 | 53160 | 0.026 |
| 10 | 28577 | 0.046 |
| 9 | 41333 | 0.054 |
| 8 | 44181 | 0.054 |
| 7 | 43477 | 0.051 |
| 6 | 51567 | 0.058 |
| 5 | 36795 | 0.060 |
| 4 | 45431 | 0.059 |
| 3 | 29329 | 0.082 |
| 2 | 36634 | 0.082 |
| 1 | 40121 | 0.072 |
| 0 | 30721 | 0.154 |

The above data were found out after slicing off the bricks into different segments. Each segment was approximately half of an inch. After having the segments in hand they were grinded into granules (5mm) and soaked in water for 24 hours. Later they were titrated using $AgNO_3$ and their $Cl^-$ contents were determined. Later they were expressed in the percentage of the mass of the brick samples taken. Then the chloride content against the level of different brick strata were plotted to find out the variation of chloride content with respect to the level as shown in the Fig-1.

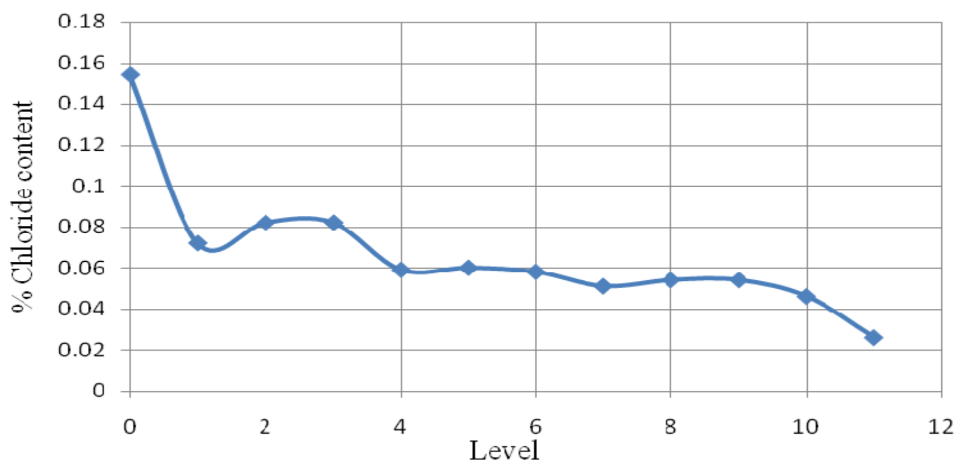


Fig-1: Level vs % $Cl^-$ content ( Sample A: 1000 mg/L)

The curve depicts a decreasing trend with respect to the height of brick column samples. When the brick came in vicinity of the saline water it started sucking water and after reaching the top surface of brick; subsequent evaporation occurred. The bottom layer depicts higher accumulation of chloride and it decreases gradually at upper levels. The reason for this phenomenon is entrapping continuously at a certain level. If saline water is considered as a package of salt molecules; then it can easily be apprehended that it losses more of its molecules during passing through the first layer. Then upper consecutive layers get smaller share from the package and smaller accumulation occurs there. Another set up which receives water from normal tap-water is still under observation. No such trend line has been prepared yet.

**3.1 Mass Balance**

Two sets of the first run were considered for the mass balance between sample & source. In sample & it is evident that total 6507 mg NaCl has passed during 190 days with water intrusion of 747 mL from which some got escaped due to evaporation. 1309 mg NaCl remained in the sample. The left over water at the bottom contained 1500 mg salt. Again in sample B total 5050 mg NaCl has passed during the same day with water intrusion of 715 mL from which some got escaped due to evaporation. Both the samples originally contained almost similar amount of salt as 8532 mg and 9161 mg for sample A and B, respectively. Therefore about 784 mL and 752 mL water were pushed in one direction and subsequent evaporation transferred 6507 mg and 5050 mg salt on its surface. Therefore the range of salt transfer through brick samples ranges from 6.7 mg/mL to 8.3 mg/mL of water supplied

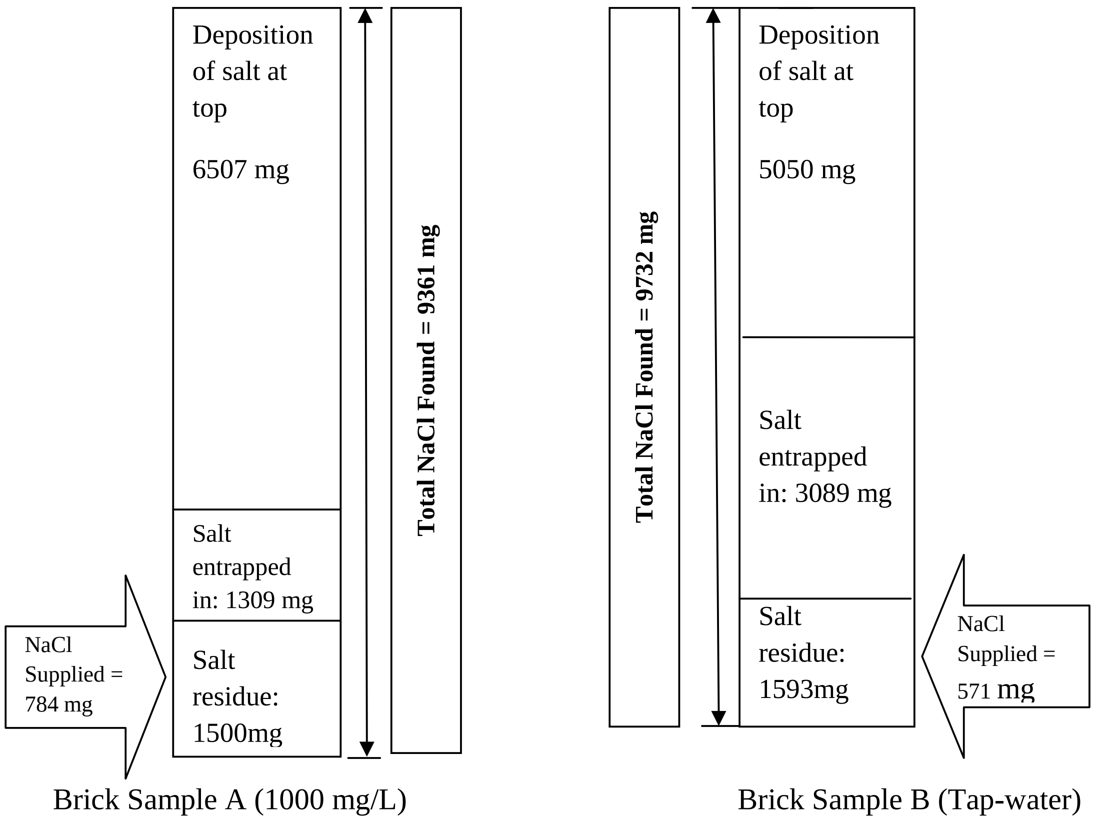


**Fig-3: Schematic diagram of NaCl intrusion, remnants of NaCl in bricks**

Two other runs with plastered and bared bricks are still under observation with saline water of specific concentrations.

### 3.2 Comparison of Salt Transport

Other in run set ups are the installation of only bricks with no wrapping peripherally. They were kept sunken in three different concentrations of NaCl as stated above. Another three set ups were prepared by wrapping the bricks peripherally by plaster of 1:5 ratio. The basic difference between the previous set ups and plastered bricks set ups was the flow direction. That is the plastered bricks received sunlight and air from all sides where previous three received from one direction only. The bare or only bricks were also exposed to the same ambience. Some very interesting results were also found from these set ups. This set up has been termed as Run-2 that is the bared bricks sunk in different specific concentrations of NaCl. The water required to overcome the depletion from a certain level were considered as the water sucked by brick samples. Amount of water absorbed by different sample in the second run are represented in Table-3 and Figure-4.

**Table 3: Amount of water sucked by plastered brick with time (Only Bricks)**

| Dates observed | Normal Water<br>Ml | 1000 mg/L of NaCl<br>ml | 35000 mg/L of NaCl<br>ml |
|---|---|---|---|
| 5/12/2010 | 230 | 225 | 230 |
| 6/12/2010 | 60 | 30 | 35 |
| 7/12/2010 | 35 | 30 | 30 |
| 8/12/2010 | 25 | 25 | 25 |
| 12/12/2010 | 100 | 90 | 85 |
| 13/12/2010 | 70 | 20 | 0 |
| 14/12/2010 | 45 | 35 | 30 |

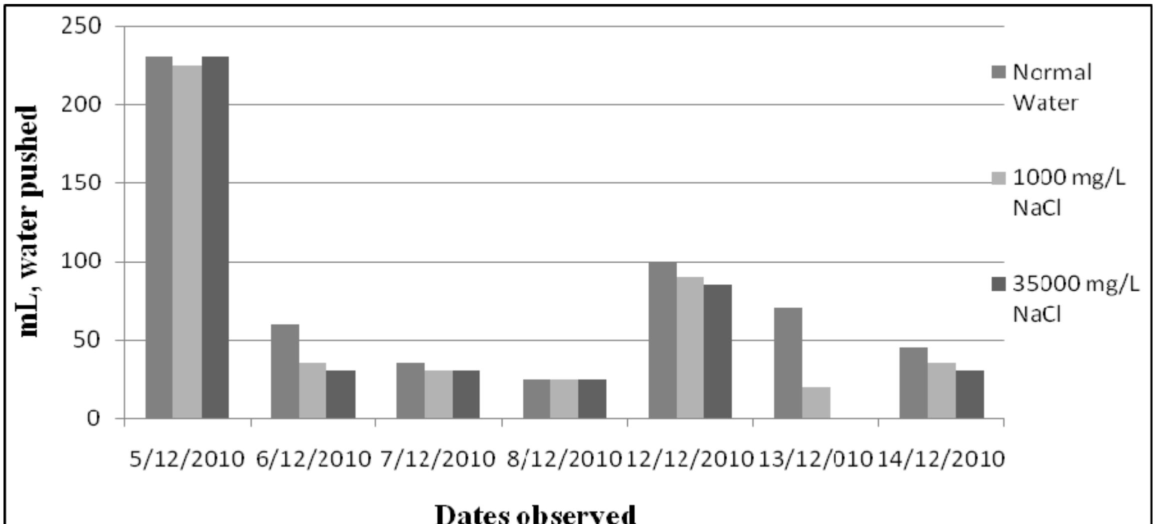


**Fig 4: Comparison of sucked water from different concentrations (Only Bricks)**

The brick samples which were sunk in lower concentration have sucked more water than that of higher concentration. Initially on 5 December 2010 water was pushed to fulfill a certain level. As the occupied volume by all three bricks was not identical as stated previously, water required to fill the certain level were not similar primarily. But in later dates water sucking amounts varied with a definite pattern.

The following data are for Run-3 that is the plastered brick set ups. The data with corresponding histogram are as follows.

**Table 4: Amount of water sucked by plastered brick with time (Plastered Bricks)**

| Dates observed | Normal Water ml | 1000 mg/L of NaCl ml | 35000 mg/L of NaCl ml |
|---|---|---|---|
| 6/12/2010 | 220 | 215 | 195 |
| 7/12/2010 | 110 | 75 | 50 |
| 8/12/2010 | 30 | 25 | 25 |
| 12/12/2010 | 73 | 25 | 32 |
| 13/12/2010 | 22 | 0 | 15 |
| 14/12/2010 | 30 | 25 | 15 |

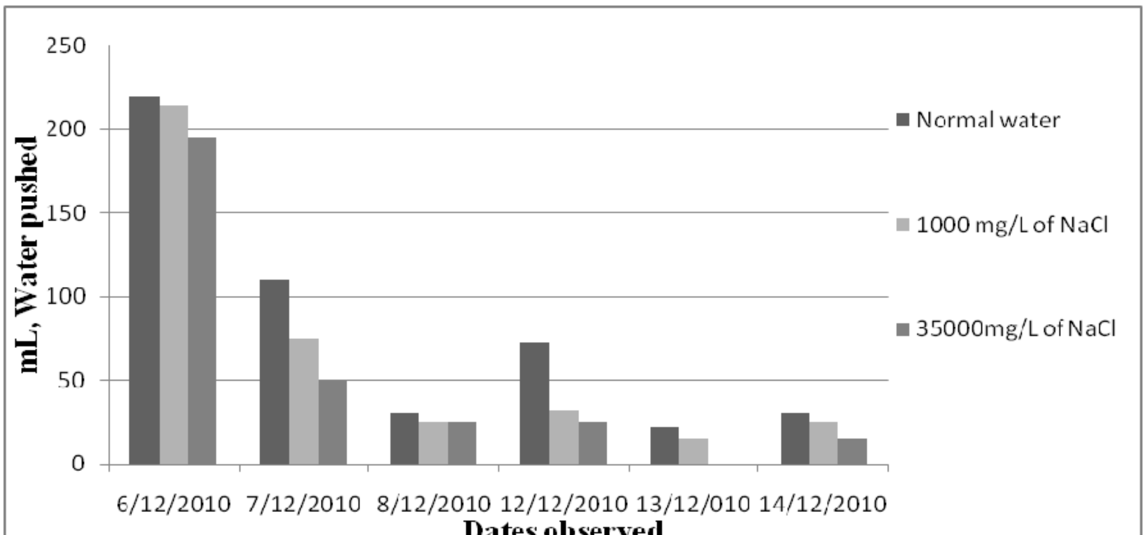


**Fig 5: Comparison of sucked water from different concentrations (Plastered Bricks)**

It is evident that bricks in both set ups had sucked more water in a certain pattern. Bricks those were sunk in normal tap-water did not suck the same water as compared to the other bricks set in other concentrations. The bricks in normal water sucked more water than 1000 mg/L. The brick sunk in 35000 mg/L had sucked lesser water as compared to 1000 mg/L. This is a very important as well as useful finding in predicting salinity pattern and saline intrusion in structures near to sea or in coastal areas.

## 4. CONCLUSION

Salinity problem in coastal areas is the most striking problem It causes manifold problems among which the efflorescence caused by dissolved salts present in vicinity of structural brick materials. This research is a little contribution in context of salinity damage in buildings or industries. Several important findings have been revealed after analyzing the data observed. The flow pattern of saline water varied with the variation of concentrations of saline water as observed in above experiments. Not only this but also another important finding was observed that the higher saline water the slower flow rate. It is observed that the range of salinity transfer through brick samples is 6.7 to 8.3 mg NaCl per mL of water moment

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# CHANGING OF TOP SOIL NUTRIENTS DUE TO RANDON STONE EXTRACTION

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## ABSTRACT

Nutrients are the elements which is necessary for living organism. It helps the living organism to continue their growing up process. Soil nutrients are essential for plant to develop their cell wall & various types of activity. Balanced soil nutrients level helps to grow up healthy plant. The study area is jaflong which is not only a resource of natural stone but also agricultural product. But unplanned stone extraction from agricultural land causes change of nutrients level in soil. It affects on crop production. As a result top soil of Jaflong is losing fertility.

**Key Words**: Environment. Jaflong, Nutrients, Top soil

## 1. INTRODUCTION

The study area is Jaflong, a well known part of Bangladesh for its natural beauty. Due to collection of stone for long time soil nutrients condition have been changed. This is harmful for both plant life & crop production. Soil nutrients condition is changing day by day particularly necessary nutrient for plant is decreasing rapidly. On the other hand some heavy metal concentration is increasing. Unplanned stone extraction from top soil, coal burning on agricultural land, using over doses of fertilizer are the main causes of imbalanced soil nutrients condition.

## 2. SOIL NUTRIENTS

Nutrients, also dubbed "plant food", are soluble minerals that, when mixed with water, allow the plant to feed. Needed nutrients fall into two categories: Macro and Micro element. Macro elements are vital to plant health; these include:

1. Nitrogen 2. Phosphorus 3.Potassium4. Calcium 5.Magnesium 6.Sulfur.

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Other elements needed are called Micro elements.  Included in this category are:

1. Boron 2.Manganese 3.Copper 4.Zinc 5.Molybdenum 6.Chlorine 7.Sodium 8.Silicon

## 3. METHODOLOGY

In order to conduct this study steps like field observation, data collection, analysis, laboratory test, economic consideration etc. measures are measured. Samples were collected from more than fifty points to find out actual condition. A mixed method of investigation is done for the purpose of present study combining both qualitative & quantities methods such survey, interviewing, case studies etc. Study areas are visited several times to know the existing condition. In this study the first aim is to find out the soil nutrients level. For this experiment soil digestion process was followed to find out required nutrients. The undisturbed and disturbed soil samples were collected by auger and by core sampling about 12 in x 12 in to a depth of about 40 cm from the surface, respectively. Disturbed samples were collected and then transferred to the soil laboratory for chemical and physical analysis. The procedure is given below-

1. Sample Collection
2. Dry sample at room temperature & then oven dry the sample
3. Take the sample according to requirement through weight meter.
4. Add 2.5ml $HNO_3$ & 7.5ml HCl for 1 gm soil sample in a glass pot.
5. Pour the soil sample into the pot & rest it for 24 hours.
6. Heat the soil sample with MENTHOL for some time.
7. Filter the solution with filter paper & Add required milliliter distilled water
8. Now the sample is ready for test.

## 4. STUDY AREA

The study area is Jaflong, a well known part of Bangladesh which is famous for natural stone collection. The study is conducted for this unplanned stone collection. This type of stone collection system causes a great threat to top soil nutrients.

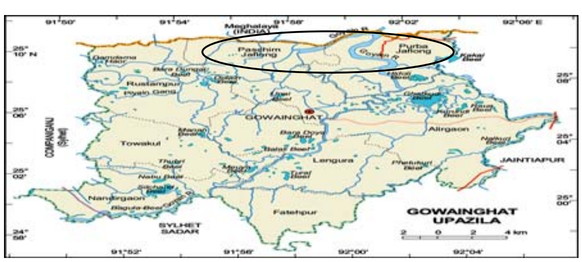



Fig 1: Study area. (source- BMD,1988)

## 5. NUTRIENTS CONDITION

The present top soil nutrients condition is shown in tabulated form in 1 and 2.

| Area | $P^H$ | $NO_3^-$-N | $SO_4^-$ | K |
|---|---|---|---|---|
| | | ppm | (meq/g) | |
| Chelakhel | 5.8 | 17 | 0.37 | 0.18 |
| Asampara | 6.0 | 2 | 0.58 | 0.18 |
| Baurbag | 5.4 | 19.02 | 0.42 | 0.16 |
| Sankidanga | 5.6 | 90.10 | 0.54 | 0.17 |
| Vitrikhel | 5.4 | 21.02 | 0.39 | 0.15 |
| Kalibari | 5.6 | 17.02 | 0.30 | 0.07 |
| Bag-haor | 5.8 | 60.06 | 0.19 | 0.08 |
| Vitri-haor | 6.0 | 16.02 | 0.28 | 0.09 |
| Cowra | 5.6 | 23.03 | 0.31 | 0.10 |
| Pach-hati | 5.6 | 120.13 | 0.36 | 0.12 |
| Borobondo | 5.9 | 70.07 | 0.41 | 0.12 |

| Area | Zn | $Fe^{2+}$ | $PO_4^{3-}$ |
|---|---|---|---|
| | µg/g | | |
| Chelakhel | 170 | 89 | 1096 |
| Asam-para | 370 | 324 | 2020 |
| Baurbag | 310 | 422 | 920 |
| Sankidanga | 110 | 1069 | 760 |
| Vitrikhel | 80 | 2917 | 640 |
| Kalibari | 30 | 5200 | 920 |
| Bag-haor | 130 | 356 | 760 |
| Vitri-haor | 160 | 680 | 600 |
| Cowra | 110 | 648 | 520 |
| Pach-hati | 600 | 1329 | 720 |
| Borobondo | 170 | 2917 | 520 |

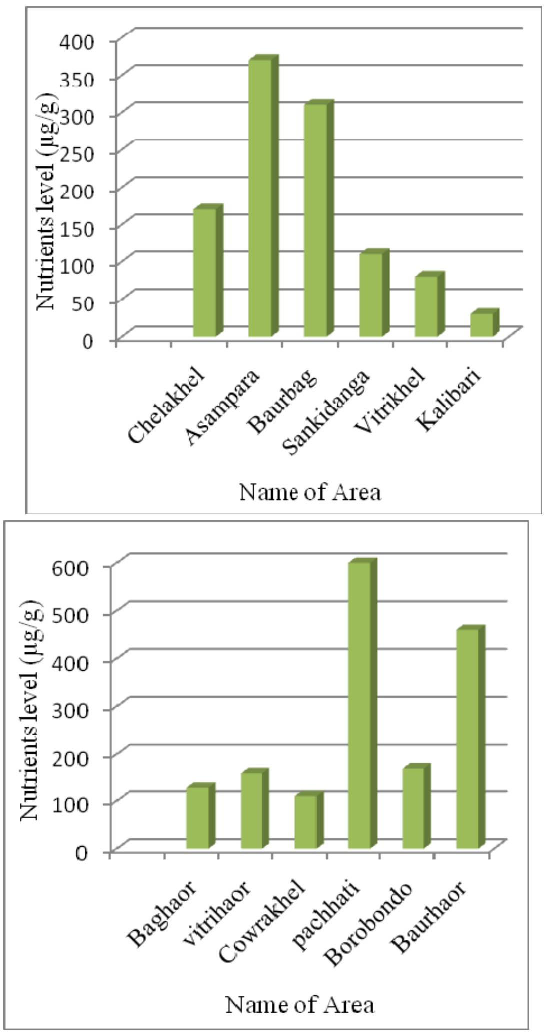
Table 1: Nutrients condition of East Jaflong soil.

| Area | $P^H$ | $NO_3^-$-N | $SO_4^-$ | K |
|---|---|---|---|---|
| | | ppm | (meq/g) | |
| Malikandi | 5.4 | 9.01 | 0.54 | 0.13 |
| khuri | 5.0 | 61.07 | 0.37 | 0.13 |
| N.prtappaur | 4.8 | 76.08 | 0.39 | 0.15 |
| Sutanpur | 5.4 | 39.04 | 0.34 | 0.12 |
| Lata | 5.6 | 69.07 | 0.51 | 0.06 |
| Luni | 5.2 | 171 | 0.33 | 0.16 |
| Ambari | 6.0 | 178 | 0.63 | 0.17 |
| Labu | 5.4 | 81 | 0.61 | 0.17 |
| Kopi | 6.2 | 89.02 | 0.45 | 0.18 |
| Goain | 5.5 | 31 | 0.41 | 0.15 |

Table 2: Nutrients condition of West Jaflong soil.

Various types of nutrients which are essential for plant growth are shown in table 1 and 2.The hazardous condition of nutrients level is shown in table 1 at East Jaflong. Experimental result shows that soil of Kalibari contains about 5000 µg/g ferrous which is so dangerous for plant growth as long as various types of crop production. These nutrients are helpful when it is in optimum condition. Again other part of Jaflong named West Jaflong nutrients level is shown in table 2.Nutrients condition is not in balanced level. All nutrients condition are shown in column diagram which are given below-

**6. ZINC LEVEL**




| Area | Zn | $Fe^{2+}$ | $PO_4^{3-}$ |
|---|---|---|---|
| | µg/g | | |
| Malikandi | 120 | 850 | 1500 |
| khuri | 170 | 680 | 480 |
| N.prtappaur | 30 | 1620 | 90 |
| Sutanpur | 130 | 1329 | 520 |
| Lata | 170 | 3435 | 440 |
| Luni | 210 | 3889 | 560 |
| Ambari | 390 | 3306 | 600 |
| Labu | 430 | 615 | 560 |
| Kopi | 460 | 680 | 524 |
| Goain | 380 | 820 | 590 |

Fig 2: Column diagram of present Zinc level at East Jaflong upland.

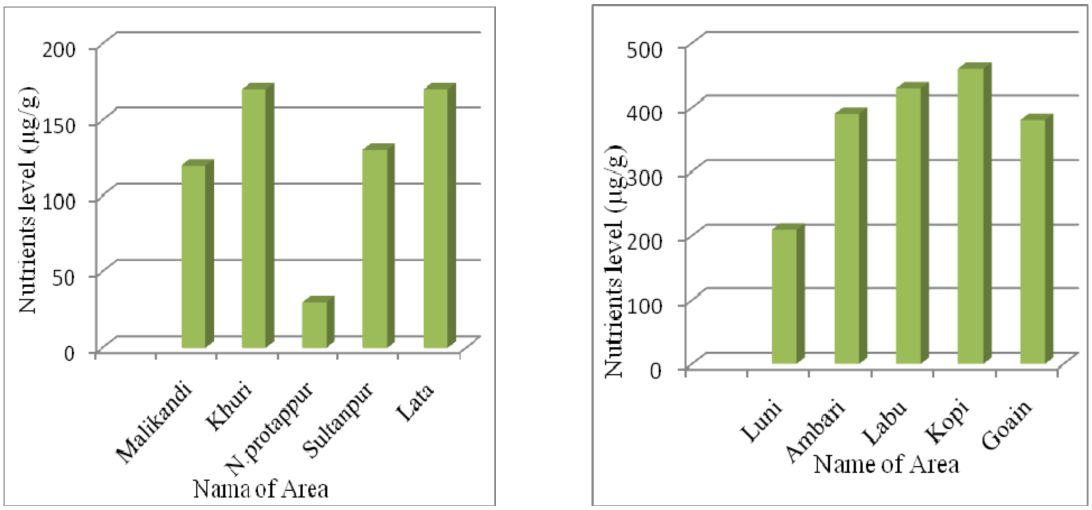



Fig 3: Column diagram of present Zinc level at West Jaflong wetland.

Zinc is essential for the normal healthy growth and reproduction of plants. When the supply of zinc is inadequate, crop yields are reduced & the quality of crop products is impaired. In plants zinc plays a key role as a structural constituent of a wide range of different enzymes & proteins. From experimental figure (fig-2 & fig-3) shows that East Jaflong soil contains excess amount zinc. It is not good for crops. Excess zinc level can reduce chlorophyll production.

## 7. POTASSIUM LEVEL

Higher soil moister usually means greater availability of potassium. When soil aeration increase then $O_2$ level in the soil increase. This aeration generally rapid at rock soil because of collecting rock from soil. Again Down land regions & hilly area's soil has high concentration of Potassium.

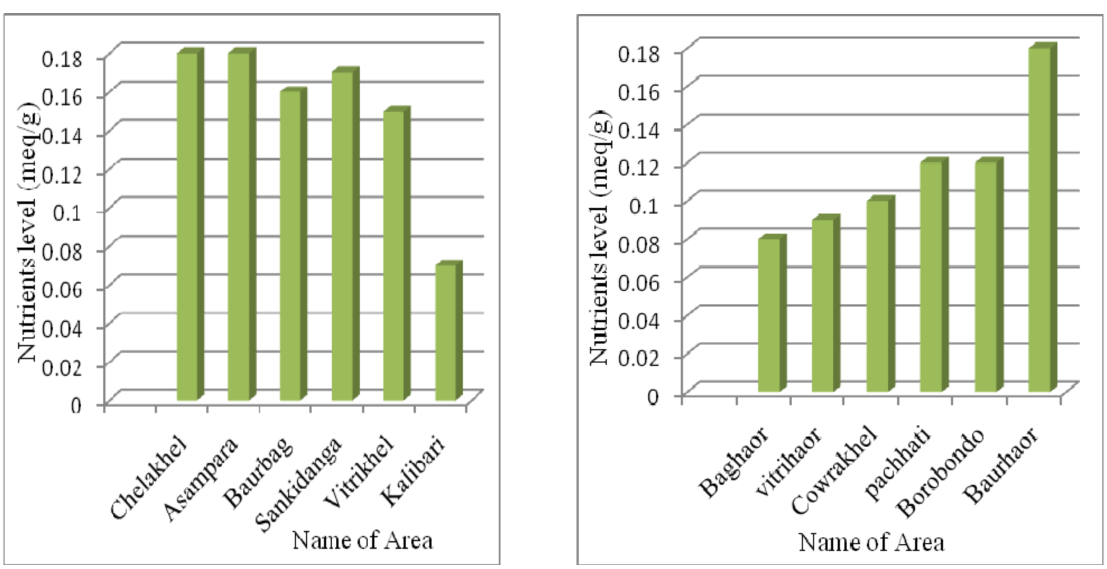



Fig 4: Column diagram of present Potassium level at East Jaflong .

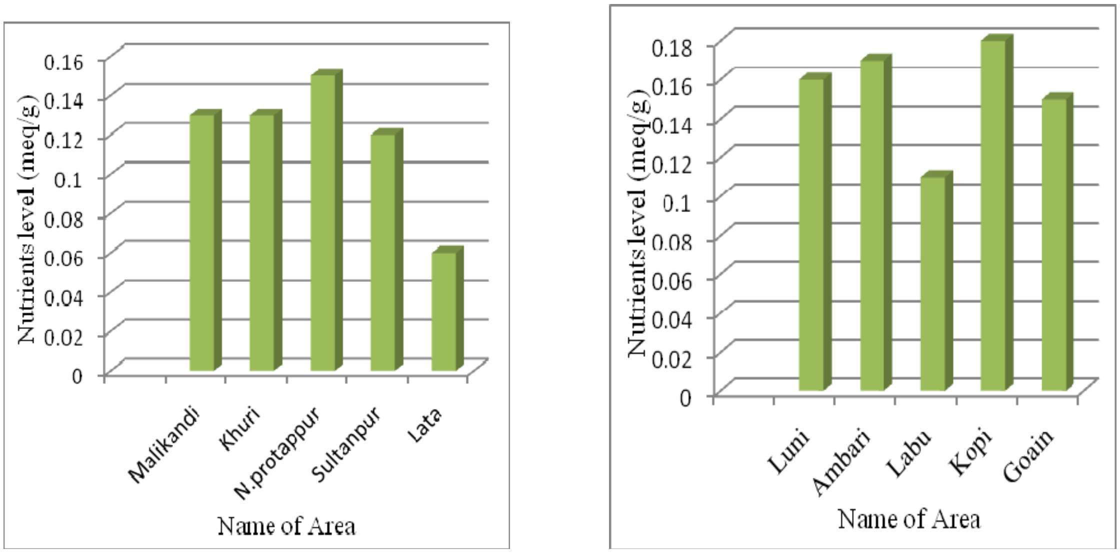



Fig 5: Column diagram of present Potassium level at West Jaflong.

Plants uptake potassium in anion form. According to experimental result (fig-4&fig-5) potassium level is so high. High amount of potassium decrease the resistance power of plant against specific disease. The albumen content of leaves is decreased by extra potassium.

**8. FERROUS LEVEL**

Ferrous is necessary for plant growth. Again it is essential for soil health. Optimum level of ferrous helps to grow out plant smoothly. Ferrous of Jaflong soil is given below-

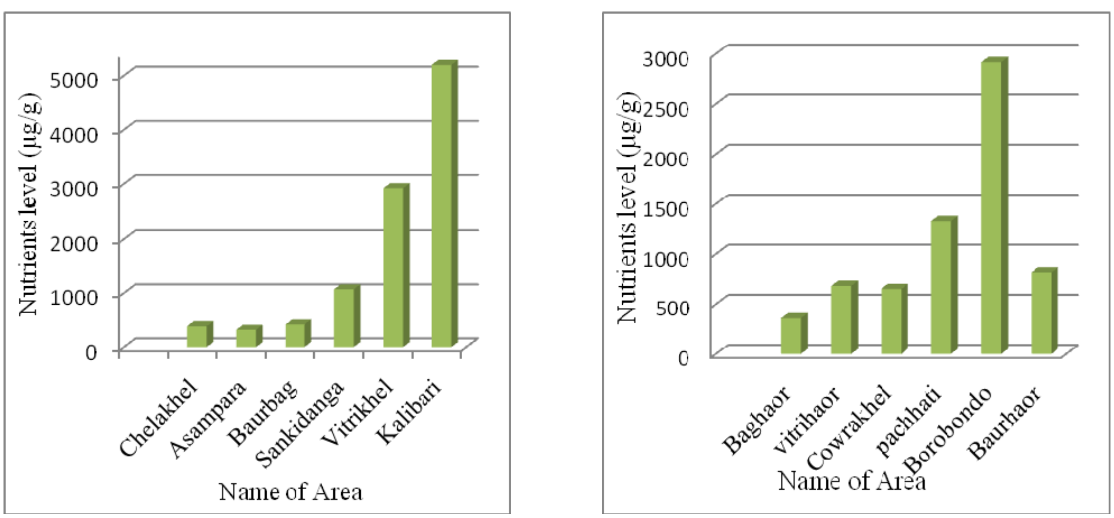



Fig 6: Column diagram of present ferrous level at East Jaflong.

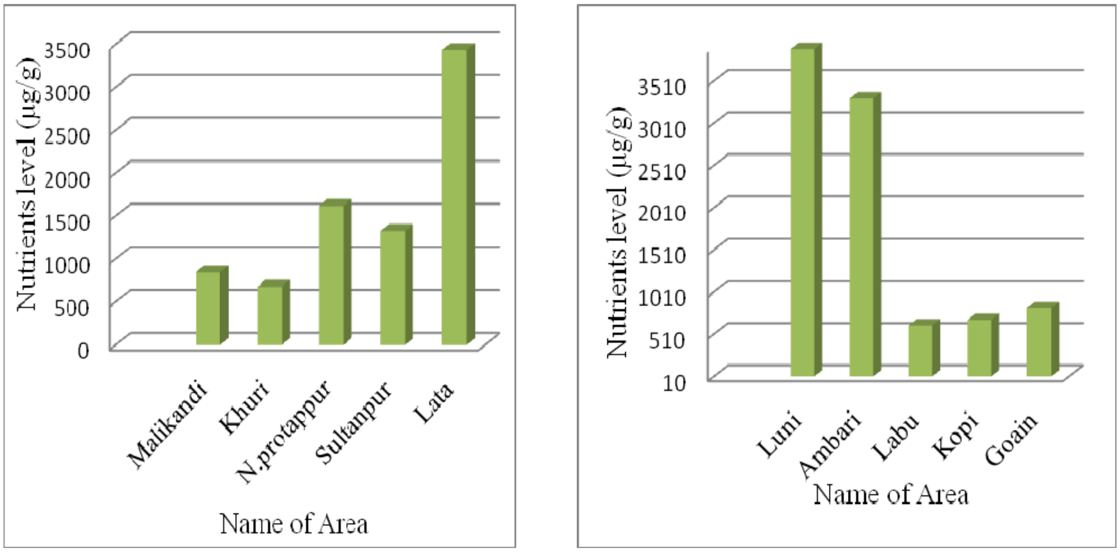



Fig 7: Column diagram of present Ferrous level at West Jaflong.

From above diagram it is clear that ferrous level is much high from standard level. Normally it depends on soil moister & pH. Acidic soil contains more ferrous concentration. For each 0.25 unit change of pH, ferrous level changes 100 times. Soil loses its fertility with increasing concentration of ferrous. It increases organic acid decomposer. It also helps to increase phosphorus & molybdenum. It breaks the soil nitrogen cycle. . Both East & West Jaflong soil contain high amount of iron. Excess iron in soil in this hilly area is normal because of geographical condition. But Experimental result shows very high concentration of iron. It is not good for soil & plant health. High concentration of iron reduces plant growth & crop production. Sometime it reduces nutrient uptake power of plant.

**9. NITRATE-NITROGEN**

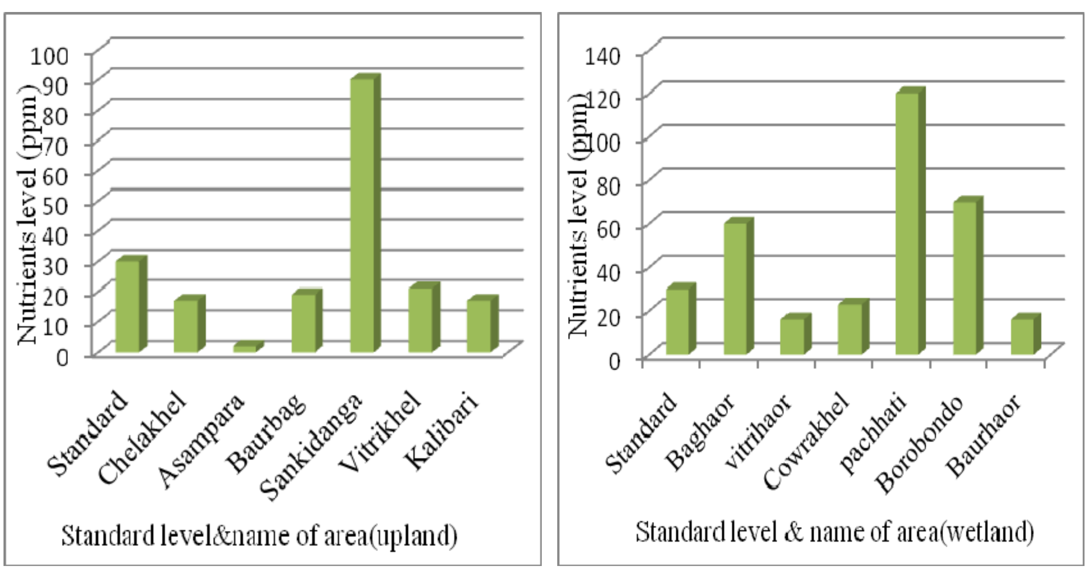
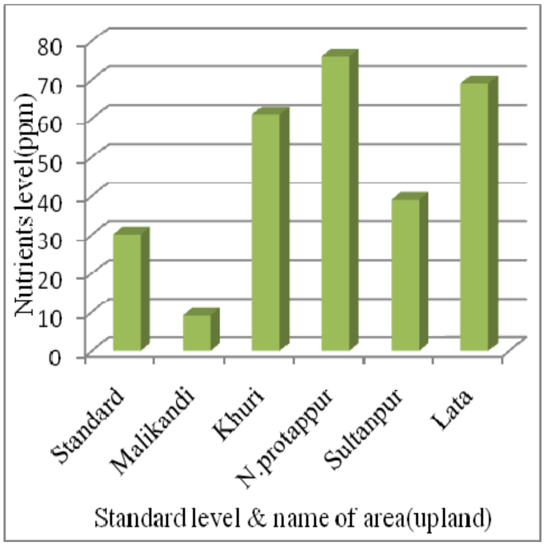



Fig 8: Column diagram of present nitrate-nitrogen level at East Jaflong.



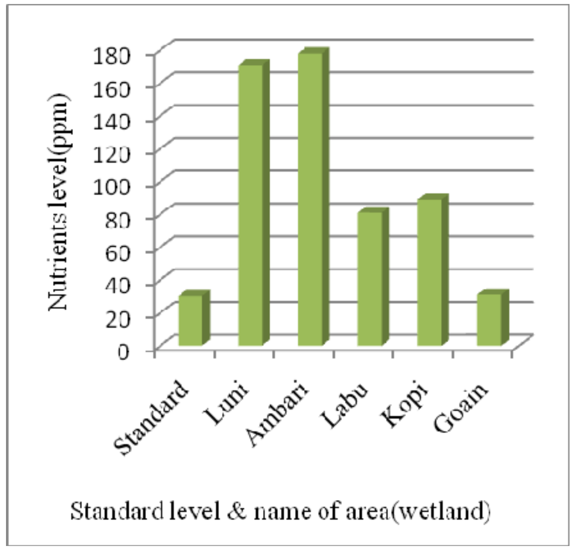




Fig 9: Column diagram of present nitrate-nitrogen level at West Jaflong.

Plant collect nitrate nitrogen as nitrate form. But when total amount of nitrogen in soil cross the optimum level then it reduces water circulation of plant's body. However optimum level of nitrogen increases the susceptibility of foliage.Fig-8 & 9 shows that the high concentration of Nitrate-nitrogen which is harmful for soil & plant health.

## 10. CONCLUSION

Random stone extraction is a great threat to agricultural top soil nutrients. Stone extraction not only affecting soil health but also destroying hill beside Jaflong. Consequently, it is necessary to maintain soil health by ensuring optimum nutrients level. According to survey conducted in the study area, various types of crops & vegetables are cultivated. Rice is the main crop. But not only rice but also Potato, Betel, Olives are cultivated. These are cultivated through the year round. Another dangerous crop named tobacco is also cultivated in West Jaflong. But it is cultivated unethical way. Random stone collection from agricultural land reduces the balance level of soil nutrients which essential for plant growth. Respective authority should take effective measure to soil nutrients level for plant life & required crop production.

## REFFRENCE

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and Construction Engineering for Sustainable Development
ICETCESD-2011, March 10-12, 2011, SUST, Sylhet, Bangladesh

# IMPACT OF STONE EXTRACTION AND CRUSHING ON HUMAN HEALTH AND ENVIRONMENT IN BHOLAGONJ, SYLHET

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## ABSTRACT

At the start of the new Millennium, stone continues to play an important role in shaping our environment. Today the extraction, processing and transport of stone are a complex issue. On the one hand it supplies materials to meet many of society's needs and creates employment, but on the other hand it can have significant impact upon the environment and local communities. This Thesis work explores some of these issues in the country’s largest stone quarry at Bholagonj, Sylhet. By this study, the present noise levels condition, dust problems and temperature threatening can be easily understood. According to the study it is observed that major problem in quarry is sanitation and noise about 40%and 39%. Though it is a residential area, about two times of standard noise level are produced here. In the Quarry area same scenario are observed. Road side crushing plants are causing both noise and dust drastically. In this study noise level and temperature of different locations in Bholagonj have been measured which express the degree of impact on human health and environment. About 70% worker faced noise related diseases. Field survey shows that 90% people think that noise causes only hearing loss and 93% people faces dust problem. About 75% people blame the quarrying for environmental change of this area. It is seen that biodiversity and occupation of the local people have been changed. About 30% people think soil erosion happened by manmade and 65% for water current of the river. Temperature graph shows that a concerning rate of temperature have been increasing. Rainfall is increasing at noticeable rate. People know about pollution but authority has no concern.

**Key word:** Quarry, Noise, Temperature

## 1. INTRODUCTION

At the start of the new Millennium, stone continues to play an important role in shaping our environment. Today the extraction, processing and transport of stone are a complex issue. On the one hand it supplies materials to meet many of society's needs and creates employment, but on the other hand it can have significant impact upon the environment and local communities. This research study explores some of these issues in the country’s largest quarry at Bholagonj, Sylhet. Over 60 thousand people including women are engaged in different jobs around the Bholagonj quarry. Among them, about 35,000 are engaged in stone collection by small country boats locally called 'BARKI.' Every morning, gigantic activities begin along the whole quarry area. Motors or shallow engines are also engaged in stone collection in the quarry.

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## 2. METHODOLOGY

In order to conducting the study, methodological steps like field observation, data collection, analysis etc are performed. Data are collected from more than ten points to find out actual condition. A mixed method of investigation for the purpose of present study combining both qualitative & quantities methods such as survey, interview, case studies etc. are selected in the study.Locationsare visited several times to know the existing condition. In depth interview is takenfromthe relevant peoples of different sectors such as local people, farmers, truck drivers, women, children, boatman & labor. To measure noise level at various position of Bholagonj a typical noise level meter, model NL-04 was used. Overall methodological steps of the study are shown in fig 1.

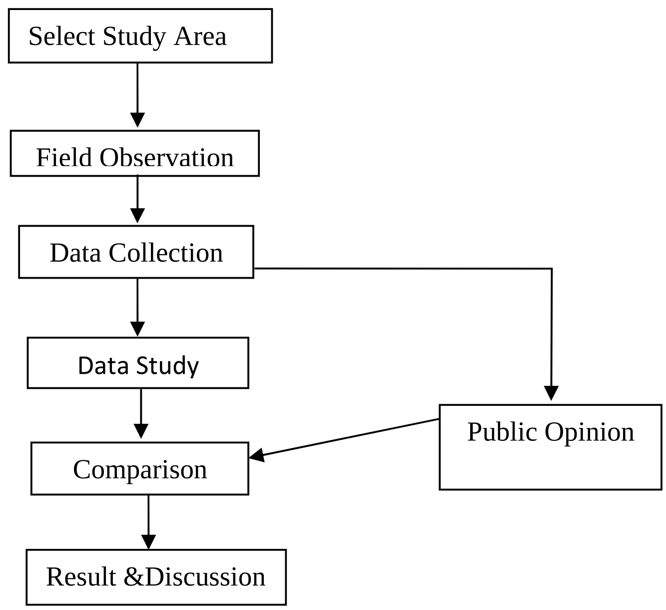


Figure 1: Methodological steps of the study

## 3. SOURCES OF NOISE

The major sources of noise in the quarry and crushing areas of the Bholgang study as shown in figure 2 depicts deteriorated view of the area.

Figure2: Various sources of noise in the study area

## 4. RESULTS AND DATA ANALYSIS

Average noise levels measured in the various establishments, quarry and crushers of the study area of Bholagang are presented in tables 1, 2 and 3.

Table1: Noise level in various locations in the study area with acceptable (2)

| Location | Existing noise level in dB | Acceptable Noise level in dB |
|---|---|---|
| Crusher machine Area | 91.03 | 45 |
| Quarry Area | 88.05 | 45 |
| Bazaar | 72.8 | 60 |
| School | 71.9 | 45 |
| Village | 59.9 | 50 |

Table2: Noise level in various Quarries in the study area

| No | Owner of the Quarry | Quarry location | Average noise level in dB |
|---|---|---|---|
| 1 | Sonamia | West Doyer bazar | 91.3 |
| 2 | Elius | Doyer bazar | 94.7 |
| 3 | Eaqube | North Banker | 90.0 |
| 4 | Nasiruddin | East Banker | 71.8 |
| 5 | Shamim | Zero line | 86.8 |
| 6 | Arju | West banker | 89.6 |
| 7 | Shahju | Das number | 84.3 |
| 8 | Al-Amin | North Banker | 91.8 |
| 9 | Selim Ahmed | East Bholagonj | 90.8 |
| 10 | Aeijuddin | East Das Number | 89.6 |

Table 3: Noise level in various crushers in the study area

| No | Crusher Name | Location | Crusher Type | Average noise levels in dB |
|---|---|---|---|---|
| 1 | Mesars five star | Kolabari | small | 89.6 |
| 2 | Allaher Dan Mayer Doa | Kolabari | Large | 91.6 |
| 3 | Salehin Stone Crusher Industries | Kolabari | Large | 91.9 |

| | | | | |
|---|---|---|---|---|
| 4 | Islam Stone Crusher Industries | Parua | Large | 90.8 |
| 5 | Esha and Shis Stone Crusher Industries | Parua | Large | 91.3 |
| 6 | Moinuddin stone crusher | Parua | small | 91.3 |
| 7 | Foyez stone crusher industries | Parua | small | 91.8 |
| 8 | Bhuiyaa Stone crusher Industries | Bholagonj | small | 90.0 |
| 9 | Manik and sons stone crusher | Bholagon | Small | 91.8 |
| 10 | Rahim stone crusher | Bholagonj | Large | 89.64 |

**4.1 Comparison between Standard Noise Levels and Acceptable Noise Levels**

According to collection of noise levels data from Quarry, crushing plant, Bazaar, near village and school area, average noise level is noticeable, maximum in quarry and crushing areaconsidering quarry and crushing area as mixed area according to DOE as depicted in figure 3.

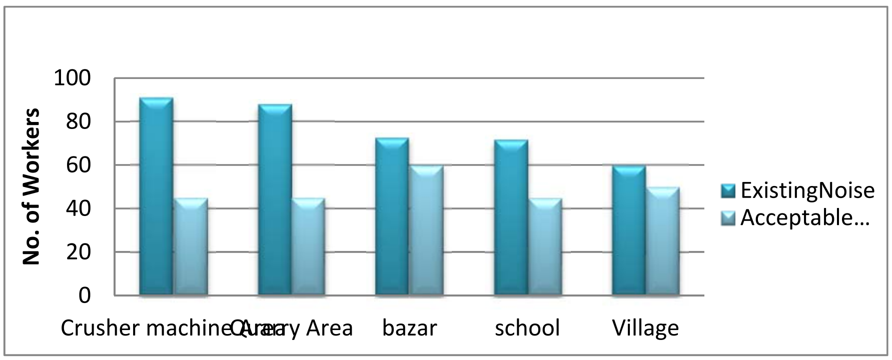


Figure 3: Comparison between standard noise level and acceptable noise level

**4.2 Comparison between quarry noise and standard noise**

There is given comparison between quarry noise levels and standard noise levels for construction work in quarry as revealed in figure 4. It has been seen that quarry noise is higher than standard average noise.

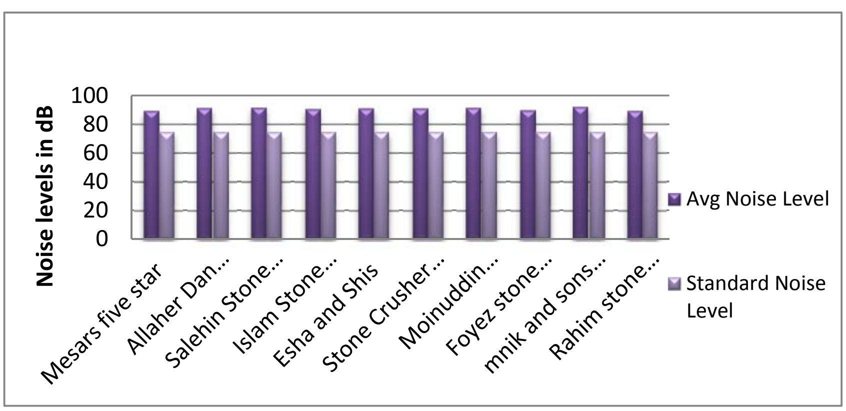


Figure 4: Comparison between quarry noise level and standard noise level

## 4.3 Comparisons between crushers noise level and standard noise level

Figure 5 compares between crusher noise levels and standard noise levels for construction work in quarry. It has seen that crusher noise level is higher than standard average noise level.

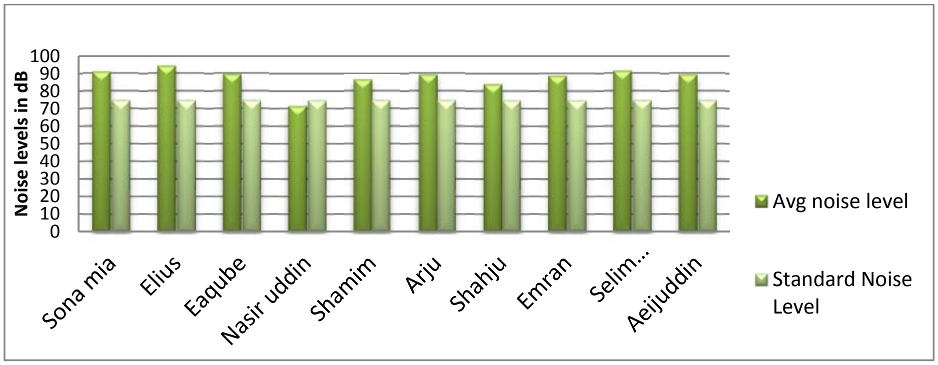


Figure 5: Comparison between crusher noise and standard noise

## 4.4 Dust awareness according to categories of worker

There are various types worker and people in Bholagonj like quarry worker, crusher worker, truck worker, driver and general people. Maximum people have no awareness about dust but few truck workers put mask, some other cover faces with handkerchief and gamcha. Figure 6 shows the scenario of dust awareness to various types of workers.

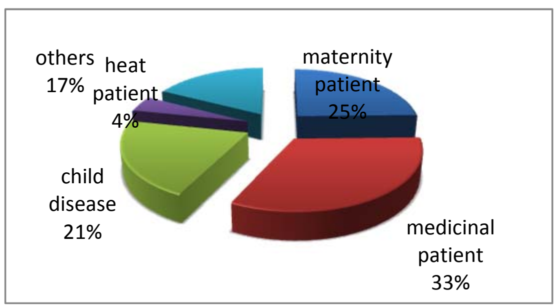


Figure 6: Dust awareness among different workers

## 4.5 Type of patient admitted in the hospital

Various type of patient is admitted in the hospitals but most of them are children and maternity patient. Patient of heart disease are very few. There is some patient of surgery. Figure 7 show that medicinal patient is predominant in the range of 33% followed by 25% maternity patient, 21% child disease, 4% heart disease and others17%.

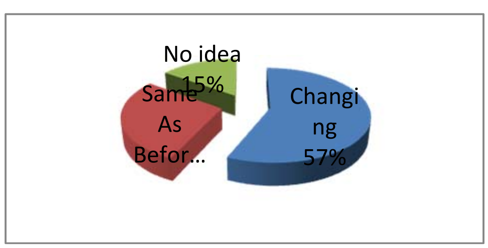


Figure 7: Type of patient admitted in the local hospital

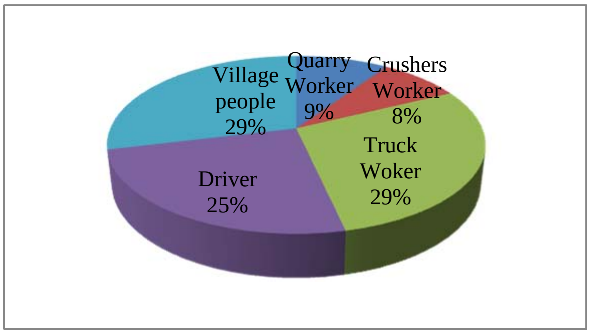


Figure 8: Public opinion about environmental change

### 4.6 Environmental change

Environment of Bholagonj and its surrounding area are changing drastically for stone extraction and stone crushing. Noise level, dust and temperature are affecting the area as per the assessment of public opinion of the questionnaires survey as shown in figure 8.

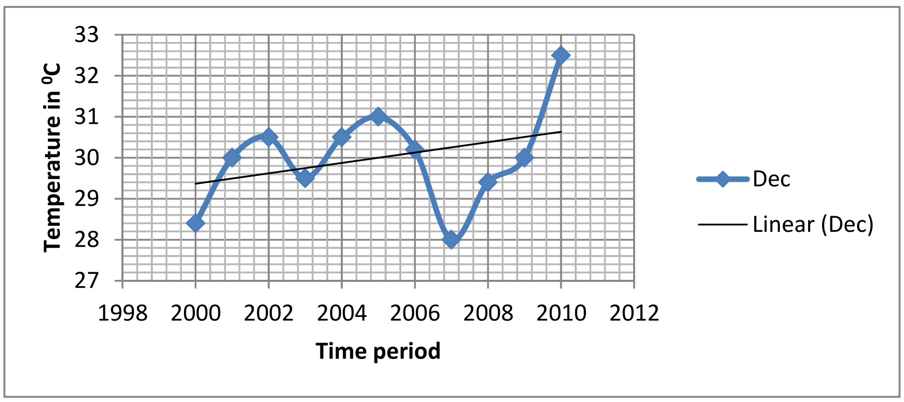


Figure 9: Average Temperature profile of December month with collected data

Collected temperature data of the month of December from Bangladesh Metrological Department shows the tremendous temperature change in between 200 to 2010 as shown in temperature profile of figure 9illustrating the increase of temperature drastically.

In this regard, maximum temperature measured the month of December of 2010 in the study area of Bholagang is given in table 4.

In the study area having large quantity shallow engine for pumping, stone crushing and vast people related to their work with machine which is increasing surrounding temperature day by day.

### 5. DISCUSSIONS

All the results show that noise level, dust problem, temperature and others environmental impact is very acute in Bholagonj. The pollution from quarries and crushers industries are serious hazardous which is faced by the local people and workers. The study deals with the major problems of the quarry which mainly includes noise, dust, temperature, environmental impact and health impact on the workers. The study also identified some techniques for the reduction of pollution of the study area. This study deals with the noise pollution effects on the local people and workers of quarry and crushers.According to the study it is observed that major problem in quarry is with the sanitation

(40%) followed by noise (39%) whereas in the crushing area major problem is with dust (47%) followed by noise (38%).90% people think that noise causes only hearing loss. Road side crushing plant is causing both noise and dust drastically. Large quarry producing more noise than small, because of they used two or three shallow machine to pump the quarry water. But large crushing plants experiences less noise levels than small because of the use of electric motor instead of shallow machine.People knows about noise pollution this types of people is about 10%, simply know 20%, never heard 45%. About 93% people face dust as a problem.People of the area think that their environment is changing and most of the people think negative environmental impact should be changed.

Table 4: Maximum Temperature of December Month 2010 of 22 days in the Study Area

| Date | Temperature in $^0$C |
|---|---|
| 7-Dec-10 | 29 |
| 8-Dec-10 | 30 |
| 9-Dec-10 | 29.5 |
| 10-Dec-10 | 32 |
| 11-Dec-10 | 29.5 |
| 12-Dec-10 | 32.5 |
| 13-Dec-10 | 29 |
| 14-Dec-10 | 28.5 |
| 15-Dec-10 | 32.5 |
| 16-Dec-10 | 29.5 |
| 17-Dec-10 | 30 |
| 18-Dec-10 | 29.5 |
| 19-Dec-10 | 29.5 |
| 20-Dec-10 | 30 |
| 21-Dec-10 | 29.5 |
| 22-Dec-10 | 31 |
| 23-Dec-10 | 28.5 |
| 24-Dec-10 | 29 |
| 25-Dec-10 | 30 |
| 26-Dec-10 | 30.5 |
| 27-Dec-10 | 30 |
| 28-Dec-10 | 30.5 |
| 29-Dec-10 | 29.5 |
| **Average** | **29.978** |

## 6. CONCLUSIONS

The study shows that the quarry area hasseriousproblems of sanitation, dust and noise. It is impacting the whole area with school children and village people.Due to the importance of stone in industries in today's environmentally aware society, it is vital that quarrying, mining and dredging operations of stones should ensure that they achieve the best possible environmental management in the activities. Poor environmental management within the industry results not only in non-compliance of legislation, which includes heavy fines, but also in poor public relations, loss of business, and loss and destruction of wildlife and habitats. Legislation – permission for extraction sites should be strict to maintain the require the strategy for the environment and human health before permission is granted during the planning process, unless restoration is restricted to commercial or domestic development to improve the existing degraded environment of Bholagang stone extraction zone

From the above discussion the following measures can be adopted to control the impact of stone extraction.

- Modern technology can reduce the emission of dust and sound levels.
- A definite area should be selected for crushing plant.
- Crushing plant should be set up far from workers.
- In quarry electric motor should be used for pumping.
- In quarry crane technology should be used instead of labors.
- Tree plantation can reduce the noise level and dust. It acts as a barrier for both noise and dust. It absorbs the sound energy and noise level reduces.
- The impact of dust emission is negative which should be reduced.
- The quarrying effect is temporary for the duration of the site operation which should be conducted for total impact.

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# NOISE POLLUTION OF EAST JAFLONG DUE TO UNORGANIZED STONE CRUSHING PLANT

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## ABSTRACT

Noise is a prominent feature of the environment which is simply defined as unwanted sound. Environmental noise consists of all the unwanted sounds in our communities. Environmental noise pollution is a threat to health and well-being. This study is conducted to find out noise pollution intensity at east Jaflong where thousands of tons of stone are crushed daily. Obviously noise pollution is more severe and widespread than ever before, and will continue to increase in magnitude and severity because of population growth, urbanization, and the associated growth in the use of increasingly powerful, varied, and highly mobile sources of noise in stone crush area of Jaflong. The potential health effects of noise pollution are numerous, pervasive, persistent, and medically and socially significant. Noise produces direct and cumulative adverse effects that impair health and that degrade residential, social, working, and learning environments with corresponding real (economic) and intangible (well-being) losses that interferes with sleep, concentration, communication, and recreation in study area.

**Key Words:** Jaflong, Noise, Decibel, Excavator. Stone, crushing plant

## 1. INTRODUCTION

Jaflong is one of the most attractive tourist spots in Sylhet division. It's about 60 km far from Sylhet town. It has total area of about 10000 hector having two part named east Jaflong & west Jaflong. Climate is moderate but rainfall is high from other side of the country. Jaflong is a reservoir of natural resources e.g. stone. Huge amount of stone about 2000 tons is extracted per day from Jaflong which is used throughout the whole country for development work in construction field. Stone collected in Jaflong come from Indian hill with the high velocity flood during monsoon. But stones are collected through the year round. About 3000 people are involved in stone collection. After collection, stone are crushed at the side of Jaflong bazaar. More than 250 machines are involved in stone crushing. There is no

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environment friendly stone crushing plant. For this a serious noise pollution is causing. Not only has it caused a threat to public health but also to entire environment.

## 2. METHODOLOGY

The most common measure of sound level is intensity & sound pressure. Sound intensity is the average rate of sound energy transmitted through a unit area perpendicular to the direction of sound propagation. To measure noise level at various position of jaflong a typical noise level meter, model nl-04 was used.

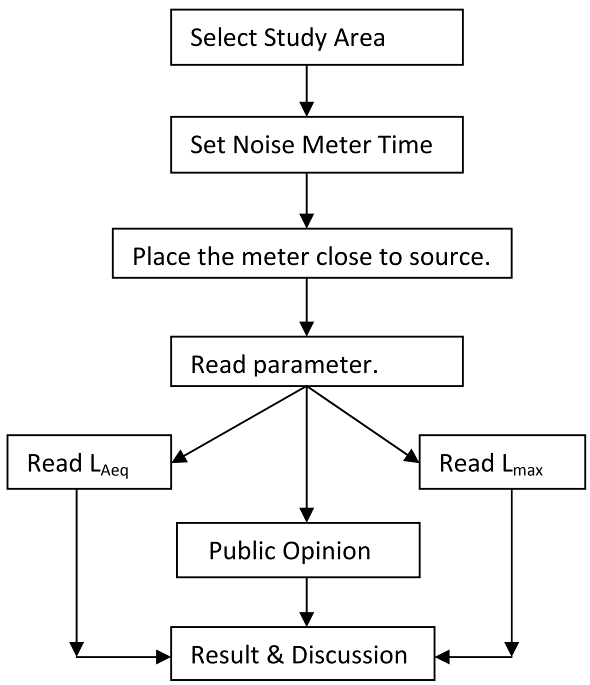


Fig-1: Flow chart for finding out Noise Pollution.

## 3. SOURCES OF NOISE

The following pictures in figure 2 and 3 depict the main sources of noise pollution at Jaflong. The hazardous condition of noise machine is shown in the figure. Excavator machines are installed here & there. All stone crushing machine are near about public place. Some Large crusher have installed more than five high power crushing machine.

Fig-2: Sources of noise pollution.

Fig-3: Noise pollution from large machine.

## 4. SAMPLING FREQUENCY

Noise level have been measured at various stone crushing position at Jaflong during 9 am to 4 pm. Noise levels measured in two time intervals namely

- 9am to 12am
- 1am to 4pm

### 4.1 Sampling Method

Noise level has been measured at the side of stone crushing machine & away from that machine. The distance is 6 ft & 100ft.This is done to analyze the effects of distance & existing side on the reduction of noise level. Sound levels have been measured for 5 munities for a couple of times. The average value of these measurements has been recorded as the sound level for the corresponding location & time interval. Data collected was analyzed statistically to determine $L_{10}$,$L_{50}$, $L_{90}$, $L_{max}$, $L_{ae}$, $L_{aeq}$.

### 4.2 Instrumentation & Data Analysis

The simple instrument available to determine sound levels has been referred as a sound level meter. The integrating sound level meter NL-04 allows not only conventional sound pressure level measurement, but also incorporate processing function, which make it possible to determine: equivalent continuous sound pressure level $L_{eq}$ sound exposure level $L_{max}$. The large backlit display shows measurement results in numerical form & on a graphical scale, and gives information on measurement parameters & settings in table 1 & 2. According to Bangladesh Department of Environment maximum noise level should be 60 dB in mixed area like Jaflong which was exceeded in all cases showing the severe noise conditions in East Jaflong. Obviously it is a threat to public health & mental health. Mainly children are affected by this type of excessive noise level intensity. Noise level of excavator machine is tabulated in table 2 and 3.

Table-1:Noise pollution level

| Crusher Name | Noise level | | | |
|---|---|---|---|---|
| | 9am-12pm | | 1pm-4pm | |
| | 6 ft | 100ft | 6 ft | 100 ft |
| Sundarbn | 91.2 | 84.4 | 95.2 | 89.5 |
| Desh | 80.3 | 76.5 | 91.7 | 85.3 |
| Progoti | 97.7 | 80.5 | 83.6 | 78.3 |
| Asa | 86.7 | 79.2 | 91.3 | 84.5 |
| Siplu | 88.5 | 78.6 | 89.7 | 83.2 |
| Al-raji | 97.8 | 89.7 | 96.8 | 88.6 |
| Jononi | 82.6 | 75.9 | 88.4 | 78.9 |
| Yousuf | 81.3 | 75.9 | 90.3 | 87.5 |
| Ekota | 90.1 | 87.8 | 97.8 | 94.6 |
| Rainbo | 89.5 | 86.2 | 113.5 | 98.5 |
| Raja | 98.8 | 96.3 | 107.6 | 96.8 |
| Ab | 96.4 | 92.1 | 102.6 | 91.2 |
| Millat | 95.1 | 90.3 | 104.3 | 97.8 |
| Chanmia | 93.3 | 90.3 | 98.7 | 95.3 |
| Doyel | 87.5 | 84.1 | 89.6 | 86.5 |
| Bengal | 86.7 | 82.8 | 86.7 | 83.1 |
| Sayem | 88.5 | 85.6 | 90.7 | 87.6 |
| Jalal | 85.4 | 81.2 | 89.8 | 86.7 |
| Mittal | 91.5 | 87.5 | 92.1 | 89.5 |

Table-2:Stone mining machine noise(Max.)

| Position | Noise level | |
|---|---|---|
| | 9am-12pm | 1pm-4pm |
| | Max. | Max. |
| East Jaflong | 112.3 | 108.2 |
| East Jaflong | 108.2 | 115.1 |
| East Jaflong | 109.2 | 110.3 |
| East Jaflong | 102.3 | 107.5 |

Table-3: Stone mining machine noise level(Avg.)

| Position | Noise level | |
|---|---|---|
| | 9am-12pm | 1pm-4pm |
| | Avg. | Avg. |
| East Jaflong | 100.8 | 102.4 |
| East Jaflong | 102.2 | 102.3 |
| East Jaflong | 105.2 | 105.7 |
| East Jaflong | 100.2 | 102.3 |

In another part of Jaflong named East Jaflong huge amount of stone are collecting by establishing high power of excavator machine. Locally it is named as Bomber machine. This type of machine creates a high power vibration & noise. These types of machines are also a source of high noise pollution. Along with this machine some high power water lifting pump are used for passing water from the large hole. It also creates noise problem. Stone mining machine noise level is shown in figure-4, 5, 6 with respect to standard noise level. But it is seen that all noise level are crossed the optimum level. Many workers are working in this situation. It is harmful for workers. Noise can break down ones concentration. Evidently, dangerous accident may occur anytime for lack of concentration in their regular works. In both figure yellow column diagram is the acceptable limit of noise.

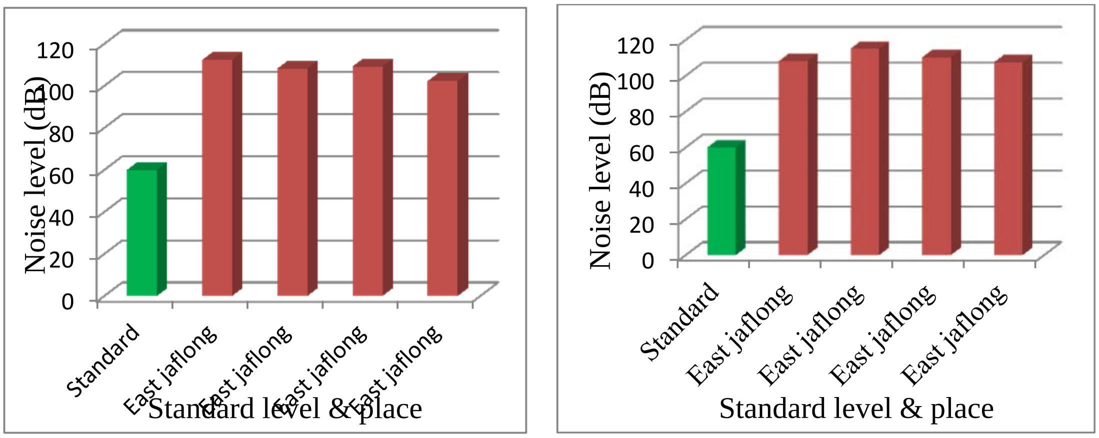


Fig-4: Maximum noise level morning (left) & afternoon (right) compare with standard level.

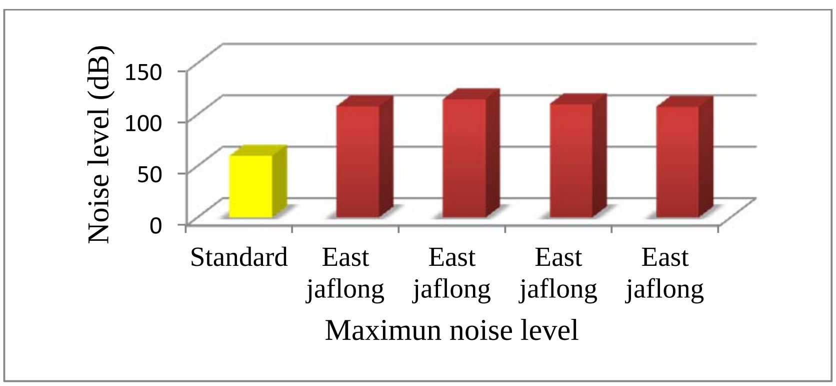


Fig-5: Comparison of maximum noise level (day time) with standard level.

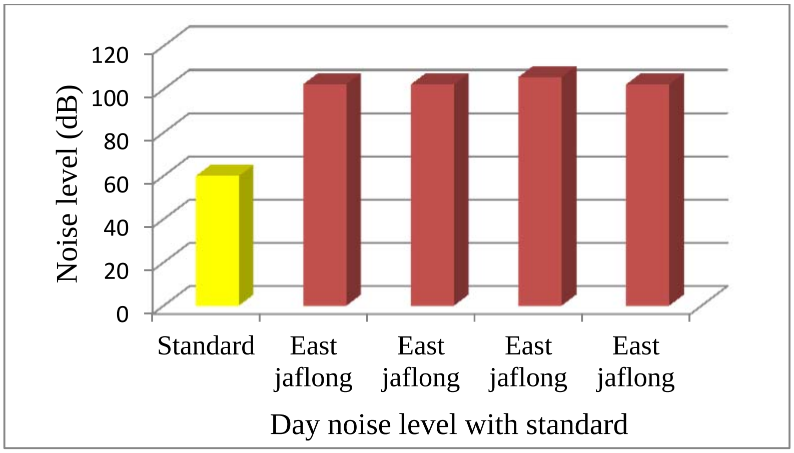


Fig-6: Comparison of average noise level (day time) with standard level.

## 5. CONCLUSION

The study was motivated due to unorganized establishment of stone crushing plant. Due to increase of population & urbanization noise pollution is increasing day by day. Various studies have been done on environmental issue but noise pollution has not been taken into an account. Evidently, concerned authority should give due attention to the noises problem. The following recommendations might be meaningful to handle the up-rise noise pollution situation in Jaflong area.

## 6. MAJOR FINDINGS OF THE STUDY

- Field survey shows that severe noise pollution is caused due to stone crushing machine.
- Noise level intensity is higher than normal level.
- Peoples are affected by various types of noise related diseases.

## 7. CLOSING STATEMENT

The output of the study reported in this thesis paper is that environment condition of Jaflong is not satisfactory. Noise pollution due to stone crushing machine is far exceeding the acceptable limit. Again stone dust from crushing unit creates various types of health problem. Mainly Children are affected by stone dust. So people awareness should be increased by undertaking awareness and motivation programs. Respective authority should take effective measure to reduce such kinds of environmental problem.

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International Conference on Environmental Technology
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# A STUDY ON PEAT DEPOSITS OF BANGLADESH AND PROSPECT OF ITS UTILIZATION

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## ABSTRACT

Bangladesh is energy starved poor country. The country does not have any significant energy resource. The colossal dependence on the natural gas will exhaust the present gas reserve by the year 2020. Although important deposit of peat has been discovered in Bangladesh several decades ago, no use of the peat has been made on a commercial basis. About seven large peat deposits have been discovered in the country and the total reserve is 146 million ton. Peat may be an important energy source. It may be used as a heating fuel in domestic households as well as in small industries like brick making, tobacco curing and small scale power generating units. Bangladesh government undertook Peat utilization and demonstration project in 1993–94 but the project was not commercially viable due to management problem. Peat could perhaps be more profitably utilized if developed locally on small scales by private entrepreneurs. Peat development may not make any significant impact on the overall national energy scenario, but its benefit to the otherwise energy starved rural population, at least locally, will certainly be major.
Key Words: peat, energy, utilization, reserve, briquettes.

## 1. INTRODUCTION

Power is the driving force of a country. At present Bangladesh is mainly dependent on natural gas for power generation. About 83.24% of power generation comes off by the gas [1]. Natural gas meets about 70% of the country's total commercial energy need [1]. But great majority of the rural people are lacking opportunity of getting commercial energy. They are depending on the availability of non-commercial biomass like fuel wood, agricultural residues, plant leaves, cow dung etc. At the same time traditional fuels as wood and agricultural residues etc. are being consumed at a rate much higher than that at which supplies are being regenerated, causing environmental degradation in the form of deforestation and loss of organic matter from the soil. The demand of fuel to meet electricity demand is skyrocketing day by day. But gas production is not increasing with the demand. For a sustainable increasing growth rate energy demand of the country must be met by increased gas production or by other alternative energy sources.

Six major coal fields have been discovered in the country. The total reserve is about 2000 million tons [2]. Coal contributes 5% of the total commercial energy consumption [1]. Production of coal from Barapukuria coal field is in the limited scale and is mainly used for thermal power generation of capacity 125 MWT [3].

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Peat may be an additional energy resource in the country. It may be used as fuel for domestic household purposes, in brick fields and also for small scale power generating plants. Use of peat as a substitute of fuel wood can save the valuable reserve forest of the country. Unfortunately, peat has not been used in Bangladesh as commercial energy, though the country has important discoveries of peat deposits.

Fig 1: Peat.

## 2. OBJECTIVES

The objectives of the study are to review the peat deposits of Bangladesh and to discuss the prospect of its utilization in Bangladesh.

## 3. PEAT

Peat is a biomass resource composed of a group of accumulated organic residues that slowly develop as a result of incomplete decomposition of plant debris in very moist and anaerobic conditions [4]. The net rate of peat accumulation depends upon factors such as water regime and temperature, but is estimated to be between 20 and 60 cm per 1000 years [5].

Peat can be found in wetlands or peatlands, often called bogs, moors, fens, muskegs, pocosins, mires and peat swamp forests along with other similar areas. Peat deposits can be found all over the world in many different forms. Bog is a subclass of peatlands that receive water solely from rain and/or snow falling on its surface. Fens is another subclass of peatlands that receive their water and nutrients from the soil, rock and groundwater.

Plant material and vegetation contain carbon in a reduced form, and this can be preserved in certain areas if the normal decay processes are inhibited. Especially marshy areas with acidic conditions the conditions are good for maintaining the carbon in its reduced form.

Peat is mainly composed of peat moss (sphagnum), but also includes other marshland vegetation such as trees, grasses, fungi, insects, animals and similar. The water that covers dead organic material prevents oxygen from oxidizing the carbon and thus energy can be stored in peat.

The growth of a peat layer is determined by the growth of the organic material and how much of this that is submerged below the water level, where it is protected from oxygen. Very wet areas will cause peat to grow faster than peat in drier places. This behavior of peat layers has been used by climatologist as an indicator of climate change.

With the right conditions peat is the first stage in the formation of coal. Just as fossil fuels peat contains unoxidized carbon that can be used for combustion, however the energy content is very low and it needs to mature over geological time, with higher pressure and temperature, to end up as lignite or coal.

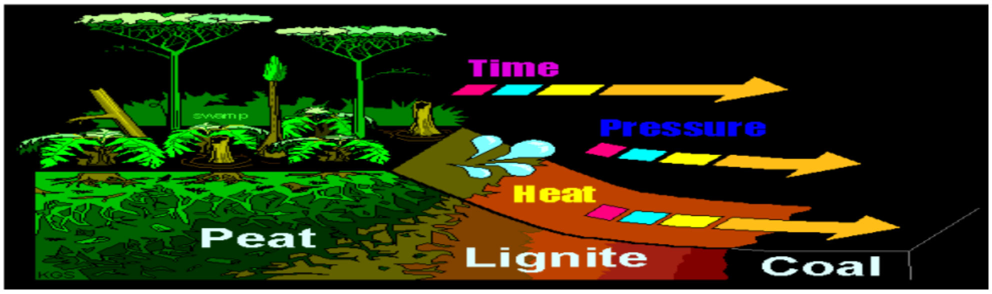


Fig 2: A coalification process where peat matures into coal with time, increasing temperature and pressure.

Table 1: Peat reserves in Bangladesh [6]

| Location | Districts | Areal extent (square km) | Reserve(dry peat) (million ton) |
|---|---|---|---|
| Baghia Chanda beel | Madaripur and Gopalganj | 518 | 125 |
| Kola Mouza | Khulna | 39 | 8 |
| Chatal beel | Moulvibazar | – | 6.2 |
| Moulvibazar | Moulvibazar | 9.5 | 2.1 |
| | | 4.5 | 0.76 |
| Pagla | Sunamganj | 11.5 | 1.8 |
| Chorkai | Sylhet | 11.6 | 1.8 |
| Katenga-Mukundpur | Brahmanbaria | – | 0.7 |

## 4. PEAT DEPOSITS IN BANGLADESH

In 1953, peat deposit was found in Bangladesh for the first time in Baghia and Chanda beel in Madaripur and Gopalganj district. In 1960, peat deposit in Kola-Barasat area of Khulna district was discovered. Some smaller peat deposits were found in Molvibazar, Sunamganj and Brahmanbaria districts. The following table lists the large peat deposits in the country.

Peat deposits in Bangladesh occur in low lying areas of the alluvial plain. These areas remain under water for large period each year. The peat is found at the surface or at shallow depths below the surface. Peat of Bangladesh is brown to black, fibrous, spongy to more compact and matured. It is soft when wet and hard when dry.

## 5. PROSPECT OF UTILIZATION OF PEAT IN BANGLADESH

Peat is not commercially utilized in Bangladesh. Peat has been used for energy generation, as a soil improvement material to retain moisture capture capacity and add nutrients and as an isolation material in many countries of the world. It is also used as an ion exchange material in some chemical processes and as a filter for capturing different materials and for softening water. Peat can be used prospectively in many ways in Bangladesh.

### 5.1. Peat for energy generation

Historically the most important use of peat has been as a fuel for combustion. In the

beginning peat was cut by hand and uses for household heating and for cooking.
Much of the world peat for energy use comes from peat briquettes. If peat is milled and compressed at high temperatures it can be pressed into briquettes with user-friendly and predictable burning properties along with a smokeless combustion. These peat briquettes are popular in households those

Fig 3: Peat briquettes.

require a fast and readily available fuel for occasional use or in cities where non-smokeless coal are banned. Peat is combusted in the same way as biomass and coal.
The energy content is lower than brown coal and it needs to be dried before combustion to reduce the water content. An advantage of burning peat together with wood and biomass is that peat reduces ash problems associated with combustion of normal wood fuel.
Under CIDA Technical Assistant Program, a feasibility study was conducted in 1985-1986 by M/S SNC W.P. London for extraction and utilization of peat in Bangladesh. It was recommended that setting up briquetting plant and small scale power generation plant are feasible with the peat reserve in south-western part of Bangladesh. According to the recommendation, a peat briquetting pilot plant was set up by Petrobangla during 1993-94 in peat area of Baghia beel. But the objective of the plant could not be met within the stipulated period due to poor management and inadequate funding [7]. Peat briquetting could be commercially viable if such plant is managed adroitly and fund is adequate.
Another study suggested that installing 10 MW peat fired power plant in Khulna would be both economically and technically feasible [8]. Setting peat briquetting plant is also possible in Chatal beel in Moulvibazar.

### 5.2. Peat in agriculture, horticulture and water treatment

For agricultural and gardening purposes peat can be used as a soil improvement material. By adding milled peat to the soil it is possible to make it better since the peat adds nutrients and retains moisture, thus making the soil more optimal for growing plants. Peat blocks are also used in gardens for creating the foundations for elevated flower arrangements. Peat moss is a good soil conditioner and it assists in loosening clay soils and increase moisture retention in sandy soils. Peat containers for plants and tree seedlings are commonly used in gardens. Due to the high content of unreduced carbon in peat it is possible to use it for ion exchange in water treatment plants. Different forms of chemical substances will react with the carbon from the peat and be rendered inert or even captured as new substances. Milled peat is mixed with sulfuric acid to provide a slurry that later can be dried into pellets suitable for treatment of contaminated water. Peat can also be used for softening tap water since it captures different salts and other compounds that make water hard. Because of its light weight, springiness and extremely low heat conductivity peat has been used as a packing material for fresh fruits and vegetables. Peat has also been used for animal bedding, because peat keeps dry for a long time periods and effectively absorbs offensive odors.

### 5.3. Other uses

Peat has also been used as an isolation material for construction due to the low thermal conductivity in many countries. Peat is used as an isolating layer between the outer wall and the inner wall or as covering material on the roof.

Peat fire also gives a very distinct smell and flavor that is used in several whiskey distilleries for obtaining unique properties. During the drying process or damp malt and barley a peat heated fire is used to produce smoke. The biting smoke will pass on flavor to the ingredients and produce a “smoky” flavor. It takes approximately 30 hours to dry barley and for the Laphroaig whiskey, one of the smokiest Scottish malt whiskeys, 18 of those hours is spent over peat fire. This will produce the special characteristics of Scottish malt whiskey.

## 6. ADVANTAGES AND DISADVANTAGES OF COMMERCIAL USE OF PEAT IN BANGLADESH

Peat has a large number of properties that can be utilized in many different ways. The greatest advantage is perhaps the flexibility of peat, since it can be used from everything from construction

Fig 4: Peat fired kiln for drying of malt and barley

and water treatment to electricity generation. Another great advantage of peat is that it can minimize energy crisis. Peat if used for electricity generation will reduce load on conventional energy source like natural gas that is not sufficient for the country. Peat is also very cheap since the extraction process is simple and uncomplicated. Since peatlands are hard to use for agriculture the commercial use of peat can make these areas more production and contributing to the society. The disadvantages are of course damages to the environment and the destruction of a biotope. By draining the peatlands and cutting away large parts of the peat layers the biota are disturbed. The road and ditches will also impact on the landscape. Another disadvantage is the slow growth of peat and that is can only be produced on small scale in a sustainable way. Peat is also even more carbon intensive than brown coal and will lead to higher emissions of $CO_2$. Also peatland contains a wide range of specialized animals and plants that are found nowhere else. By disturbing their biotope a unique ecosystem is threatened and some species can ultimately be in danger.

## 7. CONCLUSIONS

Since the energy resource is not available in the country, peat deposits in south-western part of Bangladesh should be exploited. The government sponsored Peat briquetting project was not successful due to management problem. Peat could perhaps be more profitably utilized if government takes steps to utilize peat properly. The energy crisis at least locally is possible to reduce by utilization of peat.

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# A STUDY ON EXISTING CONDITION OF SOIL ENVIRONMENT OF TWO TEA GARDEN OF MAULVIBAZAR

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## ABSTRACT

In the present study, scientific data is presented for fertility management of tea garden soil at Sreemangal in Maulvibazar and heavy metal concentrations of the tea garden soils were measured to assess environmental impact for the purposes of the maintenance of tea quality and sustainable development of tea production. The average concentration of heavy metals Cu, Zn and Cd in soil are 39.18 $mgkg^{-1}$, 18.01 $mgkg^{-1}$, 0.241 $mgkg^{-1}$ respectively and the average concentration of nutrients in soil K, Ca, Mg, and Fe are 54 $mgl^{-1}$, 8.31 $mgl^{-1}$, 12.46 $mgl^{-1}$ and 10.19 $mgl^{-1}$ respectively. The total concentrations of heavy metals were below the soil environmental standards and the total concentrations of nutrients were below the standard tea soil level. To increase nutrient concentrations and reduce the heavy metal concentrations; it is desirable to improve the fertilizer use efficiency, to reduce the amount of chemical fertilizer applied and to use organic fertilizer of the environmental preservation type, for the fertility management in the tea garden. Based on the results, environment quality management practices in tea garden were proposed.

**Key Words:** Tea garden, Soil, Heavy metal, Nutrients, Fertilizer, Simple pollution index.

## 1. INTRODUCTION

Bangladesh has about 164 tea gardens which produces about 60 million kilogram of tea annually from about 53259 hectors of land. About 94% of annual production (of which 60% of Maulvibazer district) is contributed from 131 estates in Sylhet zone, in the Surma valley. The study is aimed to identify, predict and finally assess the environmental impact assessment of tea garden soil by heavy metal in Maulvibazar. For this purpose soil samples were collected from Bilashchara Tea Garden under BTRI and Lakhaichara Tea Garden under Finley Tea at Sreemangal in Maulvibazar district of Bangladesh. On the basis of the analysis it recommends a series of measures that would contribute to sustainable environment friendly growth of the tea garden in Bangladesh.

## 2. METHODOLOGY

### 2.1. Soil sample collection & preparation

A total of 10 topsoil samples were collected from the two selected tea garden. The locations of sampling point were chosen about 0-20 cm [3] from surface during December, 2010. All

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samples were packed in polythene bags [1] for storage. After transportation to the laboratory, polythene bags were opened for the purpose of air drying at room temperature for all samples, until a constant weight was attained. Stones chips and plant debris were removed before grinding and sieving. The samples were passed through 2 mm [1] and 120μm sieves. Then the prepared samples were stored before detection.

### 2.2 Determination of pH

The pH of soil samples were determined by the 1:10 (w: v) ratio of soil (120μm) to de-ionized water using calibrated ELE pH meter [1].

### 2.3 Determination of heavy metals & nutrients

#### *2.3.1 Extraction of Zn, K, Fe, Mg and Ca*

For extraction of Zn, , K, Fe, Mg and Ca, procedure was followed according to Water Science and Technology journal (Volume: 61, Issue: 12), 5g of fine grained (120μm) fraction of each sample was weighted accurately into a beaker and mixed directly with 50 ml of aqua-regia (1:3 volumetric of nitric acid ($HNO_3$) to hydrochloric acid (HCl))**.** Afterward, all samples were kept for 24 hours in room temperature, filtered through φ150mm filter papers by gravity filtration method and diluted as required. Before analyzing, the filtrates were kept at 4˚C [4]. The concentrations of Zn, *K, Fe* were determined by UV Spectrophotometer [Model: HACH, DR/4000] and the concentrations of Mg, Ca by Flame Atomic Absorption Spectrophotometer (AAS). [Model: Varian, Spectra AA 220]

#### *2.3.2 Extraction of Cd and Cu*

For extraction of Cd and Cu, procedure was followed according to Water Science and Technology journal (Volume: 61, Issue: 12), the sieved samples (2mm) were mixed with a 1:5 (w:v) ratio of soil to 0.1N HCl [4] solution in falcon tubes by shaking at 100 rpm through a shaking water bath for 1hr. After pretreatment, the mixed solutions were filtered and stored at 4˚C before analyzing the concentrations of Cd and Cu by Flame Atomic Absorption Spectrophotometer (AAS).[Model: Varian, Spectra AA 220]

#### *2.3.3 Calculation equation of simple pollution index*

The simple pollution index [3] by a heavy metal was calculated by the equation:

Simple pollution index = measured heavy metal concentration/soil environmental standard ………. (1)

## 3. RESULTS

### 3.1 Total nutrients concentration of soil in the tea garden

For nourishment, growth and development every plants needs adequate food and tea plant is not exception. To build up plant tissues as many as sixteen elements are essential. The concentration of K, Ca, Mg, Fe in tea garden soil for two tea gardens of Maulvibazar is given in table 3.1 while the average concentration is shown in table 3.2

Table-3.1: Total nutrients concentration of soil in the tea garden ($mgl^{-1}$)

| Tea garden | Sample no. | Depth (cm) | pH | Concentration of the soil nutrients ($mgl^{-1}$) | | | |
|---|---|---|---|---|---|---|---|
| | | | | K | Fe | Ca | Mg |
| Bilashchara | S1 | 1-20 | 5.65 | 48.75 | 11.52 | 7.4 | 12.6 |
| | S2 | 1-20 | 5.61 | 63.66 | 11.06 | 8.7 | 13.2 |
| | S3 | 1-20 | 5.29 | 72.60 | 9.87 | 9.2 | 14.1 |
| | S4 | 1-20 | 5.75 | 54.62 | 10.00 | 8.1 | 11.8 |
| | S5 | 1-20 | 5.41 | 50.84 | 10.61 | 8.9 | 13.5 |
| Average | | | 5.542 | 18.094 | 10.612 | 8.46 | 13.04 |
| Lakhaichara | S1 | 1-20 | 5.23 | 40.82 | 9.25 | 7.3 | 10.8 |
| | S2 | 1-20 | 5.37 | 50.21 | 10.23 | 8.1 | 11.5 |
| | S3 | 1-20 | 5.10 | 54.75 | 8.94 | 7.8 | 12.1 |
| | S4 | 1-20 | 4.90 | 55.14 | 10.56 | 8.5 | 13.2 |
| | S5 | 1-20 | 5.05 | 48.56 | 9.82 | 9.1 | 11.8 |
| Average | | | 5.13 | 49.896 | 9.76 | 8.16 | 11.88 |
| Average of two garden | | | 5.44 | 54 | 10.19 | 8.31 | 12.46 |
| S=Soil sample | | | | | | | |

Table 3.2: The average concentration of soil nutrients in the tea garden

| Tea garden | pH | soil nutrients $mgl^{-1}$ | | | |
|---|---|---|---|---|---|
| | | K | Fe | Mg | Ca |
| Bilashchara | 5.54 | 58.1 | 10.61 | 13.04 | 8.46 |
| Lakhaichara | 5.13 | 49.89 | 9.76 | 11.88 | 8.16 |
| Average | 5.44 | 54 | 10.19 | 12.46 | 8.31 |

### 3.1.1 Concentration of pH

The pH values for soils over the study areas were varied between 4.90 and 5.75. The maximum pH was found in S4 sample of Bilashchara and minimum in S4 sample of Lakhaichara. The values of pH indicate slightly acidic soil of tea garden. The standard value of pH in tea garden soil is 4.5-5.8 [2].The concentration of pH in two tea garden soils are compared with standard concentration for tea garden soil in figure 3.1

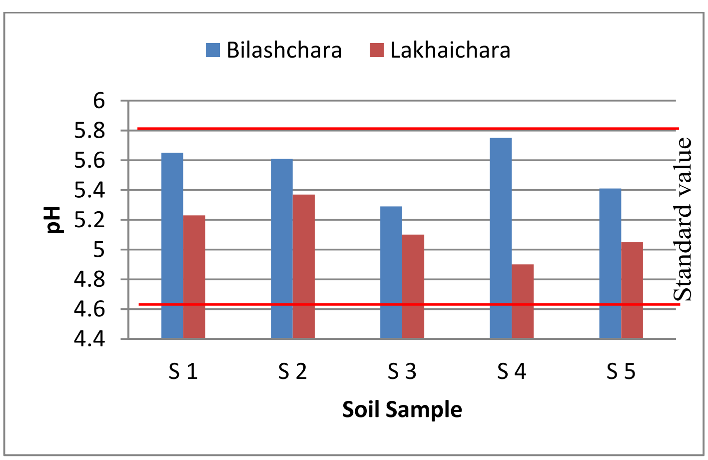


Figure-3.1 pH concentrations in Bilashchara & Lakhaichara tea garden

### 3.1.2 Concentration of nutrients

The average concentration of nutrients K, Ca, Mg, Fe are 54 $mgl^{-1}$, 10.74 $mgl^{-1}$, 12.46 $mgl^{-1}$, 10.19 $mgl^{-1}$ respectively and the standard concentration of nutrients K, Ca, Mg are 80.0 $mgl^{-1}$, 10.0 $mgl^{-1}$, and 15.0 $mgl^{-1}$ respectively [2]. The concentration of K, Fe, Ca and Mg in two tea garden soils are compared with standard concentration for tea garden soil in figure 3.2 to 3.5

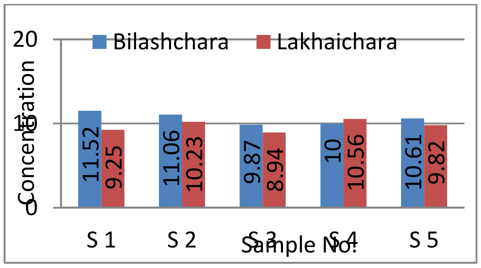


Figure-3.2: Concentration of Fe ($mgl^{-1}$) of two tea gardens

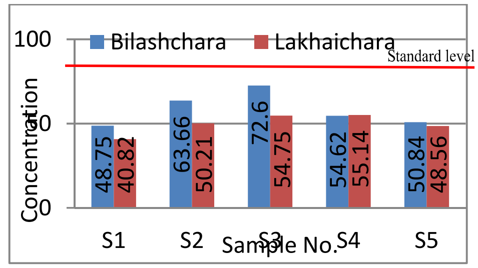


Figure-3.3: Concentration of K ($mgl^{-1}$) of two tea gardens

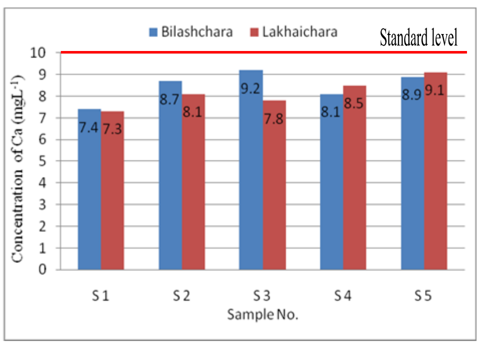


Figure-3.4: Concentration of Ca ($mgl^{-1}$) of two tea gardens

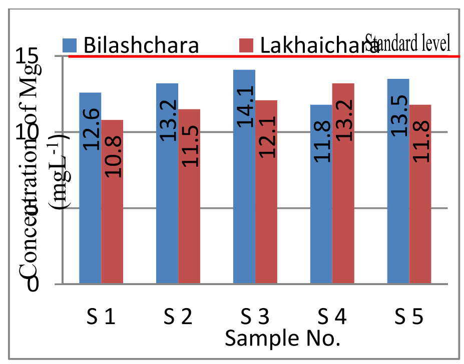


Figure-3.5: Concentration of Mg ($mgl^{-1}$) of two tea gardens

## 3.2 Total heavy metal concentrations of soil in the tea garden ($mgkg^{-1}$)

### *3.2.1 Concentration of heavy metals*

Heavy metals in soil may originate from natural and anthropogenic sources. The anthropogenic sources may be numerous and the main form of accumulation of heavy metals in soil from anthropogenic sources is represented by dry and wet atmospheric deposition. The depositions of heavy metals are established by dependence of weather conditions and vegetation period from air into plants**.** Heavy metal concentrations of top soils over the study areas are shown in table 3.3 for Cu, Zn and Cd accordingly while average values are tabulated in table 3.4

Table 3.3: Total heavy metal concentration of soils in the tea garden ($mgkg^{-1}$)

| Tea Garden | Sample no. | Depth (cm) | Concentration of heavy metals ( $mgkg^{-1}$) | | |
|---|---|---|---|---|---|
| | | | Cu | Zn | Cd |
| Bilashchara | S1 | 1-20 | 26.5 | 19.78 | 0.249 |
| | S2 | 1-20 | 42.0 | 15.02 | 0.237 |
| | S3 | 1-20 | 37.7 | 16.49 | 0.240 |
| | S4 | 1-20 | 43.5 | 18.25 | 0.246 |
| | S5 | 1-20 | 36.8 | 18.32 | 0.291 |
| Average concentration | | | 37.3 | 17.572 | 0.21 |
| Lakhaichara | S1 | 1-20 | 40.1 | 17.81 | 0.219 |
| | S2 | 1-20 | 45.2 | 16.94 | 0.228 |
| | S3 | 1-20 | 37.9 | 19.10 | 0.321 |
| | S4 | 1-20 | 32.8 | 19.83 | 0.310 |
| | S5 | 1-20 | 49.3 | 18.51 | 0.289 |
| Average concentration | | | 41.06 | 18.438 | 0.2734 |
| Average concentration of two garden | | | 39.18 | 18.01 | 0.241 |

S=Soil sample

Table 3.4: The average heavy metal concentrations of soil in the tea garden

| Tea garden | Depth cm | Concentration of heavy metals $mgkg^{-1}$ | | |
|---|---|---|---|---|
| | | Cu | Zn | Cd |
| Bilashchara | 1-20 | 37.30 | 17.572 | 0.210 |
| Lakhaichara | 1-20 | 41.06 | 18.438 | 0.273 |
| Average | | 39.18 | 18.01 | 0.241 |

From above table it is shown that the average concentration of heavy metals in soil Cu, Zn, and Cd are 39.18 $mgkg^{-1}$, 18.01 $mgkg^{-1}$and 0.241 $mgkg^{-1}$ respectively in the study area. The average concentration of Cu, Zn and Cd in two tea garden soils are compared with trouble-some metal contamination standard for soil in figure 3.7 to 3.9

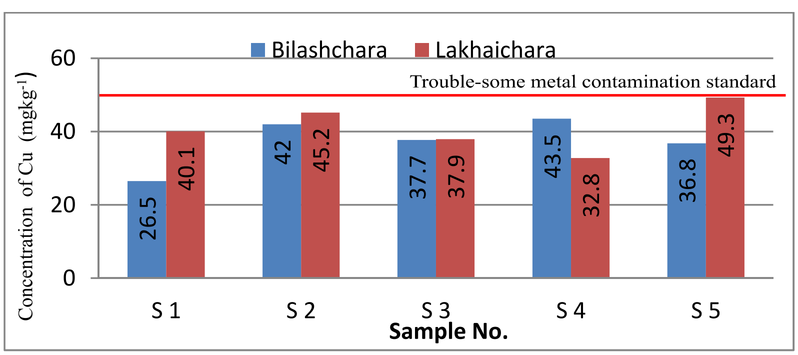


Figure-3.7: Concentration of Cu ($mgkg^{-1}$) of two tea gardens

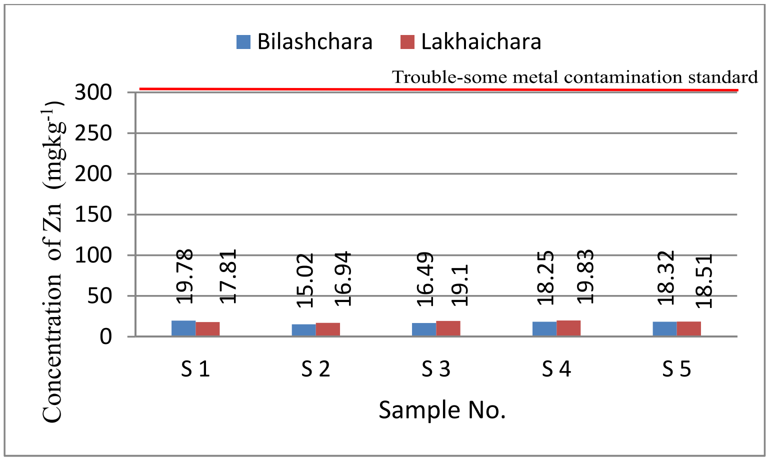


Figure-3.8: Concentration of Zn (mgkg$^{-1}$) of two tea gardens

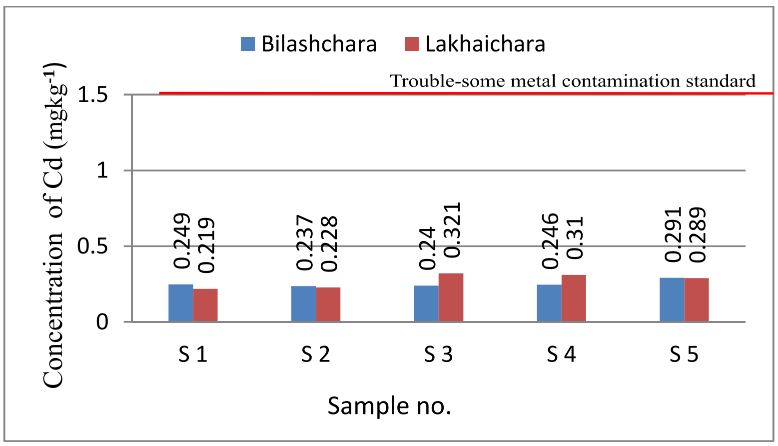


Figure-3.9: Concentration of Cd (mgkg$^{-1}$) of two tea gardens

### *3.2.2 Simple pollution index*

The simple pollution index by heavy metal for two tea gardens is calculated in table 3.5 and 3.6 while the average value of simple pollution index is cited in table 3.7

Table-3.5: The simple pollution index by the heavy metal concentration for different heavy metals in Bilashchara tea garden

| Heavy metal | Average mgkg$^{-1}$ | Soil environment standard mgkg$^{-1}$ | Simple pollution index |
|---|---|---|---|
| Cu | 37.3 | 150 | 0.25 |
| Zn | 17.572 | 200 | 0.087 |
| Cd | 0.21 | 0.30 | 0.7 |

Table-3.6: The simple pollution index by the heavy metal concentration for different heavy metals in Lakhaichara tea garden

| Heavy metal | Average $mgkg^{-1}$ | Soil environment standard $mgkg^{-1}$ | Sample pollution index |
|---|---|---|---|
| Cu | 41.06 | 150 | 0.27 |
| Zn | 18.438 | 200 | 0.092 |
| Cd | 0.2734 | 0.30 | 0.91 |

Table-3.7: The average value of simple pollution index of the tea garden soil by the heavy metal concentration for different heavy metals for two tea gardens

| Heavy metal | Average ($mgkg^{-1}$) | Soil environment standard ($mgkg^{-1}$) | Sample pollution index |
|---|---|---|---|
| Cu | 39.18 | 150 | 0.261 |
| Zn | 18.01 | 200 | 0.09 |
| Cd | 0.241 | 0.30 | 0.8 |

From table above table it is shown that the simple pollution index don't exceed 1, i.e. yet it isn't starting pollution. But the simple pollution index of Cd is 0.8 which is nearer to 1.0, so it is alarming for tea garden.

**4. DISCUSSION**

A tendency of acidification was noticed to the soils in the tea garden at Bilashchara Tea Garden under BTRI and Lakhaichara Tea Garden under Finley Tea on Srimangal in Maulvibazer district of Bangladesh. The acidification of the tea garden soils was ascribed to application of a large amount of chemical fertilizers. A regional difference was recognized to the organic matter content of the tea garden soils, which is probably caused by the difference in plant nutrient management practice, but the content itself was generally low. The total K, Fe, Ca, Mg contents in both tea garden were also found to be low and the average concentration of nutrients K, Ca, Mg, and Fe are $54mgl^{-1}$, $8.31mgl^{-1}$, $12.46mgl^{-1}$ and $10.19mgl^{-1}$ respectively. These poor properties of the tea garden soils suggest the necessity of fertility management of tea garden soil based on the soil diagnosis. For fertility management of tea garden soil high amount of chemical fertilizer is used. The fertilizer used in tea garden is surely higher in the Cu and Zn concentrations; the average concentration (Table 3.4) was compared with its soil environmental standard (Table 3.7) in different heavy metals. Total concentrations of Cu, Zn, Cd were within the soil environmental standards, and the tea garden soils were judged to be not polluted by these heavy metals. The total concentration in the soil of tea garden were $39.18mgkg^{-1}$, $18.01mgkg^{-1}$ and $0.241mgkg^{-1}$ for Cu, Zn and Cd respectively while the soil environmental standard of Cu, Zn & Cd are 50mgl-1, 300mgl-1& 1.5gl-1 respectively. The simple pollution indexes by the total heavy metal concentrations were evaluated for the environmental impact assessment of the soils in the tea garden. The simple pollution index of Cu, Zn, Cd is 0.25, 0.087, 0.70 for Bilashchara (table 3.5) and 0.27, 0.092, 0.91 for Lakhaichara (table 3.6) tea garden. The simple pollution index was low for Cu, Zn, Cd and average value was 0.261, 0.09, and 0.8 respectively. From this pollution level it was seen that, contribution of Cd is great to the tea garden soils. However, absorption of Cd by tea plants would hardly occur. Based on the above discussion, it is mentioned that status of soil pollution is more worsened without proper and scientific field management practice. It will adversely affect quality of tea and retard the sustainable tea production. Since the Cd concentrations of tea garden soil are high, it is necessary and important to take measures for remediation of Cd pollution on the practice of field management in the tea garden. Use of biological control agent is necessary, which exerts little pollution to the environment, when pesticide is applied.

## 5. CONCLUSION

The total K, Fe, Ca, Mg contents in both tea gardens were found to be low and acidification was characterized, indicating that for fertility management of tea garden soil high amount of chemical fertilizer is used. The fertilizer used in tea garden is surely higher in the Cu and Zn concentrations. The total Cd concentration of tea garden in study area is high, and its simple pollution index was highest among the three heavy metals of Cu, Zn, and Cd examined. To increase nutrient concentration and reduce the heavy metal concentration, it is desirable to improve the fertilizer use efficiency, to reduce the amount of chemical fertilizer applied and to use organic fertilizer of the environmental preservation type, for the fertility management in the tea garden. Application of biological control agent is to be recommended, which exerts less pollution to the environment, when pesticide is applied. Also sustainability of water supply and sanitation system must be considered for achieving good health for all and keep the environment healthy.

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# ENVIRONMENT FRIENDLY INTEGRATED SOLID WASTE MANAGEMENT

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## ABSTRACT

In developing countries like Bangladesh development of integrated solid waste management can be achieved through a comprehensive and integrated waste prevention and disposal program through effective use of Rs. To improve human health and protect the environment, integrated solid waste management suited to the local and specific region would be developed incorporating the uses of 14 Rs like reduce, reuse , recycling, recovery, refuse, return, repair, re-hauling, remanufactures, replace, renew, recharge, recondition, refill with environmental impact assessment(EIA), environmental monitoring (EM), environmental management plan (EMP) ensuring participation of all kind of stakeholders and communities from all walks of life, social mobilization, public awareness, advocacy, enforcement, willingness to pay in order to achieve the sustainable green environment. Rs could be an imperative and essential function to trim down the solid waste intensity in the urban and semi-urban centers as well as the rural agglomeration of not only the developing countries but also the developed countries. Evidently solid waste management utilities should give due considerations on the effective uses of Rs that will not drop off the titanic size of solid waste in the landfill alone will also save the cash and kinds of utility, guarantee the eco-friendly environment, sustainable community life as well as will contribute significantly to back to natural green earth once more.

**Key Words:** Integrated solid waste management (ISWM), 14 Rs, EIA, EM, EMP

## 1. INTRODUCTION:

Many cities and towns face serious environmental degradation and health risk due to throwing and keeping domestic refuse on streets and public areas, clogged urban drainage system by indiscriminately dumped wastes to the drains and severe contamination of water resources near uncontrolled dumping sites. In such situations, integrated solid waste management (ISWM) is essential to handle solid waste problem of the urban and rural centers to establish a sustainable green environment. Integrated solid waste management is a comprehensive waste prevention, recycling, composting and disposal program. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions

## 2.MATERIALS & METHODS

Figure-01 illustrates how an ISWM plan can be implemented. Available and existing technologies has also been conducted and analyzed. Data and information collected and compiled from various primary and secondary sources on waste management in Sylhet.

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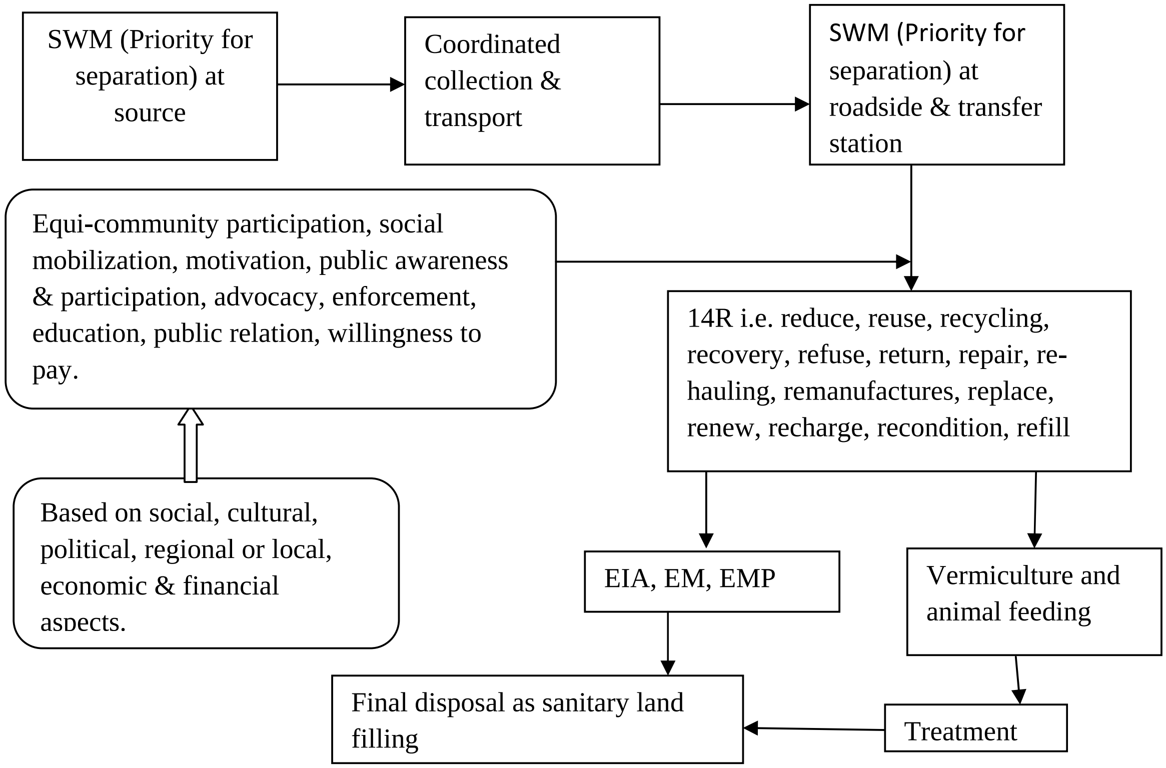


**Figure -01: ISWM for urban & rural agglomeration**

## 3.WASTE GENERATION & COLLECTION

Solid waste management is an obligatory function of Urban Local Bodies in Bangladesh. At present there are 522 urban centers in the country including 254 municipalities and 6 City Corporations (BBS, 1997 and NILG, 2002). With over 3.3% annual growth in urban population in Bangladesh during 1991-2001 census years, solid waste generation has also increased proportionately with the growth of urban population. As such, most of the urban local bodies are finding it difficult to keep pace with the demand for adequate solid waste management and conservancy services provided by the urban local bodies. Following table 1 & 2 shows the waste collection & management department of SCC.

**Table 1: SCC waste collection & management department**

| | | |
|---|---|---|
| 1 | City area | 26.50sqkm |
| 2 | Number of wards | 27 |
| 3 | population | .6 million |
| 4. | daily Generated waste | 160-180 mton(approx) |
| 5. | Waste collection | 140-160 mton(approx) |
| 6. | Canals | 9 |
| 7. | Distributory canals | 10-12 |

| | | |
|---|---|---|
| 8. | Drain | 667km(approx) |
| 9. | Dumping Ground | 1(approx7 acre) , Lalmatia |
| 10 | Proposed Dumping Ground | 1(3 acre) ,Khadim |
| 11. | Number of Clinics | 34+ |
| 12. | Number of Pathology Diagnostics | 50+ |
| 13. | Total Waste generation of Private Clinic | 690kg/day<br>Infectious waste:157kg/day<br>Sharp edged waste:6.89kg/day |
| 14. | Total Waste generation of Diagnostics Clinic | Hazardous Waste:45 kg/day<br>Infectious waste:42.75kg/day<br>Sharp edged waste:2.25kg/day |

**Table 2: Manpower**

| | | |
|---|---|---|
| 1. | Conservancy Inspector | 1 |
| 2. | Driver | 25 |
| 3. | Supervisor | 15 |
| 4. | Labor | 146 |
| 5. | Sweeper | 159 |
| 6. | Number of Vehicle | Truck:17<br>Tractor:3 |
| | | |

## 4. SOLID WASTE MINIMIZATION THROUGH 14RS:

It's very important to minimize the waste as because it is impossible to the disposal of all the solid waste to the landfill area for a country like Bangladesh. The R's can be an effective technique to minimize the waste. From our survey and analysis the feasibility of R's to trim down the solid waste are following.

**4.1. REDUCE:** Reducing waste is the most important part of waste minimization. The aim of waste reduction is to eliminate waste before it is produced and to reduce both the quantity and toxicity of waste. By interviewing Shopkeepers, customers we get some simple ways of reducing the amount of solid waste we produce:

**4.2. REFUSE:** Based on the field study and the experience the following current practices can be changed by new practice. If we refuse this current practice and use this new practice instead of them then solid waste can be minimized.

| Current practice | New practice |
|---|---|
| × Plastic wrap | ✓ Reusable containers with lids |
| × New books | ✓ Second-hand or library books |
| × Tissues | ✓ Handkerchiefs |
| × Tea Bags | ✓ Loose tea leaves |

**4.3. REUSE**

Reusing an item means it doesn't go in the rubbish and end up in the landfill. From field study we found the following automobile parts if in good condition that can be reused.

| | |
|---|---|
| Bumper. | Head light, back light bulb. |
| Door locks. | Wheels. |
| Mats. | Window motors |
| Looking glass. | Leaf spring, ring spring. |

**4.4. RECYCLE**

Based on the field study and the experience the following benefits of recycling are found (a) Recycling saves energy (b) Recycling decreases emissions of greenhouse gases that contribute to global climate change and (c) Recycling helps sustain the environment for future generations.

**4.5. REPAIR**

The study found that some other products which can be repaired from the study. These are computers, electronics, furniture, buildings, communications equipment, plastic toys, etc.

**4.6. REMANUFACTURE**

From the field study and by interviewing relevant class of peoples the study entails that the following products can be remanufactured. **A**utomotive parts; **F**urniture; **M**edical equipment; **P**ersonal computers; **P**hotocopiers;; **T**ires; **T**oner cartridges etc. During the study the following important benefits of remanufacturing came out (a) Saving in labor, materials and energy costs (b) New market development opportunities (c) A positive, socially concerned image.

**4.7. REFILL**

Refill containers use less packaging material than primary containers. Some refillable products are beverage/soft drink bottles, printer cartridges, inkjet cartridges etc.

In Bangladesh Soft drink producing companies are refilling the glass bottles but in small in scale because of now plastic bottles and Aluminum cans are more popular to the consumers. Printer cartridges can be refilled indefinitely or recycled through Laser Connection. Refilling is environmentally friendly and cost effective at 20% less than buying new.

### 4.8. RECHARGE

In Bangladesh all lead acid batteries are rechargeable. But the torch light batteries and most of the pencil batteries are non- rechargeable. Rechargeable battery can reduce the amount of solid waste**.**

### 4.9. RESOURCE RECOVERY

In Bangladesh lead are recovering from the old damaged lead acid batteries. Lead acid battery is mainly used in automobile vehicle. In Bangladesh batteries are mainly produced by some formal battery manufacturing industry namely, Rahimafrooz, Navana, Rangs/Yuasa and Hamko.

### 4.10. RENEW OF ENERGY

Renew of the energy is the conversion of waste to energy as an alternative waste management option for example bio gas is renewed from cow dung. Waste to energy facilitates through renew of energy reduce green house gas emission from fossil fuel based electrical generation. It eliminates methane gas that would have occurred if the waste was placed in a land fill.

### 4.11. RETURN

It refers to what can be return to retailer, whole seller , suppliers and finally to manufacturer or producer. Different type of plastic packets, bottles can be returned. The practice of return can minimize waste disposal in the land fill significantly.

### 4.12. REPLACE

Means changing of non working parts of a plant or equipment than purchasing a new plant or equipments. Study shows that replacement is more than a financial decision which must be integrated into an organizations business planning and requires the integration of operational, mechanical and financial aspects of the decision.

### 4.13. RE-HAULING

Indicates the nursing of energy, plant or industry time to time changing fuel, oil, grease etc. For operating the plant and utility properly. Re-hauling also emphasizes on maintenance of the plants.

### 4.14. RE-CONDITION

It means to put into a good condition. Car, air-condition, refrigerator, other electronic goods can be re-conditioned and can be used again. It will reduce the cost.

## 5. DISCUSSIONS

Let us give the attention to such socio-economic factors how they influence and affect the functional elements of solid waste management in the urban centers enhancing the significant minimization of solid waste reducing environmental degradation leading to sustainable ISWM.

### 5.1 ADVOCACY

Advocacy is speaking up, drawing attention, winning the support of key constituencies in order to influence policies and spending and brings about change success. The objective of the advocacy is to raise awareness and convince others of the need to take action. Advocacy program make aware of the general public of the urban and rural centers and they will be accustomed of the practice of functional elements of ISWM properly by the course of time.

### 5.2 EQUI-COMMUNITY PARTICIPATION, PUBLIC PARTICIPATION & AWARENESS, HARMONIOUS PUBLIC RELATIONSHIP WITH STAKEHOLDERS

Equi-community participation refers to the equal participation and involvement of people from all walks of life. It focus on the group discussions, and awareness rising which is an integral part of the ISWM. For the improvement of the services of any utility good and harmonious public relation is essential and most significant. Utility present their services in such a way that community gets a clear overview of the services and always takes service very positively. It influences them positively to come forward and contribute significantly in the ISWM activities.

### 5.3 SOCIAL MOTIVATION & MOBILIZATION

Motivation and mobilization is felt fruitful especially in developing countries where majority of the people illiterate and not aware of the utility services and facilities due to ignorance. To change the situation, mobilization to all walks of life has to be initiated in a planned way. Social mobilization can perform by users of the facility, community leaders, social workers, and young people of the society, teachers and students of the institutions. As a result of the social mobilization to all wings of the society the following positive results on ISWM system of urban areas are obvious:

- A remarkable increase of sorting & separating practice of SW in the household in the social mobilization intervention areas.
- Improvement of SW storage practice & collection in the urban areas.
- Increase practice of Rs.
- Growing overall awareness of ISWM

### 5.4 LEGISLATION & ENFORCEMENT

Laws and legislation gives the opportunity to keep the publics and utility in the right track for implementing the utility functions and to make the beneficent for getting the best output. Legal authority like department of environment monitors the activities and prevailing standard of the services of the utility time to time: if finds any discrepancy with the standard, takes legal action with the help of law enforcing agency. Local laws also need to provide for punishment on the spot to those who do not maintaining solid waste management system in the urban areas giving adequate power to the local authorities to punish the offenders.

### 5.5 TO IMPART EDUCATION AND TRAINING

To handle the solid waste accurately, there is no alternative than providing proper education to the public and to train up the utility peoples who involve in ISWM.

### 5.6 WILLINGNESS TO PAY

Willingness to pay is the maximum monetary amount that an individual would pay to obtain a good or service. Involving the public from the start of a project in a transparent way helps to increase their willingness to pay. Motivation on WTP conducts ISWM more effectively.

Following table 4 shows the response &awareness of the house holders about socio-economic factors of ISWM in SCC (20 house holders from each area).

Table 4: Result of the house holders interview for ISWM in SCC.

| Area | Equi-community participation | social mobilization, motivation | Public awareness & participation | Advocacy | Enforcement | Public Relation | WTP |
|---|---|---|---|---|---|---|---|
| Londoni Road | 10 | 8 | 5 | 8 | 3 | 3 | 15 |
| Jalalabad R/a | 15 | 7 | 4 | 10 | 4 | 4 | 15 |
| Housing Estate | 18 | 5 | 5 | 10 | 5 | 5 | 10 |
| Mirabazar | 12 | 6 | 6 | 15 | 3 | 3 | 8 |
| Uposhohor | 15 | 10 | 5 | 18 | 5 | 5 | 15 |

### CONCLUSION

Based on the conducted study, it is obvious that proper utilization of Rs through the practice of social tools like advocacy, equi-community participation, public awareness, enforcement of legal actions, WTP etc. can be opted as efficient mechanism to formulate ISWM.

### ACKNOWLEDGEMENT

Special thanks to SYLHET BELA and SYLHET CITY CORPORATION.

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# REINFORCED CONCRETE BLOCK MASONRY—AN INNOVATIVE BUILDING CONSTRUCTION TECHNIQUE

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## ABSTRACT

RC frame and Load Bearing Wall are conventional building construction techniques. For vertical loads—such as live load and dead load— both the techniques are good. For such loads load bearing wall has got advantage over RC Frame in terms of cost and construction time. When dynamic load like earthquake load or wind load is imposed, RC Frame is the only or better alternative. Reinforced Concrete Block Masonry—a composition of RC Frame and load bearing wall – is both economic and quicker construction technique than RC frame. In this paper we have introduced R.C.B.M. technique and provided comparative study referring R.C. Frame and Load Bearing Wall.

**Key Words:** RC FRAME, RCBM, LOAD BEARING WALL.

## 1. INTRODUCTION

In our country, damage during natural hazards, particularly during earthquakes, has been mostly to the brick masonry buildings, constructed conventionally by Private and Government sectors. Buildings of low rise (one to five floors), which are prevalent in many places, become the first target during natural hazards like earthquakes. It is well known that the normal *dead and live* loads which are gravity loads, induces compressive stresses associated with a little or no tensile stresses in the masonry wall elements of low rise building structures. However, during natural hazards like earthquakes, cyclone/storms, etc, the loading is predominantly lateral (horizontal) and dynamic, tending to introduce high tensile stresses in the masonry elements of the buildings. The conventional masonry being very weak in resisting such tensile stresses fails and this leads to heavy damage to property and loss of lives. Further, the traditionally constructed building systems are fundamentally lacking in the lateral load transfer mechanisms through diaphragm and shear wall interaction. Although fully reinforced cement concrete (RCC) walls are ideal for disaster resistant construction of building structures, it is prohibitively costly. In order to balance both economy and safety, it can be limited judiciously by incorporating the reinforcing elements only at the critical

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sections of the building. However, there are practical construction difficulties in reinforcing the conventional solid brick masonry as it would lead to discontinuity in the masonry. Hence, the ideal solution would be to reinforce the hollow concrete block masonry by taking advantage of its hollow spaces and shapes of the blocks as formwork for reinforcing the masonry elements. It also improves the integrity of each masonry element as an effective shear wall, unlike the reinforced solid brick masonry.

## 2. INTRODUCTION OF CONCRETE HOLLOW BLOCK:

There are many types of hollow concrete blocks which vary with the grade of concrete mix used in the manufacture and based on the dimensions of the block. At present there are no standard blocks consistently manufactured all over Bangladesh. The commonly used hollow concrete blocks are of low grade concrete [7 Mpa] and used in Boundary wall and Partition wall of building. Load Bearing Block is of high grade concrete[15Mpa] and is Used RCBM building. Hollow concrete block made of low grade concrete [7Mpa] is also used for Slab casting.

**Table 1 – The available sizes that now manufactured are shown below:**

| **Items** | **Size (mm)** |
|---|---|
| **Concrete hollow Block (Wall)** | |
| 90 mm Block | 390x190x90 |
| 100 mm Block | 390x190x100 |
| 140 mm Block | 390x190x140 |
| 190 mm Block | 390x190x190 |
| **Load Bearing Block:** | |
| 140 mm block | 390x190x140 |
| 190 mm block | 390x190x190 |
| **Ceiling Block:** | |
| 250mm depth Block | 600x200x250 |
| 200mm depth Block | 600x200x200 |

| | |
|---|---|
| 150mm depth Block | 600x200x150 |
| 140mm depth Block | 390x190x140 |
| 100mm depth Block | 390x190x100 |
| 90mm depth Block | 390x190x90 |

**3.1. STRUCTURAL FEATURES OF THE PROPOSED CONSTRUCTION SYSTEM.**

- Each masonry element is vertically reinforced with steel rods and concrete/grout fills, at regular intervals, through the continuous vertical hollow cavities of hollow concrete blocks.
- Similarly, each masonry element is horizontally reinforced with steel rods and concrete/grout fill at plinth, sill, lintel and roof levels, as continuous RCC bands, using U-shaped concrete blocks as the masonry course at respective levels.
- Grid of reinforcement can be built into each masonry element without the requirement of any shuttering and reducing the scope for reinforcement corrosion.
- As the reinforcement rods in both vertical and horizontal directions can be continued into the roof slab and into the lateral walls respectively, the structural integrity in all three dimensions is achieved.
- In this construction system, structurally each wall and slab behaves as a shear wall and a diaphragm respectively, reducing the vulnerability of disastrous damage to the structure/building, during the natural hazards.
- Due to the uniform distribution of reinforcement in both vertical and horizontal directions, through each masonry element, increase tensile resistance and ductile behaviour of elements could be achieved. Hence, this construction system would safely resist cyclic loading when compared to other conventional masonry construction systems. This construction system has also been proved to be comparatively better under dynamic loading.
- Slab is also casted by incorporating hollow concrete block like R.B. Slab or Rib Slab. The design of one way, two way or flat slab can be used while using block. Block is placed in tension zone of slab. This way dead load of slab is reduced drastically—30%.
- Act as a structurally efficient system, as each masonry elements is a combined load bearing wall and a shear wall.
- The following are the pictures of building, which are designed and built by the Author following RCBM method .

**3.1 DESIGN OF VERTICAL REINFORCEMENT**

Vertical reinforcement in a wall is designed to resist the overturning moment. The vertical reinforcement in a wall is distributed over the entire tensile zone at both ends to resist the seismic forces in both directions

Fig 1: 3 storied Triplex RCBM Building          Fig 1.2: 5storied Flat RCBM Building

**3.2 DESIGN OF HORIZONTAL REINFORCEMENT**

The actual design shear is checked against the allowable shear stress of the masonry. The horizontal reinforcement is designed to resist the design shear forces and is placed as bands at plinth, sill, and lintel and at roof levels.

The distribution reinforcement placed uniformly throughout the wall in vertical direction is designed to resist the out of plane bending moment of the wall. A typical reinforced hollow unit masonry construction is shown in fig. 2.

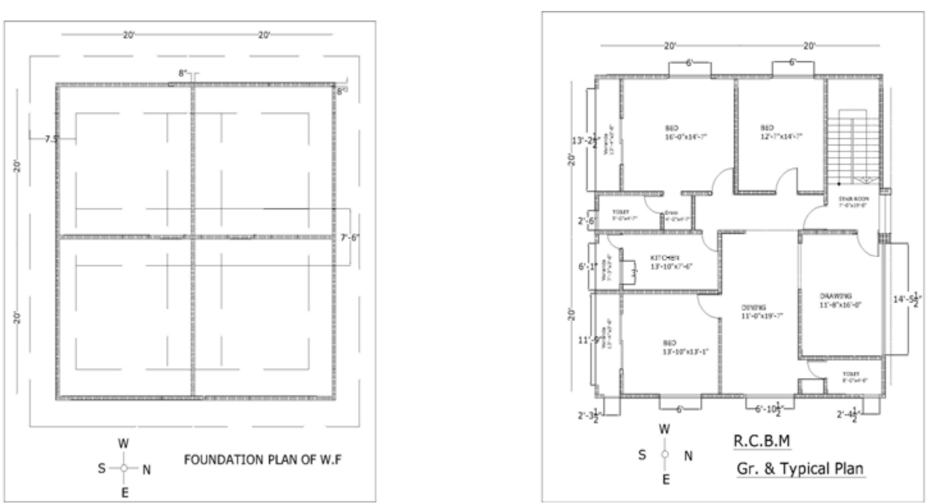


Fig 2: Foundation plan of Wall Footing & plan

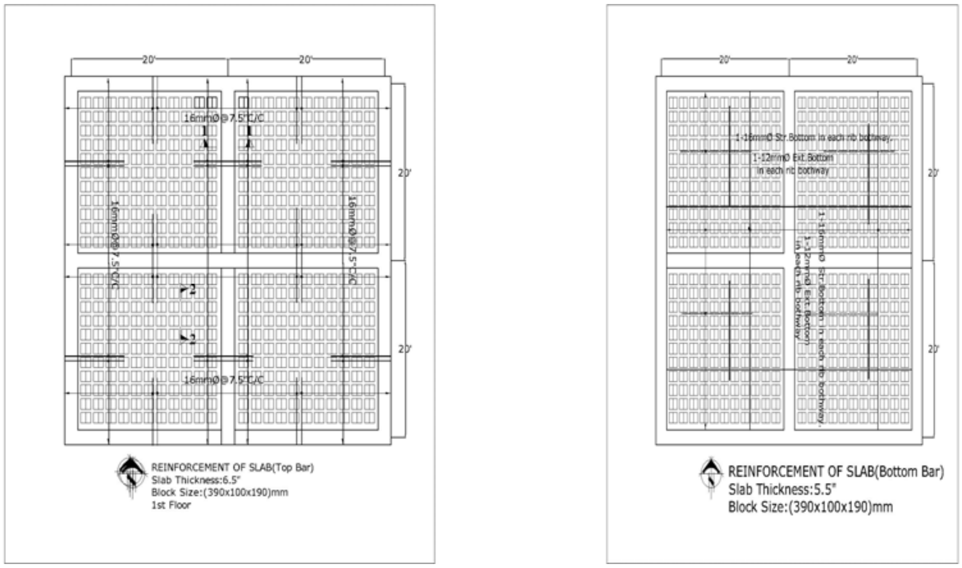


Fig 3: Reinforcement of Slab Made of Block

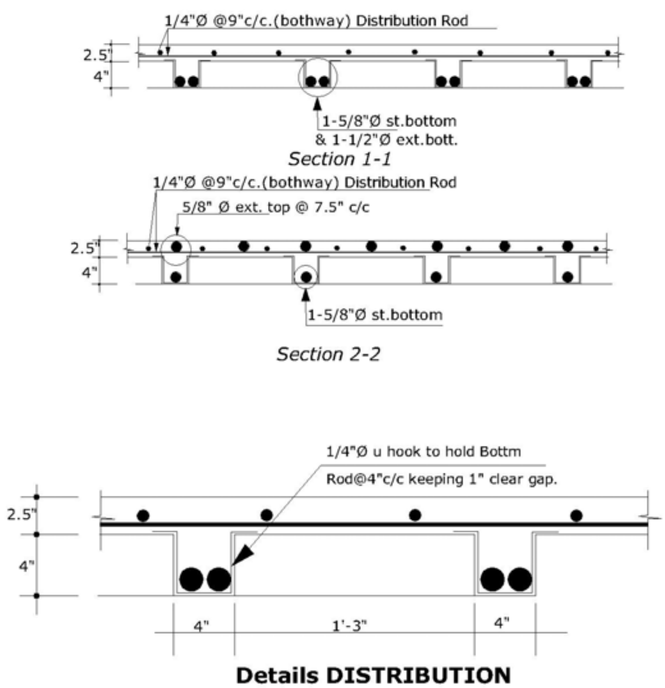


Fig 4: Section of Slab

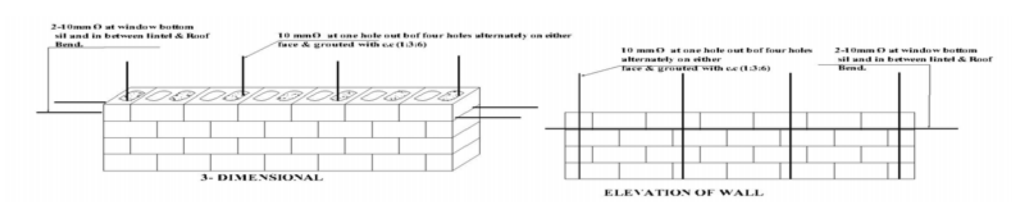


Fig 5: Bock Wall

## 4. COST COMPARISON OF PROPOSED SYSTEM WITH THE CONVENTIONAL CONSTRUCTION SYSTEMS

To evaluate the cost economics, a typical low-rise building of ground plus four floors located in seismic zone 1 was selected. Three structural systems—1) Load bearing brick masonry structure with RC roof/floor slab, 2) Reinforced Hollow Concrete Block Masonry structure with RC roof/floor slab with hollow block and, 3) RC framed structure with clay brick infill and RC roof/floor slab— were considered for comparison of cost economics. Designs were prepared as per BNBC.

Comparison of different construction systems:

Comparative schedule of different construction systems quantities and their cost economics are famished in table 2. Overall comparison of different aspects of proposed system and conventional construction systems are summarized in table 3.

**Table 2 – Comparative schedule of quantities and cost economics**

| Items of work | Reinforced concrete block masonry [RCBM] | | | RC framed structure with brick infill | | | Load bearing masonry structure | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Rate in Tk. | Total Cost BDT | Quantity | Rate in Tk. | Total Cost BDT | Quantity | Rate in Tk. | Total Cost BDT |
| **Total DL at foundation (in kips)** | 1505.64 | | | 1899 | | | 1915.4 | | |
| **Total floor area (sft)** | 1361 | | | 1396 | | | 1285 | | |
| **Construction Cost** | | | 4,098,277 | | | 4,639,020.60 | | | 3,430,562.39 |
| **Unit cost/sft** | | 512.3 | | | 579.9 | | | 428.8 | |

**Table 3 – Summary of relative cost elements**

| No. | Reinforced concrete block masonry | Conventional construction systems | |
|---|---|---|---|
| | | As compared to load bearing brick masonry | As compared to RC framed structure with infill brick masonry |
| **1** | Percentage saving in cost | -16.3 | 13.19 |

| | | | |
|---|---|---|---|
| **2** | Percentage increase in floor area | 5.9 | -2.57 |
| **3** | Percentage reduction in total dead load at foundation level | 27.22 | 26.2 |

## 5. CONCLUSIONS

Relative cost economics indicate that the Reinforced Hollow concrete Block Masonry construction system is cheaper than conventional construction systems, it is also structurally superior system. Further it possesses additional advantages, such as:

- Hollow space in wall and roof makes the building comfortable: cooler in summer and warmer in winter.
- It provides comparatively higher floor area.
- Its reduced dead load attracts lesser earthquake load and thus reduces earthquake vulnerability.
- It has demands lesser construction time.
- It also provides better sound proof.
- Less shuttering work is required.
- Aesthetic look is better.
- Environmentally is more friendly as block is manufactured by inert material—sand and stone chips—while clay brick uses fertile top soil.
- Concealing of ancillary building elements—sanitary line and electrical line work—is easier and incurs less cost.
- **6. ACKNOWLEDGEMENT**

Authors wish to thank all the engineers and staffs of EPCT (Engineering Planning Consultancy team).

## 7. Table 2 – Comparative schedule of quantities and cost economics

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# USE OF BAMBOO WITH MORTER & CONCRETE AS A CONSTRUCTION MATERIAL

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## ABSTRACT

Bamboo has remarkable properties as a construction material, being both light weight and extremely strength and durable. Moreover it grows all over the Bangladesh; a South Asian lower-middle income country where rural people is the majority of the total population. Bamboo as a construction material is used widely in Bangladesh. It has a considerable tensile and compressive strength. But the main problem that it has is less sustainability. But if it is mixed with some durable material like mortar and concrete than its durability as well as the strength taking ability will be much higher. This study concentrates on the strength test of composite members made accompanied by bamboo. It determines the compressive strength of bamboo, the strength of composite column made of bamboo and mortar in its hollow area, and the strength of composite column of bamboo and concrete. Different mixing ratios and cross-sectional areas are used for conducting the study. This study is performed mainly for the rural areas, where bamboo grows in ample amount, steel is rare, expensive or transportation cost is high. In coastal area the economic condition of people is also low. In these type of backward such study may essential for their development as well as an assurance for low cost housing. After the study it is seen that samples constructed is aid of bamboo can offer respectable amount of strength that can be safely used for low-cost housing.

**Key word:** Compressive strength, column, composite member, mortar, stone

## 1.0 INTRODUCTION

In Bangladesh, a South-Asian country, bamboo is a common material to build low cost houses especially in rural areas (Rashid 2007). One billion people in the earth live in bamboo houses. In Bangladesh, about 73% of the population lives in houses where bamboo is very common building material. It provides pillars, walls, window frames, rafters, room separators, ceilings and roofs. It is also used as a common fuel product in Bangladesh as well as different part of South Asia (Bhatt and Sachan 2004, Leach 1987 and Miah at el 2010). Environmental benefit is a major consideration given preference in the recent years all over the world. Construction program should emphasize use of local materials, energy efficient designs and materials that don't harm health and the environment and labor intensive technologies that employ more

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people. Only bamboo can meet most of these criteria. Bamboo requires a little energy for the production of normal use of several building materials. Almost no labor is needed for its growth. Studies show that processing of bamboo requires only 1/8 of the energy that concrete needs to create a building material of the same capacity. In comparison to steel bamboo needs only 1/50 the amount of energy for processing. It is well known that Construction Industry is one of the most polluting industries in the world. Production of both concert and steel causes considerable deterioration of the environment. For example cement requires over $1400^{o}C$ by burning fossil fuel (CS Monitor, 2008, Aziz 1995). Even the flame temperature may reach to $1650^{o}C$ (Neville 1995). Production of every ton cement results the emission of at least one ton of $CO_2$ (Baba 2009). Similarly, production of per ton of steel releases over two tons of $CO_2$ in the atmosphere. (Ghavami 2007). The steel making process is very energy intensive. The majority of energy used in the production of steel comes from coke/coal, electricity, liquid oxygen, and the raw ingredients themselves (www.energytechpro.com , 2004). Even transportation of the construction materials is also associated with the emission of $CO_2$. All the steps of production to transportation of construction materials are hugely dependent to the ample consumption oil, coal and gas. (Scientific American 2008). Due to high cost of building materials for low cost housing search of low cost housing material is always a good area of research (Mahzuz at el 2009).

## 2.0 METHODOLOGY

In order to prepare this study major steps like work procedure design, sample preparation, laboratory test and comparison etc are done. Four basic types of samples are prepared for study at this test; all are accompanied by bamboo at different form. The basic types of samples are, a) Bamboo sample alone, b) Composite sample of bamboo with mortar poured in its hole, c) Composite sample of bamboo with the mixture of cement, sand and stone chips poured in its hole, d) Bamboo reinforced column sample where bamboo sticks are used as an alternative of steel. It is to be noted that all the bamboo samples used for this study were at least of 3years of age. In the following section the preparation of those samples and the test procedures are discussed.

### 3.1. Preparation of Bamboo sample

The bamboo samples selected for the study were properly dry and worm free. Bamboo was sized into sample of one feet length as shown in Fig: 1. Samples were taken from the interval of splints so that samples were fully hollow. The two ends of the bamboo were kept perpendicular to the surface/length of the bamboo. After drying and curing it is prepared for the compression test. Three samples were tested under compression machine and the average was taken as the result. In total 3 samples were prepared.

### 3.2. Preparation of Composite sample of bamboo with mortar poured in its hole

Each of the bamboo samples was taken of one feet length as stated above. Then Mortar (cement and sand) is poured at the hole of the bamboo sample. After drying and curing properly it is prepared for the compression test. Water/cement ratio was kept constant (0.45). The mortar was prepared in three (1:5, 1:4 and 1:3) mixing ratios of cement and sand. Three samples were tested for each ratio. That is in total nine samples were made.

| | | |
|---|---|---|
|  *Figure* 01: Prepared bamboo sample for compression test. |  *Figure* 02: Prepared bamboo splints. |  *Figure* 03: Preparation of bamboo reinforcement case with tie bar. |

After the preparation of the sample it was dried for one day in normal weather. Due to swelling and odorous problem of bamboo at the 16$^{th}$ day of curing the samples were dried for two days. The curing water was changed as well. Due to the same problem the samples were dried for two days after curing. Within this time the bamboo became perfectly dry. That is at the 31st day the compression strengths of the samples were tested by the compression test machine.

### 3.3. Composite sample of bamboo with the mixture of cement, sand and stone chips poured in its hole

Each of the bamboo samples was taken of one feet length as stated above. Then mixture of cement, sand and stone chips (of about 0.25 inch size) are poured at the hole of the bamboo sample. After drying and curing it is prepared for the compression test. Used water ratio was 0.45 as well. The mixture was prepared in three (1: 1.5:3, 1:2:4 and 1:2.5:5) mixing ratios of cement, sand and stone chips. Three samples were tested for each ratio. That is in total nine samples were made. After the preparation of the sample it was dried for one day in normal weather. Curing of concrete mixture was performed for 28 days. Due to swelling and odorous problem of bamboo at the 16$^{th}$ day of curing the samples were dried for two days. The curing water was changed as well. Due to the same problem the samples were dried for two days after curing. Within this time the bamboo became perfectly dry. That is at the 31st day the compression strengths of the samples were tested by the compression test machine.

### 3.4. Preparation of Bamboo reinforced column sample

Here bamboo splints are made to test their effectiveness as an alternative of steel in concrete column. The moulds used to create the samples were circular in shape $(\text{Height}: 1', \text{Dia}: 6'')$. Each sample was provided with six number of bamboo splints. Three types of splints of cross sectional area of $(0.5\times0.5)$ in$^2$, $(0.35\times0.35)$ in$^2$ & $(0.43\times0.43)$ in$^2$ were used. Two concrete mix ratios were used for study purpose (1:1.25:2.5, 1:1.5:3). Three samples were made for each mixing ratio and each splint size. That is in total 18 samples were made. For all samples water ratio was taken as 0.45. GI weir was used to hold the bamboo splints in position while concrete is poured in mould (Fig: 03). For all sample a clear cover of ½ inch was maintained. Concrete mix was prepared with pit sand, cement & stone $(0.75''\ size)$. After the preparation of sample it was dried for one day in normal weather. Curing was performed for 28 days. After 28 days excess portion of the bamboo splints were cut smoothly. Then the compression strengths of the samples were determined by the compression test machine.

## 4.0 RESULT

### 4.1 Compressive stress of bamboo

Three samples of bamboo were tested, each of which was about one foot in height as shown in the Figure: 1. The cutting surface of the samples were kept exactly smooth and parallel for the test in compression machine. Test results are shown in the following table.
Table 01: Determination of the compressive stress of bamboo.

| **Sample no** | **Outer Dia Cm** | **Inner Dia cm** | **Cross sectional Area cm$^2$** | **Stress Mpa** |
|---|---|---|---|---|
| 01 | 7.44 | 6.1 | 14.24 | 41.5 |
| 02 | 8.03 | 6.5 | 17.46 | 38.32 |
| 03 | 7.4 | 6.2 | 12.81 | 43.22 |
| **Average compressive strength of Bamboo sample** | | | | **41.02 Mpa (5.93 Ksi)** |

### 4.2 Compressive strength of Composite sample of bamboo with mortar poured in its hole

It is evident that cross-sectional area of bamboo depends on its inner and outer dia. And with in the hole mortar of different ratio were pored. Test results are shown from Table 2, 3 and 4.

Table 02: Determination of stress (ratio 1:5) :

| **Sample no** | **Outer Dia Cm** | **Inner Dia cm** | **Cross sectional area cm$^2$** | **Stress Mpa** |
|---|---|---|---|---|
| **01** | 7.12 | 5.9 | 39.8 | 9.2 |
| **02** | 6.82 | 5.65 | 36.53 | 7.83 |
| **03** | 8.1 | 6.67 | 51.53 | 9.88 |
| **Average compressive strength** | | | | 8.97 Mpa (1.3Ksi) |

Table 03: Determination of stress (ratio 1:4) :

| Sample no | Outer Dia Cm | Inner Dia cm | Cross sectional area $cm^2$ | Stress Mpa |
|---|---|---|---|---|
| **01** | 8.01 | 6.51 | 50.39 | 15.9 |
| **02** | 7.91 | 6.42 | 49.14 | 13.96 |
| **03** | 7.17 | 5.69 | 40.38 | 7.33 |
| **Average compressive strength** | | | | 12.39 Mpa (1.792 Ksi) |

Table 04: Determination of stress (ratio 1:3) :

| Sample no | Outer Dia Cm | Inner Dia cm | Cross sectional area $cm^2$ | Stress Mpa |
|---|---|---|---|---|
| **01** | 5.606 | 4.43 | 24.68 | 14.91 |
| **02** | 5.94 | 5.09 | 27.71 | 16.1 |
| **03** | 8.28 | 6.49 | 53.846 | 10.753 |
| **Average compressive strength** | | | | 13.92 Mpa (2.13 Ksi) |

**4.3 Compressive Strength of Composite sample of bamboo with the mixture of cement, sand and stone chips poured in its hole:**

Within the hole of bamboo the mixture of cement, sand and stone chips were pored. Three different mixing ratios (1:1.5:3, 1:2:4 and 1:2.5:5) were taken in this test. The results are shown in Fig: 4.

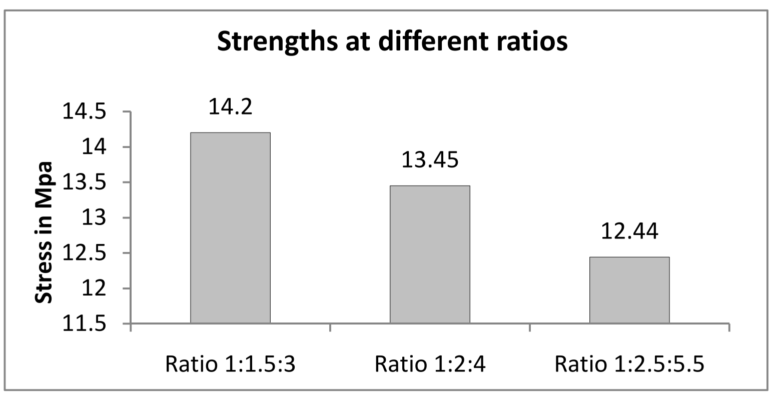


*Figure* 4: Strength of bamboo column at different ratio of concret

**4.4. Compressive Strength of Bamboo Reinforces Concrete:**

Two different concrete ratios (1:1.25:2.5 and 1:1.5:3) were used to find out its cylinder strength where bamboo was used as reinforcement. Three different bamboo ratios $\rho_{ba} = \dfrac{Bamboo\ area}{Gross\ concrete\ area}$ (0.026, 0.039, 0.053) were used for this test. Each cylinder was 15.24 in dia and 182.41 $cm^2$ in cross-sectional area. Six bamboo splints were used in each cylinder. The test result is shown in Fig 5 and 6.

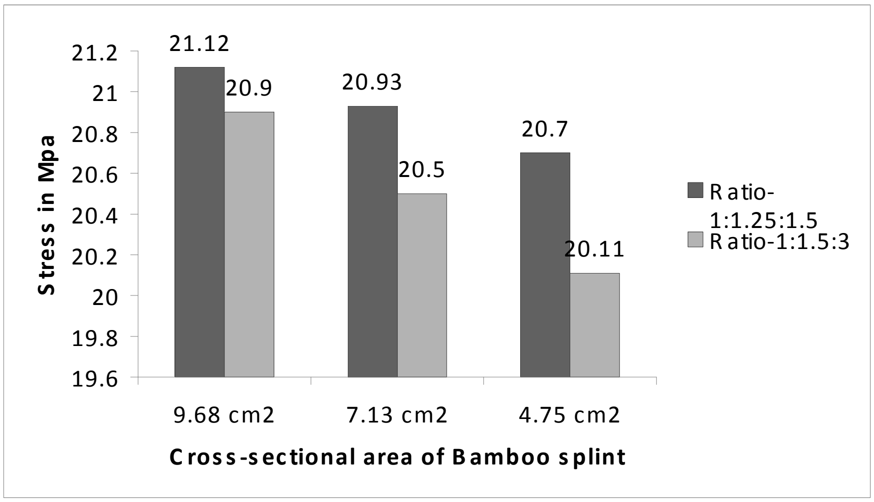


*Figure* 5: Comparison between the ratio in the basis of their strength capacity.

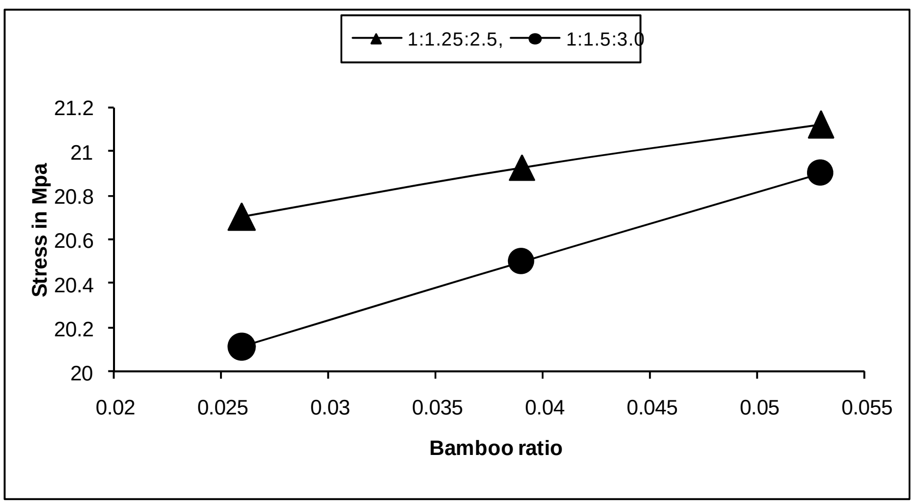


*Figure* 6: Change of stress at different Bamboo ratio

**6.0 DISCUSSION**

It is seen from the study that compression test of bamboo gives an average stress of 41.02 Mpa (5.93 Ksi) that is a good value to resist moderate loads specially of low cost buildings. Because load of low cost buildings are not so high. Such bamboo can be safely used as the feasible alternative of steel reinforced concrete column. If more than one bamboo is used than the resulting composite column can provide more resistance against more load. Table 01 shows the quantitative result of the compressive stress test of bamboo samples. The Composite sample of bamboo with mortar poured in its hole also shown respectable amount of stress before failure. At the mix ratio of 1:3, 1:4 and 1:5 the average stresses are 13.92 Mpa, 12.39 Mpa and 8.97 Mpa respectively. That is the stress got at the mix ratio of 1:3 is 12.35% higher than that of the mix ratio of 1:4, and the stress got at the mix ratio of 1:4 is 38.13% higher than that of the mix ratio of 1:5. It means that at lower mortar mix ratio composite members provide better strength. Table 02, 03 and 04 show the result of the tests of samples related to these types of sample. Composite sample of bamboo with the mixture of cement, sand and stone chips poured in its hole have shown higher strength than the composite sample of bamboo with mortar poured in its hole. It is seen from the test results that at the mix ratio of 1:1.5:3, 1:2:4 and 1:2.5:5 the average stresses are 14.20 Mpa, 13.45 Mpa and 12.44 Mpa respectively. That is the stress got at the mix ratio of 1:1.5:3 is 5.58% higher than that of the stress of the mix ratio 1:2:4, and the stress got at the mix ratio of 1:2:4 is 8.12% higher than that of the mix ratio of 1:2.5:5. It means that at lower stress ratio composite members provide better strength. Finally the summer of the result is shown in Figure 4. At Bamboo reinforced concrete three types of bamboo area are used (9.68 $cm^2$, 7.13 $cm^2$ and 4.75 $cm^2$) having the same gross area 182.41 $cm^2$. Two types of mix ratios are use for stud purpose.  The bamboo ratios are, 0.53, 0.39 and 0.26 respectively. The test results are shown in Figure 5 and 6. It is to be noticed that at higher bamboo ratio there higher resistance against load.

**7.0 CONCLUSION**

As an excellent building materials it is relatively cheap, easy to work with and readily available in most of the countries where bamboo grows. The importance of bamboo as a construction material particularly for housing has received a greater attention in recent years. In Asia, traditional bamboo houses of the low-income group use bamboo for supporting the structure. Even when other materials are used, bamboo forms a major part of the unit. Low cost bamboo houses are a cheap and safe alternative to the shelters of plastic, wood, stone and steel those are currently being used by many homeless people. These houses are made from prefabricated and natural bamboo generally associated with other kinds of building materials like wood, mud, brick and concrete as per necessary so as to make house in different appearances and to increase durability. The global shortage of housing materials especially in the developing countries is such that it warrants serious consideration. Of all the advantages of bamboo housing technology, the most important is its low cost that doesn't sacrifice quality, durability or space. In stead it allows an option that is feasible for populations of scarce resources. The manufacturing and distribution of low cost bamboo houses itself will provide employment to a range of people and there will be extra employment generation in its forward and backward linkages such as cultivation, harvesting, primary processing, transport and marketing of bamboo. In this study attempt is taken to introduce bamboo in mortar and concrete. Finally using different mixing techniques and ratios the resting strength is observed. Further studies are also necessary to find the more efficient use of bamboo for using it in low cost housing.

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# DESIGN OF TRIANGULAR REINFORCED CONCRETE BEAM IN USD

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## ABSTRACT

In construction works use of rectangular reinforced concrete beam section is a common practice. Different scale of architectural benefits may be achieved if beam shape can be changed. In this paper the mathematical equations of triangular reinforced beam section are formulated. Considering the beam as single reinforced the entire research is done in Ultimate Strength Design (USD) method. It is also assumed that tensile stress and compression stress act at below and above the neutral axis respectively. That is mid section of a beam is only taken into account. As bending moment and shear force are the two main factors of design of a beam therefore attention has been given to discover the equations relating to them. At the end of the study it is seen that relatively lower amount of material is needed by triangular beams than that of the conventional rectangular beam.

**Key words:** Reinforcement, Bending moment, Shear force, volume, economy.

## 1.0 INTRODUCTION

In any kind of building Beam is one of the most important structural components. A reinforced concrete (RCC) beam can be designed using both Ultimate Strength Design (USD) and Working Stress Design (WSD). In WSD a structural member is so designed that the stress resulting form the action of service loads and computed by the mechanics of elastic members do not exceed some pre-designated allowable values [1]. In USD ultimate stress of materials is used for design. The general shape of an RCC beam is rectangular and it may be single, double reinforced. Single reinforced beam is the preliminary type of beam from which other types of beams are developed. In such a beam the main reinforcement is provided near the face of the beam subjected to tension [2]. Beams sizes are usually governed by the negative moments and the shear at the supports, where the effective section is rectangular. Alternatively many designers prefer to estimate the depth of beams at about ¾ inch per foot of span, with the width equal to about one-half the depth [3]. In most cases stresses produced by shears are much smaller than those produced by moment. Therefore most beams are routinely proportioned for moment rather than shear. Once the beam has been sized, shear is checked to determine whether and at which amount shear reinforcement is required [4]. The purpose of all types of shear reinforcement is to increase shear capacity of members and to add ductility to their post-peak load behavior [5]. Fiber reinforced plastic (FRP) composites can be effectively used as an external reinforcement to upgrade the strength of reinforced concrete structures [6]. Strengthening the RC flexural and shear beams with external bonded FRP laminates and fabrics has been studied b several investigators [7,8,9,10]. Evidently, deflections are highly sensitive to length of beam (or even slab). Also end condition as well

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as loading pattern contributes in deflection. In designing beams, controlling the magnitude of deflection is always a major problem. A common empirical criterion used for dead plus live load deflections is typically limited to L/240 of the span [11]. Material property is an important factor for beam design. The modulus of elasticity $E_s$ for bar reinforcement is taken as 29,000,000 psi [12]. For normal weight concrete the modulus of elasticity is $E_c = 57000\sqrt{f_c^{'}}$ [13]. Sometimes bundle bars are also provided in beams as well as columns. Such bars are placed especially when the steel area becomes comparatively high. But it has some considerations. No. 14 and No. 18 cannot be bundled in beams. A maximum of four bars may be bundled [14]. The two most common shapes of beams are I and T. The analysis and design of an I-beam is similar to that of a T-beam [15]. In this paper another new section i.e. triangular section is discussed.

## 3.0 REVIEW OF EQUATIONS FOR RECTANGULAR SINGLE REINFORCED BEAM

### 3.1. Equation for flexure:

In USD the moment capacity of a rectangular concrete portion of a single reinforced beam having a width 'b' and depth 'd' is:

$$M_c = \rho f_y b d^2 (1 - 0.59 \frac{\rho f_y}{f_c^{'}})$$

$$=> d_{rec} = \sqrt{\frac{M_c}{\rho f_y b (1 - 0.59 \frac{\rho f_y}{f_c^{'}})}} \;\ldots\ldots\ldots\ldots(1)$$

In USD The moment capacity of the steel portion of a single reinforced rectangular beam is

$$M_s = A_s f_s (d - a/2), \text{ where } a = \frac{A_s f_y}{0.85 f_c^{'} b} \;\ldots\ldots\ldots\ldots\ldots(2)$$

### 3.2. Equation for shear:

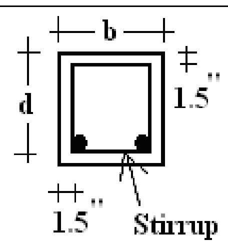

Fig 1: Stirrup shapes in triangular section

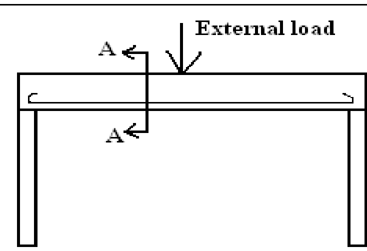

Fig.2: A Simple supported single reinforced beam

In USD method the mathematical equation for determining spacing of shear reinforcement for a rectangular RCC beam section is $s = \frac{\varphi d A_v f_v}{(V - \varphi V_c)}$, where V is the imposed shear force, Vc = $2\sqrt{f_c^{'}}bd$ is the shear force of the concrete section, d is the depth of the rectangular section, $A_v$ is the steel area, $f_v$ is the allowable steel stress. It is known that some extent of clear cover is provided in beams. Taking this in account the length of steel as the shear reinforcement needed per ft of beam, $L = \frac{(V-\varphi V_c)\times 12}{\varphi d A_v f_v} \times \text{perimeter of the steel used}$

For beams of rectangle shape (Fig: 1), $L_R = \frac{(V-\varphi V_c)\times 12}{\varphi d A_v f_y} \times 2\{(b-3)+(d-1.5)\}$ ...........(3)

## 4.0 METHODOLOGY

The entire work is based on theatrical framework. No experimental work is done to judge the newly developed equations. At first related equations are developed. Then comparisons are made with the related existing equations. All the results are plotted in tabular form. Calculations are made for different material properties ( $f_c^{'}$ and $f_y$ ) as well. Necessary comparisons for the different concrete area and steel area are made. It is to be noted that the beam is considered singly reinforced and the mid section of the beam is considered for this study. That is in such section compression and tensile stress will act at top and bottom of neutral axis respectively.

### 4.1. Equation for flexure:

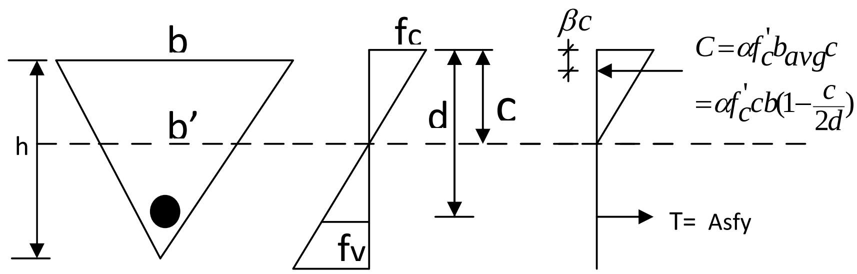


Fig. 3: Stress distribution at the maximum load in USD

For USD approach the simple supported beam of Fig.2 is considered. The empirical equations are varied due to the variation in compressive and tensile stress of the concrete and steel respectively. From the geometry at Fig 3 it can be said that:

$b_{avg} = b(1-\frac{c}{2h})$, considering $h \approx d$ , $b_{avg} = b(1-\frac{c}{2d})$

Tension, $T = stress \times area = A_s f_s$ and compression, $C = stress \times area = \alpha f_c^{'} b_{avg} c = \alpha f_c^{'} cb(1-\frac{c}{2d})$

Steel ratio, $\rho = \frac{Steel\ area}{Concrete\ area} = \frac{A_s}{\frac{1}{2}bd}$ => $A_s = \frac{1}{2}\rho bd$

At equilibrium moment of both the compression and tensile forces will be equal. That is, $C = T$

$$=> \alpha f_c^{'} cb(1-\frac{c}{2d}) = A_s f_y$$

$$=> \alpha f_c^{'} cb(1-\frac{c}{2d}) = \frac{1}{2}\rho bdf_y$$ , after simplification

$$=> c = d(1-\sqrt{1-\frac{\rho f_y}{\alpha f_c^{'}}})$$

Now let us simplify:

$M_c = Force \times distance = \alpha f_c^{'} cb(1-\frac{c}{2d})(d-\beta c)$ putting the value of 'c' and after simplification

$=> M_c = \frac{1}{2}\rho f_y bd^2(1-\beta(1-\sqrt{1-\frac{\rho f_y}{\alpha f_c^{'}}}))$ , Considering $\beta = 0.425 \text{ and } \alpha = 0.72$

$$=> M_c = \frac{1}{2}\rho f_y bd^2(1-0.425(1-\sqrt{1-\frac{\rho f_y}{0.72 f_c^{'}}})) \text{ …………(4)}$$

This is the equation for moment of concrete area in USD. Considering the effective depth of triangular section as $d_{tri}$ from equation (4) it can be said that,

$$=> d_{tri} = \sqrt{\frac{M_c}{\frac{1}{2}\rho f_y b(1-0.425(1-\sqrt{1-\frac{\rho f_y}{0.72 f_c^{'}}}))}} \text{ ……………(5)}$$

Similarly to identify the steel area from Fig 3,

$M_s = Force \times distance = A_s f_s (d-\beta c)$ Putting the value of 'c'

$=> M_s = A_s f_y (d-\beta d(1-\sqrt{1-\frac{\rho f_y}{\alpha f_c^{'}}}))$ Considering $\beta = 0.425 \text{ and } \alpha = 0.72$ for $f_c \le 4 \text{ Ksi}$ and after simplification

$$=> M_s = A_s f_y d(1-0.425(1-\sqrt{1-\frac{\rho f_y}{0.72 f_c^{'}}})) \text{ ………………..(6)}$$

This is the equation for moment of Steel area in USD.

**4.2 Equation for shear:**

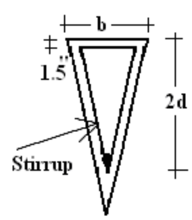


Fig. 4: Stirrup shapes in triangular section

A little consideration will reveal that in USD method the mathematical expression for determining spacing of shear reinforcement for a triangular section is the same as that of rectangular RCC beam. That is if 'd' is the depth of the triangular section: $s = \frac{dA_v f_v}{(V-V_c)}$

At same cross sectional area (i.e, $A_R = b \times d$ and $A_T = \frac{1}{2} b \times 2d$ ) and width 'b' the depth of triangular section will be just twice of that of the rectangular section. Therefore for such triangular RCC beam section the equation for determining spacing of shear reinforcement is, $s = \frac{2\varphi d A_v f_v}{(V - \varphi V_c)}$. It means that the spacing will be just the twice of that of rectangular section.

Steel Length needed per ft of beam, $L_T = \frac{(V - \varphi V_c) \times 12}{2\varphi d A_v f_v} \times \text{perimeter of the steel used}$

For triangle, $L_T = \frac{(V - \varphi V_c) \times 12}{2\varphi d A_v f_y} \times \{2\sqrt{\{2(d-1.5)\}^2 + \frac{(b-3)^2}{4}}) + (b-3)\}$ …………..(7)

Dividing equation 7 by equation 3:

$$=> \frac{L_T}{L_R} = \frac{2\sqrt{4(d-1.5)^2 + \frac{(b-3)^2}{4}} + (b-3)}{4\{(b-3) + (d-1.5)\}} \qquad \text{………………(8)}$$

**5.0 RESULT**

**5.1 Concrete area**

It is evident from the above discussion that some reasonable comparison can be made between equations (1) and (5). This case is also true for the equations (2) and (6) as well. In USD more generalized comparison between the triangular and rectangular section is presented below. At the same external moment dividing equation (5) by equation (1) we get Table 1.

$$\frac{d_{tri}}{d_{rec}} = \sqrt{\frac{2(1 - 0.59\frac{\rho_{\max} f_y}{f_c^{'}})}{(1 - 0.425(1 - \sqrt{1 - \frac{\rho_{\max} f_y}{0.72 f_c^{'}}}))}} \quad \text{(Putting } \rho_{\max} \text{ in place of } \rho\text{)}$$

Table 1: % Saving of concrete area

| $f_c^{'}$ **psi** | $f_y$ **psi** | $\beta_1$ | $\rho_b$ | $\rho_{\max} = 0.75\rho_b$ | $d_{tri}/d_{rec}$ | **Saving of concrete area in %** |
|---|---|---|---|---|---|---|
| 3000 | 60000 | 0.85 | 0.02138 | 0.016035 | 1.348677 | 32.56616 |
| 3000 | 40000 | 0.85 | 0.037121 | 0.02784 | 1.339296 | 33.0352 |
| 3500 | 60000 | 0.85 | 0.024943 | 0.018708 | 1.348677 | 32.56616 |
| 3500 | 40000 | 0.85 | 0.043307 | 0.03248 | 1.339296 | 33.0352 |
| 4000 | 60000 | 0.825 | 0.027668 | 0.020751 | 1.350485 | 32.47573 |
| 4000 | 40000 | 0.825 | 0.048038 | 0.036029 | 1.341275 | 32.93627 |
| 4500 | 60000 | 0.825 | 0.031127 | 0.023345 | 1.350485 | 32.47573 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4500 | 40000 | 0.825 | 0.054043 | 0.040532 | 1.341275 | 32.93627 |
| 5000 | 60000 | 0.8 | 0.033537 | 0.025153 | 1.352309 | 32.38456 |
| 5000 | 40000 | 0.8 | 0.058228 | 0.043671 | 1.343282 | 32.83588 |

Now to make it clear let us do it clearly. Let's think about the first row of the Table 01 where

$$\frac{d_{tri}}{d_{rec}} = 1.348677, \Rightarrow d_{tri} = 1.348677 d_{rec}$$

At same beam width 'b' that saving of concrete area with respect to the rectangular beam section becomes: $\frac{bd_{rec} - \frac{1}{2} \times bd_{tri}}{bd_{rec}} \times 100 = \frac{bd_{rec} - \frac{1}{2} \times b \times 1.348677 d_{rec}}{bd_{rec}} \times 100 = 32.566\%$.

### 5.2 Steel area:

Now let us make a comparison between the steel area. Let the material property is $f_c^{'} = 3\ ksi,\ f_y = 60\ ksi$. In Table 02 for a common beam width of 12" at different moments the respective steel areas are calculated using equation (2) and (6).

Table 02: % Saving of steel area

| Moment (Kip-inch) | d tri | As tri | d rec | As rec | Saving |
|---|---|---|---|---|---|
| 100 | 4.412257 | 0.423577 | 3.27122 | 0.627494 | 32.4971 |
| 200 | 6.239874 | 0.599028 | 4.626204 | 0.887411 | 32.4971 |
| 300 | 7.642253 | 0.733656 | 5.66592 | 1.086852 | 32.4971 |
| 400 | 8.824514 | 0.847153 | 6.542441 | 1.254988 | 32.4971 |
| 500 | 9.866106 | 0.947146 | 7.314671 | 1.403119 | 32.4971 |
| 600 | 10.80778 | 1.037547 | 8.012821 | 1.53704 | 32.4971 |
| 700 | 11.67373 | 1.120679 | 8.654835 | 1.660193 | 32.4971 |
| 800 | 12.47975 | 1.198056 | 9.252408 | 1.774821 | 32.4971 |
| 900 | 13.23677 | 1.27073 | 9.813661 | 1.882482 | 32.4971 |
| 1000 | 13.95278 | 1.339467 | 10.34451 | 1.98431 | 32.4971 |
| 1100 | 14.6338 | 1.404845 | 10.84941 | 2.081162 | 32.4971 |
| 1200 | 15.28451 | 1.467313 | 11.33184 | 2.173703 | 32.4971 |

To make easy to understand the calculation of Table 02 let us see an example. If the imposed moment is 1200 kip-inch using equations (1) and (5) the effective depths are 11.33" (for rectangular beam) and 15.28" (for triangular beam) respectively. Using equation (2) and (6) the steel areas are 2.173703 $in^2$ (for rectangular beam) and 1.467313 $in^2$ (for triangular beam) respectively. That means that saving of steel area becomes: $\frac{2.173703-1.467313}{2.173703}\times 100 = 32.4971\% \approx 32.5\%$ .

**5.3 Shear reinfoecement:**

A little investigation will make it clear that at the same concrete area, beam width, steel area and allowable stress for any value of'd' and 'V' using equation (8) it can be seen that $\frac{L_T}{L_R} < 1$ .

It means that for shear the usage of steel in a triangular section is comparatively lower than that of rectangular one. Therefore saving is also ensured. Table 3 shows that in all cases less steel is used in triangular section per linear ft in a beam that that of rectangular ones.

Table: 03: Relative values of $\frac{L_T}{L_R}$ (considering d'= 38 mm)

| **Beam depth d** | $\frac{L_T}{L_R}$ | | | |
|---|---|---|---|---|
| | **b = 10** | **b = 12** | **b = 15** | **b = 18** |
| 6 | 0.572 | 0.539 | 0.510 | 0.493 |
| 7 | 0.602 | 0.565 | 0.529 | 0.508 |
| 8 | 0.652 | 0.611 | 0.568 | 0.539 |
| 9 | 0.708 | 0.666 | 0.619 | 0.584 |
| 10 | 0.761 | 0.720 | 0.672 | 0.635 |
| 11 | 0.805 | 0.768 | 0.722 | 0.684 |
| 12 | 0.840 | 0.807 | 0.765 | 0.729 |
| 13 | 0.868 | 0.839 | 0.801 | 0.768 |
| 14 | 0.890 | 0.865 | 0.831 | 0.800 |
| 15 | 0.908 | 0.885 | 0.855 | 0.828 |
| 16 | 0.921 | 0.902 | 0.875 | 0.851 |
| 17 | 0.933 | 0.916 | 0.892 | 0.870 |
| 18 | 0.942 | 0.927 | 0.905 | 0.885 |
| 19 | 0.949 | 0.936 | 0.917 | 0.899 |
| 20 | 0.955 | 0.943 | 0.926 | 0.910 |
| 21 | 0.961 | 0.950 | 0.934 | 0.920 |

## 6.0 RESULT AND DISCUSSION

After the formulation of the basic equations in this section they are applied for comparison. It is seen from Table 01 that for the same imposed moment the resulting concrete area of triangular beam save more than 32 % of concrete material at the different combination of $f_c^{'}$ and $f_y$. Saving of steel area is also ensured for steel area as well. For $f_c^{'} = 3\,ksi,\ f_y = 60\,ksi$ and b = 12 inch for different value of moment steel areas are calculated. In all cases it is assumed that compression and tensile stresses act at the above and below respectively. This calculation is made both for rectangular and triangular section. It is clear from the Table 02 that in each case there occur some saving in steel area (32.5%). Such variation will also occur at the different combination of $f_c^{'}$ and $f_y$. Finally encouraging result is also seen from Table 3 where each value of $\frac{L_T}{L_R}$ is less than 1.

## 7.0 CONCLUSION

In construction work the construction of triangular sections will not be a great problem. Only the forms are needed to be changed. As beams may also be subjected to negative moments therefore scope is there to study the effectiveness of triangular RCC sections on this respect. Yet regarding the limit of this paper it can evidently be said that for simple supported beams having one span as well triangular sections are superior to the rectangular ones. Such beams may be effectively used as the girder of bridges. The efficiency of triangular section may be increased introducing the prestressed and FRP concept. Moreover from aesthetic point of view triangular beams are indeed a good option.

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# DISASTER MANAGEMENT AND ENVIRONMENTAL SCIENCE EDUCATION, RESEARCH AND TRAINING FOR SUSTAINABLE DEVELOPMENT: PROGRESS IN BANGLADESH AND WAY FORWARD[1]

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## ABSTRACT

Bangladesh is one of the most disaster and climate risk prone countries. Disasters are growing threat to its development. Disasters are interrupting economic activity, creating irreversible changes in the natural resource base. It showed impact on the foreign exchange balance, reduce productivity of agricultural and all other productive sectors. To ensuring sustainable development, we need to meet the challenges through professional service development in all service sector. Hence, disaster and climate risk management services should be done professionally. Developing professional with required knowledge, skill and professional ethics and attitude are therefore inevitable. To meet up the challenges for the education, research and training institutes in Bangladesh are to develop sufficient human resources. Substantial progress has been made towards professionalizing the disaster management system in Bangladesh during the year 2005-2010 for developing required human resource with competencies (knowledge, skills and attitude).

**Key words:** Disaster Management, Environmental Science, Education, Research, Training and Sustainable Development

## 1. INTRODUCTION

Bangladesh is one of the disaster prone countries and disasters are growing threat to its development. Disasters interrupting economic activity, creating irreversible changes in the natural resource base, besides it showed impact on the foreign exchange balance and reduce productivity of agricultural and productive sectors. Evaluation past disaster impact it has been identified that although Bangladesh has made a significant progress in reducing the casualty but reducing economic loss during and after disaster in increasing these days. The impact of climate change and climate variability has triggered the nature and frequency of natural disasters and well as climate induced disasters. In order to ensuring sustainable development, we need to meet the challenges of frequent disasters. Hence, demand for disaster management professionals for government, non-government humanitarian agencies are increasing. The challenges here are from the education and training institutes in Bangladesh part, are to develop sufficient human resources [1]. The role and responsibilities of the people

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and organizations have been outlined in the revised SoD [2] and National Plan for Disaster Management (2010-2015) [3]. Besides, to building the resilience of nations and communities to disasters outline in Hyogo Framework for Actions (HFA 2005-2015) [4] and BCCSAP [5], we need to promote disaster and climate change risk in national education, training and research system. This would lead to ensure the quality of the human resources considering required competencies (knowledge, skills and attitude).

## 2. STRATEGIES AND METHODOLOGIES

The CDMP of DMRD, MoFDM has initiated activities since 2004 which is supported by development partners UNDP, UK Aid, EC, Norwegian government, Australian Government and SIDA. The activities are on building partnership and establishing network to support to learning and development programme of MoFDM on disaster and climate change risks.

A number of expert consultation meetings/workshops were conducted (Table 1) with resource persons from public and private universities, research institutes, academic and training institutes. Memorandums of Understanding (MoU) have signed with National Curriculum and Text Book Board (NCTB), Bangladesh Public Administration Training Centre (BPATC), Bangladesh Academy for Rural Development (BARD), Rural Development Academy (RDA, Bogra), BCS Administration Academy, and Armed Forces Division (AFD) for developing training modules on DM and imparting the professional training on DM. Besides, MoU have been signed with DU, KU, PSTU, Jahangirnagar University (JU, Savar), University of Rajshahi (RU), Shahjalal University of Science and Technology (SUST, Sylhet), Mawlana Bhashani Science and Technology University (MBSTU, Tangail), Chittagong University of Science and Technology (CUET), BRAC University, Independent University Bangladesh (IUB), and Bangladesh Agricultural University, Mymensingh (BAU), Bangladesh University of Engineering and Technology (BUET), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU, Gazipur) to incorporate the disaster and climate risk reduction issues in relevant courses, to introduce risk reduction new course as deemed necessary and to design and develop new certificate course, diploma courses and degree programme.

**Table 1. Venue of Expert consultation meetings of BDMERTN resource persons**

| Expert Consultation | Date | Venue |
|---|---|---|
| 1st | 10-11 September 2008 | Rural Development Academy, Bogra |
| 2nd | 11-12 November 2008 | Patuakhali Science and Technology University |
| 3rd | 23-24 December 2008 | Khulna University, Khulna |
| 4th | 31 October 2009 | University of Dhaka |
| 5th | 31 July 2010 | Bangladesh University of Professional (BUP), Dhaka |
| 6th | 27 November 2010 | BRAC Centre for Development Management, (BCDM), Gazipur |

## 3. ACHIEVEMENT UP TO DATE

Comprehensive Disaster Management Programme (CDMP) has completed a number of activities on incorporation and integration disaster and climate risk management (DCRM) issues in national education, training and research system (Table 2, 3 and 4). This was aimed to have a 'professional disaster management cadre service system' developed towards improving the disaster and climate risk reduction services in line with the activities outlined in Hyogo Framework for Actions (2005-2015) [2] and revised allocation of business of Disaster Management and Relief Division of the Ministry of Food and Disaster Management, Government of Bangladesh.

National Curriculum and Textbook Board (NCTB), public and private training institutes, academies and universities were engaged through partnership development programme for carrying out these activities with technical and financial support from CDMP.

A dynamic expert group has been formed, which consisted of more than two hundred faculty members from NCTB, reputed public and private universities, and training institutes, humanitarian agencies in Bangladesh. It is named as Bangladesh Disaster Management Education, Research and Training (BDMERT) network. A total 43 institutes have been identified to bring into the network. To date, CDMP has signed Memorandum of Understating (MoU) agreement with 23 institutes out of the 43. The education, research and training activities on DCRM incorporation and integration are being planned, monitored and progress reviewed by the network. Six expert consultation meetings of BDMERT were held during 2008-2010 (Table 1) through partners of the network. It was evidenced that a substantial progress has been made during these years on education, research and training on DCRM to support for achieving community resilience to disaster and climate change risks (Table 2, 3, and 4).

With support from CDMP, research on needs assessment for disaster and climate risk information for incorporation into text book has been carried out by NCTB. The research report was then submitted to the National Curriculum Coordination Committee (NCCC) of the Ministry of Education. Based on the findings the NCCC approved on 10 February 2010 that disaster management and climate change issues should be incorporated in curriculum from class Three (III) to class Ten (X). The issues on disaster management will be placed in social sciences and geography text-books. Besides some supplementary learning materials for mock drill at education institutes will be prepared and introduced through Ministry of Education.

Table 2: Technical support rendered for certificate and degree programme introduced in public and private Universities, Bangladesh and NCTB

| **Name of Institution** | **Name of Departments** | **Level of course/degree programme and status** |
|---|---|---|
| National Curriculum and Textbook Board | Text book from class II to Class XII | |
| Patuakhali Science and Technology University(PSTU) | Department of Environmental Science and Disaster Management | Introduced in 2009<br>• B.Sc. Hons in DM<br>• Master of Science in |

| | | |
|---|---|---|
| | | Disaster Management Postgraduate Diploma in DM course |
| University of Dhaka | Department of Geography & Environment<br>Faculty of Earth and Environmental Science | Introduced in 2009<br>• Master of Science in Disaster Management- 2 years, degree programme<br>• M.Phil and PhD |
| University of Dhaka | Centre for Disaster and Vulnerability Studies (CDVS)<br>Department of Sociology | Introduced 2010<br>• Master of Disaster Management (MDM) 2 years, degree programme<br>• Post-Graduate Diploma in DM |
| University of Dhaka | Department of Geology, Faculty of Earth and Environmental Science | Developed Curriculum for M.Sc. in Geology (Disaster Management ) |
| Bangladesh University of Professional | Faculty of Strategic and Security Studies, BUP | Developed curriculum for Master of Disaster and Human Security Management |
| Khulna University | Environmental Science Discipline, Urban and Rural Planning Discipline Biotechnology and Genetic Engineering Discipline | • Introduced in 2009 Professional week long Certificate course<br>Introduced Postgraduate Diploma in DM course |
| Shahjalal University of Science and Technology | Department of Civil and Environmental Engineering | Introduced Master of Disaster and Environmental Engineering |
| Chittagong University of Engineering and Technology (CUET) | Department of Urban and Regional Planning Department of Civil Engineering | Introduced in 2010 Master of Disaster and Environmental Engineering |
| Bangladesh Agricultural University (BAU), Mymensingh | Department of Environmental Science, Graduate Training Institute (GTI), and Department of Agricultural Extension Education (DAEE) | Week long Certificate course in Disaster Management introduced in 2009 |
| Independent University Bangladesh (IUB), Dhaka | Department of Environmental Science | Master of Science in Natural Resource and Disaster Management introduced in 2010 |
| BRAC University | Department of Architecture | Postgraduate Programme in Disaster Management introduced in 2005 |
| Begum Rokeya University, Rangpur | Department of Hazards Science and Disaster Management | Curriculum development is in progress |

In case of tertiary education, examples are curriculum and syllabus for Bachelor and Masters Degree were prepared, approved by the University Grants Commission (UGC). Accordingly a four years degree programme named B Sc. (Hons) in Disaster Management has been introduced in Patuakhali Science and Technology University (PSTU). During the period, University of Dhaka (DU) established a Centre for Disaster and Vulnerability Studies (CDVS) and introduce Masters of Disaster Management (MDM) programme. Chittagong University of engineering and Technology (CUET) and Shahjalal University of Science and Technology (SUST) have introduced Master of Science in Disaster and Environmental Engineering from the year 2010. Independent University Bangladesh (IUB) recently introduced Masters in Natural Resources and Disaster Management and Post-Graduate Certificate course on Leadership in Disaster Management. Besides, five Post-graduate Diploma in Disaster Management (PGDDM) programmes have been pilot tested. Three of them were introduced in the DU, KU and PSTU.

"Introduction to Disaster Management" a 3-credit course has been designed as a general course on disaster management for all degree programme and introduced in a number of degree Bachelor and Masters degree programme on agriculture, environmental science, sociology, social work and geography and environment departments (Table 3).

**Table 3**. Technical supported provided to introduce a course on Disaster Management (3 credit) for B.Sc. (Hons), M. Sc. and M.Phil degree programme

| Name of Institution | Institution/Department |
|---|---|
| Bangladesh University of Engineering and Technology | Department of Urban and Regional Planning |
| University of Dhaka | Department of Geography & Environment<br>Department of Sociology<br>Institute of Social welfare and Research |
| University of Rajshahi | Institute of Environmental Science (IES)<br>Department of Sociology |
| Jahangirnagar University | Department of Environmental Science<br>Department of Urban and Regional Planning |
| Bangladesh Agricultural University (BAU), Mymensingh | Department of Environmental Science |
| Khulna University | Environmental Science Discipline, Urban and Rural Planning Discipline |
| Patukhali Science and Technology University (PSTU) | Department of Environmental Science and Disaster Management |
| Mawlana Bhashani Science and Technology University (MBSTU), Tangail | Department of Environmental Science and Resource Management |
| Shahjalal University of Science and Technology | Department of Civil and Environmental Engineering |
| Chittagong University of Engineering and Technology (CUET) | Department of Urban and Regional Planning<br>Department of Civil Engineering |
| Independent University Bangladesh (IUB) | Department of Environmental Science |
| North South University | Department of Environmental Science |
| Bangladesh University of Professional (BUP), Mirpur, Dhaka | Faculty of Business Studies |

Community based research initiatives on DCRM have also been introduced through the BDMERT to identify community risk and finding ways to integrate these into development planning. The areas were selected from the in Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) and Bangladesh National Plan for Disaster Management (2010-2015). In 2009, forty (40) Masters/Undergraduate thesis works were conducted on these issues under CDMP research grant support.

In order to improve the services of existing work forces of the national building departments, three sessions have been identified on disaster management. These are, i.) disaster risk reduction, ii) emergency response management, and iii) disaster and development linkage and its mainstreaming. These sessions have been incorporated in the Foundation Training course module entitled: Bangladesh and Sustainable Development". The Foundation Course Module is applicable for all 29 Bangladesh Civil Service (BCS) cadres. The revised modules have been then pilot tested in Bangladesh Public Administration Training centre (BPATC) and Bangladesh Civil Service Administration Academy, Bangladesh Academy for Rural Development (BARD) and Rural Development Academy (RDA) with the 29 Bangladesh Civil Service Cadres officials. Training of Trainers (ToT) on Disaster management has also been developed (Table 4). This courses were introduced at BARD and RDA and trained 160 BDMERT network members during the years 2008-2009.

**Table 4.** Technical support provided to introduce DRR and CCA in training modules and to introduce courses in public training institutes

| Name of Institutions | Institution/Department |
|---|---|
| Bangladesh Public Administration Training Centre (BPATC) | • DM sessions in BCS Civil Service (all Cadres) Foundation Course modules<br>• Specials course on DM for SSC and ACAD course participants |
| Bangladesh Civil Service Administration Academy | • DM Session in BCS Civil Service Cadre (Administration) Foundation Course Module<br>• Specials course on DM for BCS administration participants |
| National Academy for Educational Management (NAEM) | • BCS Civil Service Cadre (Education) Foundation Course<br>• Special course 3-days course for Principals |
| Bangladesh Academy for Rural Development (BARD) | • DM sessions in BCS Civil Service Cadre (Health) Foundation Course Modules<br>• Developed week long tailored course on Disaster and Environment management for Rural Development<br>• ToT on Comprehensive Disaster Management |
| Rural Development Academy (RDA) | • DM sessions in BCS Civil Service Cadre (Health) Foundation Course Modules<br>• Developed week long tailored course on Disaster Risk reduction in Agricultural Sector<br>• ToT on Comprehensive Disaster Management |
| Graduate Training Institute (GTA) BAU Mymensingh | Introduced DM sessions in Foundation course for university teachers and officers |
| Central Agricultural Research and Training Institute (CERDI), Gazipur | Introduced training course on "Disaster risk reduction and climate change adaptation in agricultural sector" |

Besides, One week long tailored Disaster Management training courses on “Emergency Preparedness and Civil Military Relation also designed with Bangladesh armed forces officials. In line with these a number of ‘3 days to week long’ certificate training course i.e. ‘disaster management’, ‘disaster and environment management’, ‘climate change’ have been developed in BPATC, BARD, RDA and BCS Administration Academy.

**4. WAY FORWARD**

Aiming to ensuring sustainability of the progress made on education, research and training, CDMP II will continue the support to the ongoing courses and expand it to Bangladesh Institute of Management (BIM), National Institute of Preventive and Social Medicine (NIPSOM), Bangladesh University of Engineering and Technology (BUET) and more 22 institutes in upcoming years. This will cover the instate to have divisional/zonal network on education , research and training in place and cover all the other BCS cadres service like, Bangladesh Police, Bangladesh Ansar, BCS Agriculture, BCS Fisheries, BCS Livestock, BCS Public Works, Engineers works for Water Development Board (BWDB), Power Developed Board (PDB) etc.

Through achieving the research findings by engaging the graduates and academicians of the national institutes, the network will be broadly expanded and to have in place a ‘Solution Exchange” targeted to ‘Community of Practice’ on disaster and climate risk management.

Finally these efforts from elementary to tertiary level of education, training and research will help to achieve the strategic goal of “Professionalizing Disaster Management System” as outlined in National Plan for Disaster Management (2010-2015). The professional cadre personnel can be worked as competent force at Disaster Management Bureau (DMB), Bangladesh Meteorological Department (BMD), Directorate of Relief and Rehabilitation (DoRR) and other relevant department and institutes. This also will help to achieve the goal “development and strengthening of institutions, mechanisms and capacities to build resilience to hazards” as envisaged by the Hyogo Framework for Action 2005-2015. Through this development efforts of Bangladesh can be protected, making the community disaster resilient and consequently ensure sustainable development through achieving Millennium Development Goals (MDG). The following issues are considered for achieve the MDGs through education and research;

- Strengthening and expanding the network with wide range of national and international humanitarian agencies, academic and training institutes
- Enhancement of the capacity of partners in terms of infrastructure, training, curriculum, syllabus, resource material development through education and research grant support.
- Ensuring sustainability of the programme and building linkages with competent authorities especially public and private universities for employment of the professionals.
- Include human security, conflicts with the disaster management issues and engage security forces.

## 5. ACKNOWLEDGEMENT

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# IS IT AN ISSUE TO THINK ABOUT THE SPREADING OF SHALLOW ENGINE VEHICLES? A CASE STUDY IN & AROUND KHULNA CITY

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## ABSTRACT

The urban transport issues are becoming increasingly important in Bangladesh. At present, local made shallow engine (SE) driven vehicles are very commonly seen in urban and especially in sub-urban areas. These are becoming more and more acceptable to the people for easy movement to any desired direction where there is absent of traditional vehicles. Considering their environmental, sociological position, it is high time to take an attempt to know their impact on transportation, economy and any further modification. A detailed questionnaire survey is performed in two phases in three locations of SE vehicles in and around Khulna City. The results show (i) There are three types of SE vehicles and most of them are socially accepted (ii) the vehicles are very noisy with noise level of 84 to 76 db. Various opportunities and interventions for alleviating the problems caused by these vehicles are discussed. Considering economical and sociological impact on transportation, SE vehicles cannot be ignored from roadways.

**Key Words:** SE vehicles, Noise, Traffic, Passenger, Safety, Mechanical, Improvement.

## 1. INTRODUCTION

The urban transport issues of mobility, congestion, safety and environmental aspects are becoming increasingly important and critical in Bangladesh. At present, local made shallow engine (SE) driven vehicles are very commonly and sometimes abundantly seen in urban and especially in sub-urban centers like market places, junction of roads or street etc. These are becoming more and more adaptable and acceptable to the people as there are inadequate or totally absent of the traditional vehicle in the remote desired direction. They can easily move to any desired ways in the rural area [1]. These vehicles are called differently such as Nosimon, Korimon, RahimShadu etc. in all over Bangladesh. They called Votvoty in North Bengal [1]. There are also many workshops only specialized for servicing of SE vehicles as their maintenance is easy. Considering their environmental, sociological position, it is high time to take an attempt to know their present impact on transportation, economy and any suggested engineering modification. The key purpose of this study is to discuss the characteristics, importance and acceptance of some selected local made shallow engine driven vehicles in and around Khulna city and to discuss their improvement options and opportunities, which can be applicable throughout the country. These vehicles are allowed to move through the different routes in and around Khulna city. Three SE vehicle stations in the

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vicinity of the City are selected through preliminary survey for this research where numerous SE vehicles are seen.

## 2. METHODOLOGY

Mostly primary data is collected for this research through an extensive questionnaire survey on random basis. The SE vehicles are allowed to move through the following routes in and around Khulna city: (a) Razapur to Terokhada, Tazapur to Kalia, Razapur to Chapla; (b) Thukra to Dumuria, Shahapur to Jamira, Shahapur to Khornia; and, (c) Internal roadway. Particular SE vehicle stations situated among these routes have been selected for this survey. The selected locations/stations are namely: Jailkhana ghat, Doulotpur (Arongghata), and Fultola Bazaar. Different types of SE vehicles are abundantly found in all the selected locations. The survey is done in two phase namely initial and final phase. During the survey the selected location has been visited several times. At the initial phase of the survey introduction with the concern people was very important as at the beginning the work was doubtful to them. They thought that it was an initiation of some legal actions against them from the government, although the permission of the research work from KUET authority is shown. In every station soft motivation to the responsible people of the association of the owner of the SE vehicle is needed. After motivation they agreed to talk. Formatted conversations with four to five persons who use these vehicles both in roadway and waterway have been made and primary data about the acceptability of these vehicles have been found out. At the same time, problems occurred due to these vehicles both for safety purposes and accidents have been also found out.

At the second phase of the survey, information about the fabrication of the SE vehicles has been collected and different dimensions have been measured. The measurement mainly consists of the length and width of the vehicles, weight carrying capacity, and passenger sitting capacity, speed of the vehicle, engine types, and hood condition. These data would finally be compared with the other traditional vehicles available in the urban areas. Photographs are also taken for different SE vehicles. At the same time facilities provided to the users in a consideration of fare have also been compared with the other transportation modes. At the time of last part of second phase of the survey, occurrences of accident of these vehicles, emergency and compulsory equipments and sound produced by these vehicles have been measured. A noise meter have been used to measure the noise produced by these vehicles and the reading has been taken at several distances (of 0.0 m; 5.0 m; 10.0 m) from the engine.

## 3. RESULTS

Different types of SE vehicles are found in the selected area depending on the size as mentioned in Table 1. The first fabricated vehicle is very simple. They are generally hoodless and have wooden flat surface or have steel body frame as shown in Figure 1. They are used for the carrying both passengers and goods. During rainfall they use simply polythene paper to save the passengers or goods from rain water. The others are with hood and have tiny sitting arrangement generally used for carrying passengers. Those kinds of vehicle are shown in Figure 2. Their body frame is also made from wood or steel. They are usually 5 to 6.5 ft long and 4 to 4.5 ft wide. In Jailkhana ghat the size is 9 ft long and 4.5 ft wide. The assembling of this kind of SE vehicles is performed locally by the technicians only based on their practical experience. Therefore, the shape, size and the capacity is different in different places.


**Fig.1** SE vehicle without hood

Most of the SE vehicles found in the selected locations have three wheels. The engine is placed at the front side of the vehicle under the seat of the driver as shown in Figures 1 & 2. The SE vehicle of the Jailkhana ghat carries 7 to 8 passengers as presented in Table 2. In all other locations the carrying capacity is 10 to 15 passengers.

The average speed of the SE vehicles at Jailkhana ghat is 20 to 25 km/hr with maximum speed is 50 km/hr. In n Doulatpur and Fultola the average speed is 30 to 40 km/ hr with the range of maximum speed is 45 to 50 km/hr.

The limit of fare is little high in Doulotpur route as 1.30 to 1.70 tk/km.person. In all other route the limit is 1.30 to 1.50 tk/km.person. The fare can be compare with local bus and auto rickshaw run in the City and that is found to be higher for SE vehicle. The fare for local bus and auto rickshaw are 0.85 tk/km.person and 1.2 tk/km.person, respectively. As the people do not have other options those routes, are forced to use the SE vehicle.

The vehicles are also used to carry different agricultural and other goods towards and apart the urban centre like vegetables, fish, poultry, building materials, etc. The range of weight carrying capacity of the vehicles is  450 to 625 kg/SE vehicle. At Jailkhana ghat the capacity is 450 to 500 kg/SE vehicle


**Fig.2** SE vehicle with hood

The selected stations are situated around Khulna City as mention before. Peoples from remote rural areas usually come to Khulna City in morning for their different business. Therefore, there is traffic flow towards Khulna during morning and away from Khulna in the afternoon. Between 10:30 to 12:00 am there are many SE vehicles standing in the station. The range of the standing vehicle is shown in Table 2. In Jailkhana ghat the range is 60 to 70 numbers SE vehicle.

Four wheels SE vehicles are also exist in different places like in Kustia districts. The four wheel vehicles are look like a micro truck of very old model with fully steel body as shown in Figure 3. These vehicles are mostly used to carry goods from one place to other. The engine is larger and is placed at the front side of the vehicle as shown in Figure 3. There was a little scope to know the power in hp of the engine.

**Table 1:** Basic data on the size of the SE vehicle found in different location (L)

| Location (L) | Length | Width | Height | Hood (Number[a]) |
|---|---|---|---|---|
| Jailkhana Ghat (J) | 9 | 4.5 | 7 | Yes (60-70) |
| Doulotpur (D) | 6-6.5 | 4-4.5 | 3.5 | No (80-110) |
| Fultola (F) | 9-10 | 4.5 | 3.5 | No (80-85) |
| Others (O) | 5-5.5 | 4-4.5 | 3.5 | Both (95-120) |

[a]Number of SE vehicle during 10 am to 11:30 am

**Table 2:** Capacity of the SE vehicle

| L | Passenger Nos. | Weight Kg | Speed km/hr | Fare tk/km |
|---|---|---|---|---|
| J | 7-8 | 450-500 | 20-25 | 1.4-1.5 |
| D | 10-12 | 600-625 | 30-40 | 1.3-1.7 |
| F | 12-15 | 550-615 | 30-40 | 1.3-1.5 |
| O | 10-15 | 450-475 | 25-30 | 1.2-1.5 |

The engines of the SE vehicles are used engine of the shallow pump. Initially those were used for irrigation and after that are used for SE vehicle. The range of horse power of the engines is 3.7 to 8.5 hp as shown in Table 3. The fuel is generally diesel. The vehicles have a very simple unsafe break system with no gears. The break is master single cylinder as like as the break of the scooter. Insufficient lighting system is provided only for the front light. Most of the vehicle do not have back side signal light or light for the passengers. Therefore, there are some risks to drive in night time or in fog. The price of each vehicle varied from 80,000.00 to 125,000.00 taka depending on the size of the vehicle and on the other facilities.

The SE vehicle owners have not got any permission from BRTA [1]. Some owners have permission from their association as in Jailkhana ghat.

Indication of accidents is found in all of the locations as also shown in Table 3. There are minor to major hazards in those accidents. The route which is not directly connected with highways have only minor hazards due to accident like in Jailkhana ghat.

**Fig. 3** Four wheel SE vehicle used for carrying sand

**Table 3:** Overall conditions and accidents

| L | Engine condition | Permission of authority | Accident | Price in thousand tk. |
|---|---|---|---|---|
| J | Used (5.3-8.5) | yes | Minor | 100-125 |
| D | Used (3.7) | nil | Minor, major | 80-100 |
| F | Used (3.7-7.7) | nil | Minor, major | 80-85 |
| O | used | nil | Minor, Major | 80-125 |

() horse power; *Price of SE vehicle in thousand taka

## 4. DISCUSSION:

The SE vehicles are now abundantly found in most of Bazaar place in sub-urban and rural area. The different aspects including social impact of the SE vehicle are widely discussed in by the journalists [1, 2]. Many technical papers discussed about the rural transportation vehicles used in Bangladesh or the causes of accidents in rural roads [3, 4]. However, they have not directly mentioned their names or characteristics. The just mention as other vehicle compared to bus, trucks or motorcycles. Although there are thousands of SE vehicles are exists in suburban and rural areas of Bangladesh and other country. The picture of SE vehicle found in other country is shown in the appendix.

### 4.1. Peoples acceptance

In past, there were varieties of transport modes in remote rural areas like boats, horse carts, cow carts, etc. The people in those days are also had to walk for long distance in absences of any vehicle. Due to different obstacles, the water communication is tremendously reduced in most of the small streams. On the other hand the culture to ride on horse or cow carts is reduced to zero due to different acceptable reasons. The present living standard, increased paralyzed road network developed by the different organization and the absence of the previous transportation mode have created a vacuum in rural transportation. This vacuum is rapidly filled by the local made SE vehicles. Those are named as Nosimon, Korimon, Alam Sadu or Votvoty (as called in north Bengal). Now it is almost impossible to exclude them practically from the transportation. The people have been accepted them in most of their route.

### 4.2. Probable long term hazards

There are some hazards in future which are now in dark. The SE vehicle creates noise and vibration, which are harmful to both long time riding drivers and passengers. The vehicles are very noisy with noise level of a single SE vehicle ranged between 84 to 76 db measure at 5m and 10m distances. The sound pressure of a single SE vehicle is in the range of average street traffic or can be compared with that of a heavy truck [5, 6]; however more SE vehicle can produce more pressure.

### 4.3. Probable accidents

It is reported that the buses and trucks are involved in 71% of all major fatal road accidents. Compared to Buses and Trucks, Babi taxis and Tempos are involved only in 10 cases [5]. The hazard from any accident of a SE vehicle would be minor to major as different reasons as observed. The reasons caused by the SE vehicle itself are discussed in the section 4.4.

## 5. CONCLUSIONS:

The results show

(i) There are three types of SE vehicles according to passenger carrying capacity, optional hood and length as indicted in Figures 1, 2 &3;

(ii) Most of the SE vehicles have old or used engine with poor body fabrication and have speed limit between 20 to 40 km/hr with maximum speed of 50 km/hr;

(iii) The vehicles are very noisy with noise level of 84 to 76 db measure at 5m and 10m distance from the SE vehicle during the study period; and,

(iv) The fare ranged between 1.5 to 2.5 tk/km is seems to be reasonable to the user when there is no other alternatives than by foot to travel in to those routes. It is also observed that various opportunities and interventions for alleviating the problems caused by these vehicles are discussed with particular reference to both existing and future context. Considering environmental, economical and sociological impact on transportation mode in and around Khulna City, shallow engine driven vehicles can’t be ignored from roadways. The importance of Nosimon, Korimon etc. can’t be ignored at totally as they are most easily used in the rural and sub-urban roadways for carrying goods and passengers for short distances. Therefore, it is an Urgent need to improve mechanically these vehicle for safe and sound service while especially are used for carrying passengers.

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# URBAN HEAT ISLAND (UHI) DRIFT IN RAJSHAHI METROPOLITAN CITY

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**ABSTRACT**

Rajshahi Metropolitan City is being raised to high due to rural-urban migration and high population growth rate where migration is a result of the ‘pull factors’ of urban settlements-such as perceived job opportunities, and better infrastructure and housing-in addition to 'push factors' from rural areas such as shortage of land and declining returns from agriculture. The process of urbanization in Rajshahi Metropolitan City is being done through a much unplanned manner when the city growth alters the urban fabric by man-made asphalt roads and tar roofs and other features substituting forest growth. These surfaces absorb rather than reflect the sun’s heat, causing surface temperatures and overall ambient temperatures to rise in compare to its rural surroundings, resulting the city as an Urban Heat Island (UHI). The study clarified the detailed temporal and spatial patterns of urban heat islands in Rajshahi Metropolitan City where METOS (Metropolitan Environmental Temperature Observation System) was used and installed meteorological equipments on the rooftop of twelve buildings in the city comprising its rural surroundings as meteorological data acquisition stations from July 01 to August 01, 2010. Analyzing the horizontal and vertical temperatures recorded in this stations, UHI indices of $2^0$-$3^0$C has been found in Rajshahi Metropolitan City. Finally relevant mitigation measures to get rid of the UHI effects in the city is recommended with the subsequent conclusion.

***Keywords:*** *UHI index, settlement, infrastructures, energy use, cooled roof*

## 1. INTRODUCTION

A UHI is a metropolitan area which is significantly warmer than its surrounding rural areas. Heat islands of cities located in the mid latitudes usually are strongest in the summer or winter seasons. In tropical climates, the dry season may favor large heat island magnitudes. The temperature difference usually is larger at night than during the daytime and larger in winter than in summer, and is most apparent when winds are weak. The main cause of the urban heat island is modification of the land surface by urban development; waste heat generated by energy usage is a secondary contributor. Since we have covered most of the land surface of Rajshahi city with concrete and asphalt pavements, the city has become an oven with millions of people in it. Annual mean temperatures in central Rajshahi have increased 2-3 degrees Celsius for the last 50 years, which is around five times as fast as that of global warming. In summer, although daily minimum temperatures might be highest in central Rajshahi as a typical heat island pattern, daily maximum temperatures often appears in the southwestern residential area of Rajshahi Metropolitan City. We settled twelve monitoring station called METOS in Rajshahi Metropolitan area since July, 2010 with own finance. Only collected temperature data were acquired and analyzed. Here we show some results of acquired data analysis in the last summer season.

## 2. SIGNIFICANCE

UHIs have the latent to directly influence the health and welfare of the urbanites. Compared to rural areas, cities experience higher rates of heat-related illness and death. The heat island effect is one factor among several that can raise summertime temperatures to levels that pose a threat to public health. The nighttime effect of UHIs can be particularly harmful during a heat wave, as it deprives urban residents of the cool relief found in rural areas during the night. Furthermore, the poor air quality that results from this increased energy usage can affect our health, aggravating asthma and other respiratory illnesses. People in Dhaka, especially the poor, suffer from various acute respiratory diseases during summer. In 1995, a heat wave in Chicago illustrated why excessive temperature and heat islands are of concern. This episode of unusually hot weather resulted in the deaths of over 700 people.

Another consequence of urban heat islands is the increased energy required for air conditioning and refrigeration in cities that are in comparatively hot climates. The Heat Island Group, a research and advocacy organization that works to educate the public and policymakers about the heat island effect, estimates that the city of Los Angeles spends about $100 million per year in extra energy costs to offset its heat island effect. Urban heat islands also can impact local weather, altering local wind patterns, spurring the development of clouds and fog, increasing the number of lightning strikes, and influencing the rates of precipitation as we are experiencing now in Dhaka. Sometimes it also affects growth of the trees. Using satellite images, researchers discovered that plants take more time to grow in UHIs than the rural areas.

## 3. METHODOLOGY

### 3.1 Horizontal distribution change of daily temperature

There are two parts to this study. The first part is data collection system and secondly collected data adjustments analysis. The study has been used METOS (Metropolitan Environmental Temperature Observation System) to clarify the detailed temporal and spatial patterns of Urban Heat Island (UHI) in Rajshahi City.  Meteorological equipments were installed on the rooftop of 12 buildings as meteorological data acquisition stations from July 13 to September 9, 2010. There are 12 stations (Table-1) which are installed at Rural and Urban area among the City Corporation area to show clearly the horizontal distribution change of daily temperature. Table-1 evaluates the Meteorological Data Acquirement Station with global position.

### 3.2 Field data collection

For vertical data collection twelve stations were setup over the Rajshahi City among the dwellers. A data collection sheet has been provided among them. Temperature data was collected daily four times as Before Sun rise, Noon, After Sun set and Mid Night. Here at the Map the YELLOW point has indicated Suburban Station (SS) and BLUE point indicate Urban Station (US) [Figure-3].

### 3.3 Vertical temperature profiles

For acquisition of vertical temperature profile and surface temperature by different land cover 4 high-rise buildings (Table-3.2) were selected and air temperature in each of 10 feet height was recorded at 5pm to 8pm in an interval of 1 hour.

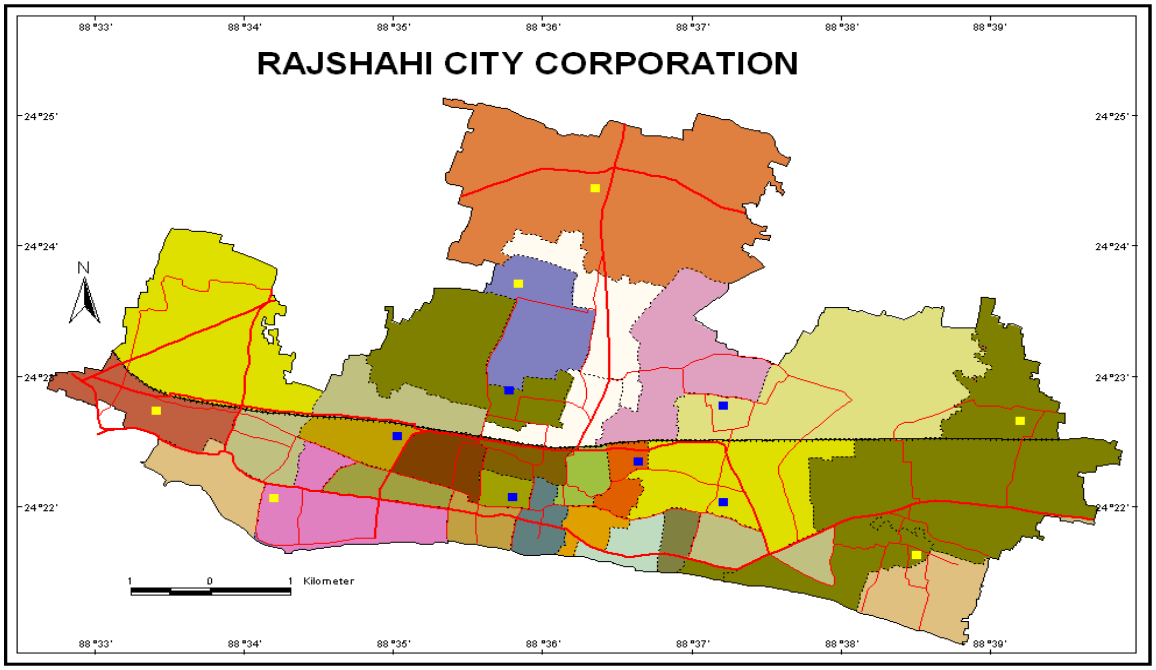


Figure 3: Twelve METOS station in Rajshahi City Corporation area
(YELLOW: Suburban station & BLUE: Urban station)

Table-3.2: Meteorological Data Acquisition Stations to determine vertical temperature profile in Rajshahi City.

| **Station No.** | **Date of Observation** | **Local Address** | **Global Position** | |
|---|---|---|---|---|
| | | | Latitude (N) | Longitude (E) |
| **13** | July27, 2010 | View Point, Binodpur | 24$^0$21’49.80” | 88$^0$38’30.30” |
| **17/ 14** | July 28, 2010 | CNB Point, Lokhipur | 24$^0$21’30.00” | 88$^0$35’25.50” |
| **18/15** | July 29, 2010 | Islamic hospital, Nowdapara | 24$^0$21’40.30” | 88$^0$42’30.40” |
| **19/16** | July 30, 2010 | Zero point, Shaheb Bazar | 24$^0$22’70.30” | 88$^0$36’15.20” |

**3.4 Temperature data from Bangladesh meteorological department (BMD)**

An assessment of annual mean, maximum and minimum temperature of Rajshahi using weather station data operated by Bangladesh Meteorological Department (BMD) shows continuous warming of the region since 1964.

**3.5 Remote sensing (RS)**

An application of Remote Sensing (RS) to specify the selected station globally which make it easy to plot In Google map. It makes work easy to identify the difference of surface temperature between urban infrastructures (buildings, roads) and vegetation area. It acquits the distribution of surface temperature of the materials, easily and instantly.

### 3.6 Statistical procedure and error reducing approach

The dataset for climate change analysis was collected from the data archives of Bangladesh Meteorological Department (BMD). The data that were analyzed were temperature for Rajshahi station of BMD.

In order to verify whether significant changes have taken place in various stations and in the areas surrounding them in the various parts of the study area, a multivariate regression analysis was carried out on a panel dataset, where time (in years) and stations provided the dimensions of the panel. Each observation in the dataset was the average monthly data for maximum and minimum temperature for up to year 2009 from the year of establishment of respective stations. The stations provided the other dimensions for the dataset to complete the panel. The main purpose of the regression analysis was to answer,

i. Whether there has been any significant change in temperature in this region,
ii. Whether there were significant differences across stations in the way temperature have changed and,
iii. Whether there were differences in the rates of changes in temperature across different months of the year.

## 4. RESULT & DISCUSSION

### 4.1 Assessment of temperature fluctuations

Assessing meteorological data of 45 years (1964-2009), collected from the Rajshahi Stations of Bangladesh Meteorological Department (BMD) and analyzed using the regression model developed by Islam and Neelim (2010), the average maximum and average minimum temperature from January to December has been determined (Fig-7).

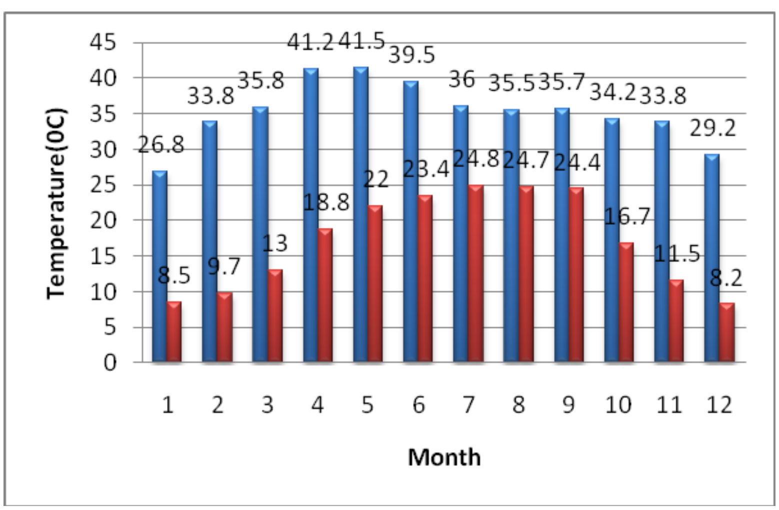


Figure 6: Average maxi and average min temperature from January to December

### 4.2 Climate line for Rajshahi city at last 45 years

Using the data collected from the Rajshahi Station of Bangladesh Meteorological Department (BMD), a climate line has been determined by calculating the Maximum temperature for years from 1964 to 2009.

Furthermore, two summer time climate lines for the city have been determined by calculating the average Maximum and minimum temperature ($^{0}$C) respectively for 45 years from 1964 to 2009.

Therefore the Climate line for summer time (April to May) average Maximum and Minimum temperature are 21.9 $^{0}$C and 20.8 $^{0}$C respectively.

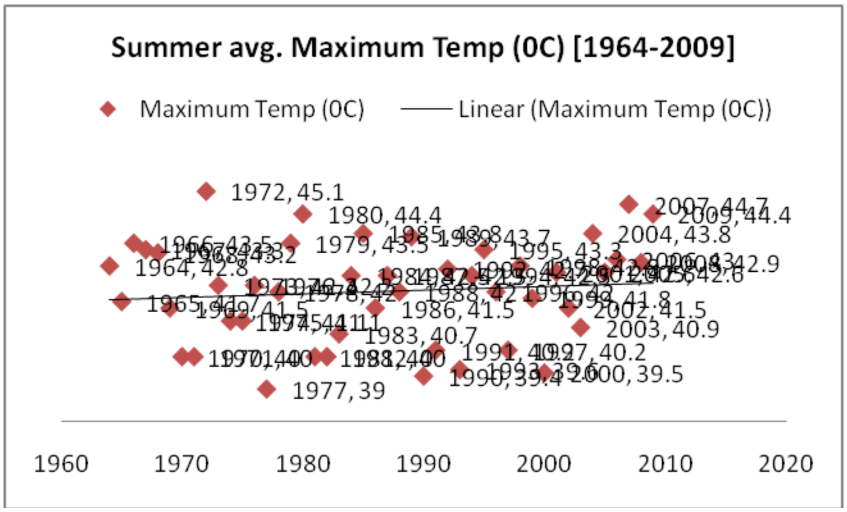


Figure 7: Climate line for Summer time (April to May) avg. Maximum Temperature (0C) During 1964 to 2009.

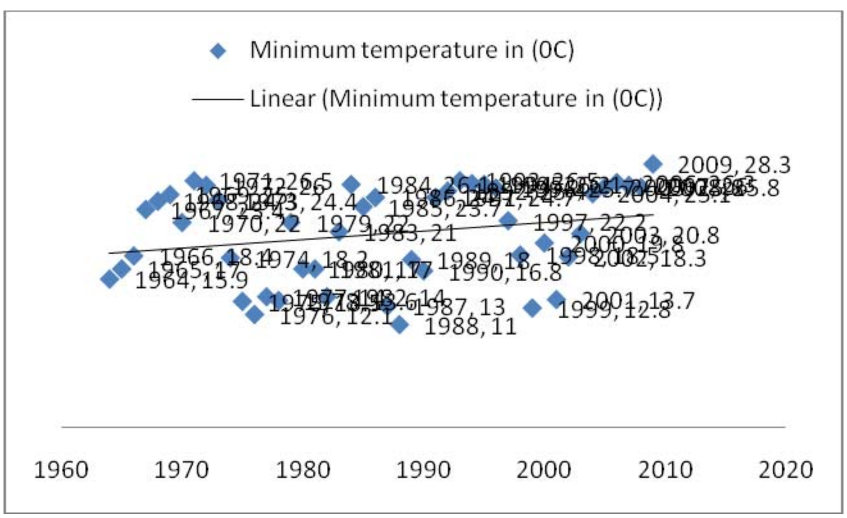


Figure 8: Climate line for Summer time (April to May) avg. Minimum Temperature (0C) During 1964 to 2009.

### 4.3 Temperature Deviation from climate line of Rajshahi city at last 45 years

Then yearly temperature deviations from that climate line have been determined and presented as graphically.

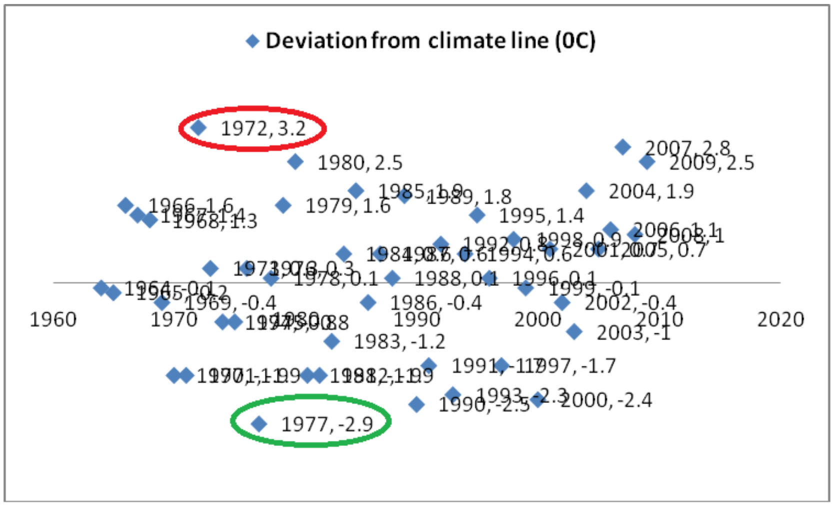


Figure 9: Warmest Year and Coolest Year due to temperature deviation ($^{0}$C) from climate line (41.9 $^{0}$C) during summer time (April to May) Average Maximum temperature.

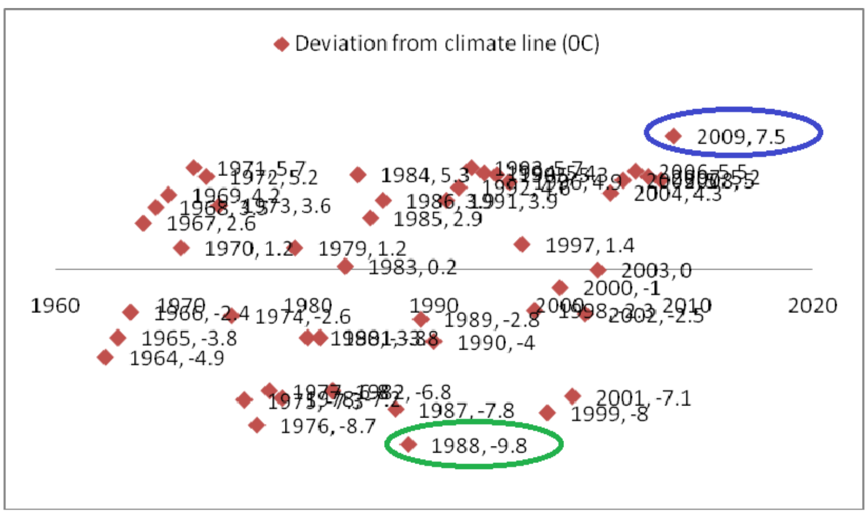


Figure 10: Warmest Year and Coolest Year due to temperature deviation ($^{0}$C) from climate line (20.8 $^{0}$C) during summer time (April to May) Average Minimum temperature.

### 4.4 Results of fixed points observation

Topographically Rajshahi City is in flat-plain region and situated on the bank of the Padma River. But the city is in the hottest climatic sub-zone (Western Sub-zone) of Bangladesh. Moreover, the rate of urbanization in Rajshahi City is being raised to high due to rural-urban migration and high population growth rate. Migration is a result of the 'pull factors' of urban settlements-such as perceived job opportunities, and better infrastructure and housing-in addition to 'push factors' from rural areas such as shortage of land and declining returns from agriculture.

In this study, it is found that the Urban Heat Island (UHI) phenomena were clearly appeared in the urbanized area of Rajshahi City after sunset which was kept through the midnight. This is because of the greater potential heat capacity of urban area than sub-urban area. In urban areas, heat is absorbed by the urban surfaces in the daytime and is released after sunset.

Since because of sky view factor and air pollution of urbanized areas, it is found a little or zero Urban Heat Island Intensity (UHII) in the daytime for both the cities. But the nocturnal UHII was more.

### 4.5 Determination of UHII

Figure-12, shows the average maximum Urban Heat Island Intensity (UHII) of 12 stations in Rajshahi City. The study has determined the maximum UHII is 2.5 $^0$C at station RS-7 and minimum UHII is 1.1 $^0$C at station RS-5 in Rajshahi City at the midnight on July 29, 2010 at 12:00 am. It is important to mention that station RS-5 located at Urban area and station RS-5 located at Suburban area. In my study RS-2, RS-3, RS-6, RS-7, RS-8 and RS-11 stations are situated in Urban area & RS-1, RS-4, RS-5, RS-9, RS-10 and RS-12 are in Suburban area. Here in graph it is easy to identify that the Urban Stations are show higher index then the suburban station.

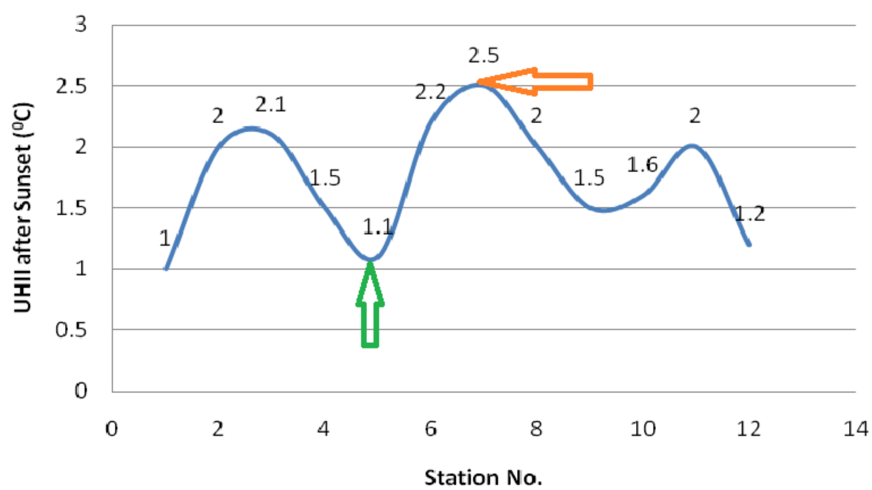


Figure 11: Average maximum UHII of 12 stations in Rajshahi city

## 5. DISCUSSION

The data collection of temperature has been conducted within a time interval from July 13 to September 9, 2010 which was considered as summer season. Many of climate change studies in Bangladesh (e.g. RCC, IPCC) has considered April, May and June as summer. However, this study conceives that consideration of Mid-June-Mid-August as summer season may help to avoid the effects of rainfall variable on temperature. For instance, the temperature of April has got some influence of March temperature (Rashid; 1991). Again, up to the Mid-June, the monsoon induced rainfalls always have an influence on summer temperature.

However, the assessment of horizontal distribution change of temperature data and the vertical temperature profile reveals Rajshahi City as an Urban Heat Island.

Therefore the Climate line for Summer time (April to May) average Maximum and Minimum temperature are 41.9 $^{0}$C and 20.8 $^{0}$C respectively.

It is therefore this study find out the Warmest Year and Coolest Year due to temperature deviation ($^{0}$C) from climate line (41.9 $^{0}$C) during summer time (April to May) Average Maximum temperature and also determination of Warmest Year and Coolest Year due to temperature deviation ($^{0}$C) from climate line (20.8 $^{0}$C) during summer time (April to May) Average Minimum temperature.

The study shows a maximum of 2.5$^{0}$C Urban Heat Island Intensity (UHII) has been found. And find the horizontal and vertical temperature profile for various station in Rajshahi. Finally it is determined the Cooler and Hot spots and mapping.

## 6. LIMITATIONS & CONCLUTION

Luckily, since we know what causes the urban heat island effect, we can control it to a significant extent. The fact is green trees and only trees can help us. Yes, to escape the heat island effects, cities need a lot more vegetation and a lot fewer dark and hard surfaces. But the inconvenient truth is that some of our wise guys are plotting to cut down hundreds of trees. But there must be something that we can do to ameliorate the existing condition. We cannot be apathetic any more regarding the apocalyptic effects of climate change. Our governments should also contemplate this matter seriously and more Environmental Engineers and urban planners are needed to attempt the situation.

In this study we used Hydrometer & Room Thermometer with required modified figure. However in this study are going to make a concern about the UHI effects in the Rajshahi City. There is no doubt about that the high rate of urbanization threats the city for rising as an Urban Heat Island. Many problems already have beset our adored Rashahi City. Let's not contradict the situation and make it worse.

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# CLIMATE CHANGE PATTERN IN SYLHET CITY, BANGLADESH

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## ABSTRACT

Until recently, Sylhet City was known as the “green city” of Bangladesh due to its presence of green trees and hilly areas. Currently the city is known for its business boom; being one of the richest cities in Bangladesh, with new investments of hotels, shopping malls and luxury housing estates, brought mainly by expatriates living all over the world. METO (Metropolitan Environmental Temperature Observation) system was used to clarify the detailed temporal and spatial patterns of Urban Heat Island (UHI) in Sylhet City and meteorological equipments were installed on the rooftop of twelve buildings in the city comprising its rural surroundings as meteorological data acquisition stations from June to August, 2010. Analyzing the horizontal and vertical temperatures recorded in these stations, UHI indices of $1^0$-$3^0$C has been found for the City. The high-rise infrastructures and widespread asphalt roads comprises a wide range of dry and dark surfaces which absorbs rather than reflects more sunlight during day time and radiate heat after sunset resulting the temperature to rise. During the night, the warmer area has been appeared in the highly urbanized centers of the city in compare to its rural surroundings. Obviously, unplanned urbanization is the major cause of UHI in Sylhet City. The impact of UHI on energy use and public health was also highlighted. Finally the paper suggests some guidelines to mitigate the UHI effects in the city.

***Keywords:*** *UHI index, temperature, unplanned urbanization, energy use, green building*

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## 1. INTRODUCTION

The urban heat island phenomenon was first discovered in the early 1800s in London. As urban areas develop, changes occur in their landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape [Climate Change Cell (CCC). (2009a)].So far, most of the Urban Heat Island (UHI) phenomena have been detected in high and mid-latitude mega cities of the northern hemisphere. But many of the cities of developing countries are also associated with the effects of Urban Heat Island (UHI) where the urbanization is in progress. This study selected Sylhet City, being urbanized with an alarming rate for one of the richest cities in Bangladesh, with new investments of hotels, shopping malls and luxury housing estates, brought mainly by expatriates living all over the world. The study aims to explain, first, the relationship between land-use changes and surface temperature to show clearly the horizontal and vertical distribution changes of daily temperature which are being altered with urbanization in Sylhet City.

## 2. METHODOLOGY

### 2.1 Horizontal Distribution Change of Daily Temperature

The study has been used METO (Metropolitan Environmental Temperature Observation) system to clarify the detailed temporal and spatial patterns of Urban Heat Island (UHI) in Sylhet City. Meteorological equipments were installed on the rooftop of 12 buildings as meteorological data acquisition stations from June to August, 2010. These 12 stations were installed in and out of Sylhet City to show clearly the horizontal distribution change of daily temperature. Temperature data was collected daily at 6 am, 12 pm, 6 pm and 12 am from June to August, 2010 in each of the stations.

### 2.2 Vertical Temperature Profile

For acquisition of vertical temperature profile and surface temperature by different land cover 8 high-rise buildings (Station 13 to Station 20) were selected and air temperature in each of 10 feet height was recorded at 5pm to 8pm in an interval of 1 hour.

### 2.3 Annual Mean, Maximum and Minimum Temperature

An assessment of annual mean, maximum and minimum temperature of Sylhet using weather station data operated by Bangladesh Meteorological Department (BMD) and Climate Change Cell (CCC) shows continuous warming of the region since 1961.

### 2.4 Application of Global Information System (GIS) and Remote Sensing (RS)

The difference of surface temperature between urban infrastructures (buildings, roads) and vegetation area was determined using GIS and RS. A thermo-graphic camera system can remotely measure the surface temperature of the materials through infrared radiation. It acquits the distribution of surface temperature of the materials, easily and instantly.

## 3. RESULT

### 3.1 Sylhet Climate

Temperature, rainfall, wind pattern and solar radiation mainly characterize the climate systems and determine the seasons. Brammer (2002) classified Bangladesh into four distinct climatic seasons. These are: (1) Pre-monsoon (March to May) with high temperatures and evaporation rates (2) Monsoon (June to September) with high intensity of rainfall occurrence (3) Post-monsoon (October to November) characterized as hot and humid period with decreasing rainfall (4) Dry or winter season (December to February) portrayed as the coolest, driest and sunniest period of the year. The climate of Sylhet is tropical monsoon with a predominantly hot and humid summer and a relatively cool winter. The city is within the monsoon climatic zone, with annual average highest temperatures of 31°C in June-August and average lowest temperature of 10°C in January (Tawhidul-2010). Rashid (1991) provides detail descriptions about the pattern of climate variables of Bangladesh and characterizes the Sylhet climate as milder summer, heavy rainfall and cloudy cool winter.

### 3.2 Assessment of Temperature Fluctuations

Assessing meteorological data of 50 years (1960-2009), collected from the Sylhet Station of Bangladesh Meteorological Department (BMD) and Climate Change Cell (CCC), the average maximum and average minimum temperature from January to December has been determined (Figure -3.1).Furthermore, a climate line has been determined by calculating the mean temperature for 50 years from 1960 to 2009. Then yearly temperature deviations from that climate line have been determined.

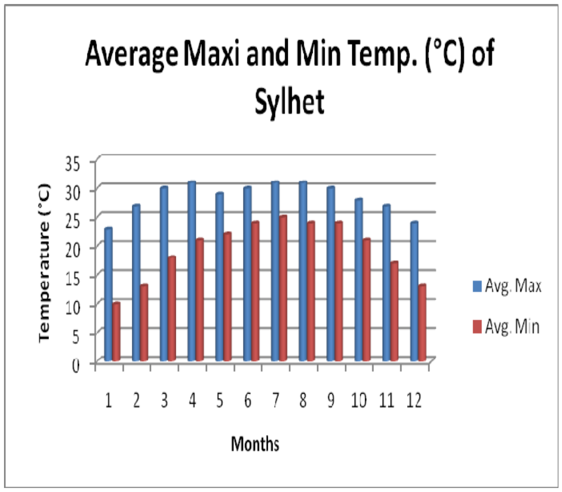


**Figure 3.1: Average maxi and average min temperature from January to December**

**Table 3.1: Average maximum and minimum temperature fluctuations from 1960 to 2009**

| **Season** | **Fluctuations** | **Climate Line ($^0$C)** | **Warmest Year (deviation from climate line) ($^0$C)** | **Coolest Year (deviation from climate line) ($^0$C)** |
|---|---|---|---|---|
| **Winter Average Maximum (December. to January)** | Increase | 25.78 | 1997 (+1.97) | 1964 (-1.08) |
| **Winter Average Minimum (December. to January)** | Increase | 13.32 | 2002 (+1.38) | 1962 (-1.27) |
| **Summer Average Maximum (April to May)** | No Change | 30.98 | 1960 (+3.27) | 1977 (-3.23) |
| **Winter Average Minimum (April to May)** | Slight increase | 22.14 | 1979 (+1.11) | 1986 (-1.89) |

However, International Panel on Climate Change (IPCC) states in their Third (2001) and Fourth Assessment (2007) Reports that by 2030, a $0.7^0$C temperature rise in monsoon season and a $1.3^0$C rise in the winter season might take place in this region.

### 3.3 Results of Fixed Points Observation

Heat islands occur on the surface and in the atmosphere. On a hot, sunny summer day, the sun can heat dry, exposed urban surfaces, such as roofs and pavement, hotter than the air while shaded or moist surfaces—often in more rural surroundings—remain close to air temperatures. Surface urban heat islands are typically present day and night, but tend to be strongest during the day when the sun is shining. In contrast, atmospheric urban heat islands are often weak during the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban infrastructure. In this study METO (Metropolitan Environmental Temperature Observation) system was used and meteorological equipments were installed on the rooftop of twelve buildings in the city (urbanized area) comprising its rural surroundings (suburban area) as meteorological data acquisition stations from June to August, 2010. Station-01 to Station-05 is located in sub-urban area and Station-06 to Station-12 is located in the centre of build-up, urbanized area. It is found that the Urban Heat Island (UHI) phenomena was clearly appeared in the urbanized area after sunset and kept through the night. Because the potential heat capacity in build-up area is larger than sub-urban, and heat from the building materials would be released through the night. Also a little or zero Urban Heat Island Intensity (UHII) was found in the daytime. The diurnal UHII was $0.3^0$C at 17:30 pm, because of lower solar radiation of Station -10 than Station-01 by sky view factor and air pollution. The nocturnal UHII was more than $2.5^0$C in the midnight. The maximum of UHII was $2.5^0$C. The daily extremes, $3.1^0$C appeared between Station-01 and Station-11 on July 14, 2010 at 12:00 am.

Figure 3.2 illustrates the average maximum temperature of 12 stations at different period of a day. However, Figure 3.3 shows the temperature profile of 12 stations on July 28, 2010 (summer) after sunset. Figure 3.4 shows the Urban Heat Island Intensity (UHII) of fine day between Station-01 and Station-11 in July, 2010.

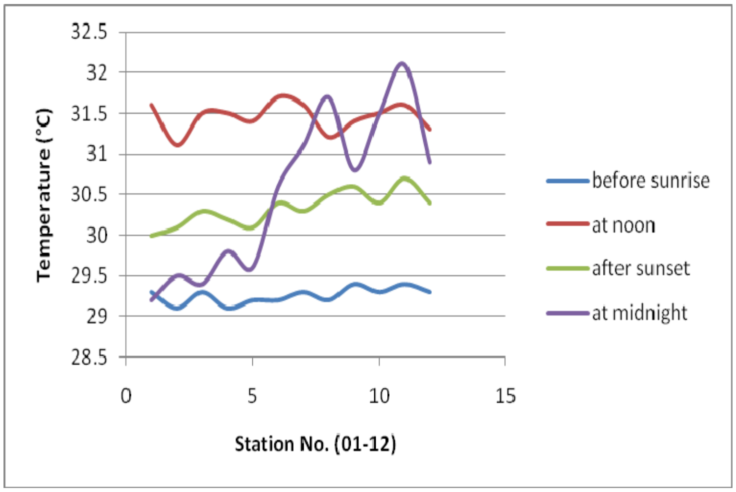


**Figure 3.2: Average maximum temperature of 12 stations at different periods of a day**

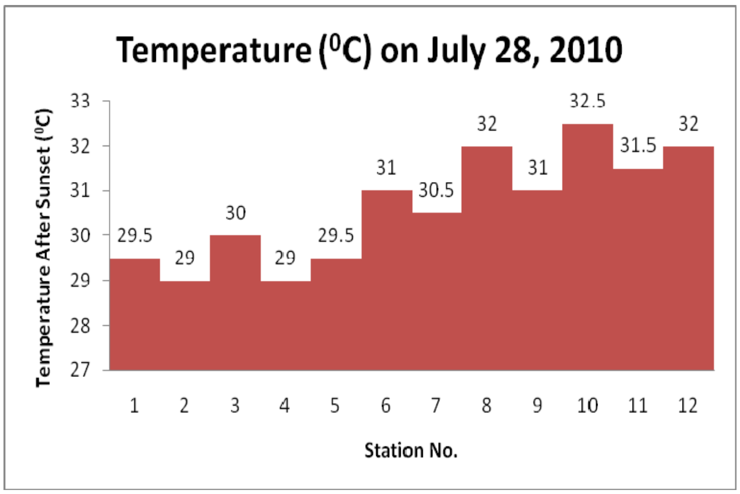


**Figure 3.3: Temperature profile of 12 stations on July 28, 2010 (summer) after sunset**

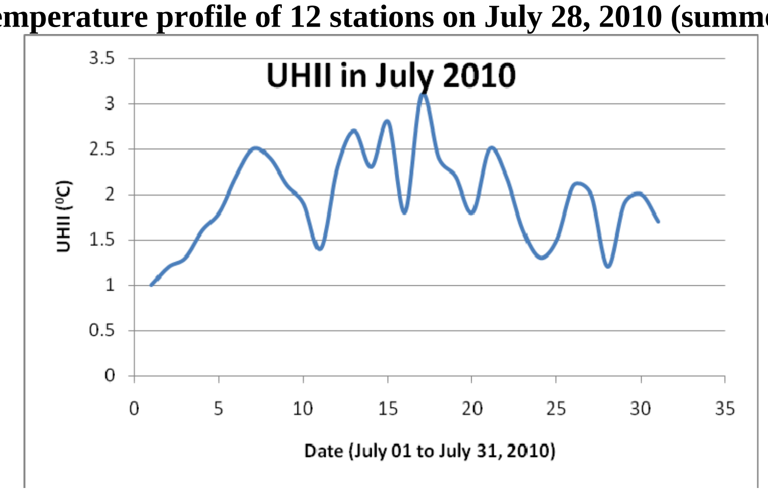


**Figure 3.4: Urban Heat Island Intensity (UHII) between Station-01 and Station-11 in July, 2010 after sunset.**

Thus, it is very interesting that UHII of Sylhet appears larger at night than in the day and the daily maximum of UHII was around $3.0^0$C, diurnal temperature in city center are not so much different from suburban by sky view factor and air pollution.

### 3.5 Thermo Graphic Observations

With process of urbanization, the city growth alters the urban fabric by man-made asphalt roads and tar roofs and other features substituting forest growth. These surfaces absorb-rather than reflect- the sun’s heat, causing surface temperatures and overall ambient temperatures to rise, resulting the Sylhet City as an Urban Heat Island. Thermal images detected by thermo-graphic camera according to different types of surface materials shown in Figure-3.7. The surface temperature of roads, buildings were more than $35^0$C. Especially, the surface temperature of the roofs was more than $40^0$C. Otherwise, vegetations were around $28^0$C. 2 buildings, painted with brown and white were observed and it was found the surface temperature of these two was $33^0$C (brown) and $31^0$C (white). The reason why the surface temperature of 2 buildings were different was that the albedo of white paint is higher than brown.

## 4. DISCUSSION

The study reveals that that the development of the Sylhet City is growing at an alarming rate without adequate planning. New skyscrapers are being built up all over the city. Moreover, the asphalt roads are also being elongated and expanded with the increase in population and development pattern. Hence, the city comprises a wide range of dry and dark surfaces which absorb rather than reflect more sunlight, resulting in an Urban Heat Island.

## 5. CONCLUSION

Whoever has experienced the sweltering summer days of Sylhet City will agree that average temperature of the City has increased over the decades. The scorching heat during daytime and hot, see thing nights coupled with load shedding are the bane of the city dweller's life. And it is the unique feature of the urban climate known as Urban Heat Island (UHI) Effect why the temperature is so high in Sylhet. Approximately half of the world’s population currently lives in cities, and this value is expected to increase to 61% by 2030 (U.S. Environmental Protection Agency -2009). The high rate of urbanization, in this regards, means that increasing numbers of people will be exposed to impacts resulting from heat islands in the future. Most policymakers and environmental activists concerned with the threat of global warming urge two strategies to combat it; cutting the use of fossil fuels and planting trees, which sequester carbon dioxide in their wood. The planting of trees in cities does both of these, and is far more effective than planting trees in forests.

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# A COMPARATIVE STUDY OF EXISTING NOISE POLLUTION BETWEEN DHAKA AND SYLHET CITY

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## ABSTRACT

Noise is not an element of environment; rather it is the abused form of sound. When sound goes up the acceptable limit, then it is termed as noise. This research work is aimed to reveal and make a comparison of the existing noise pollution of Dhaka and Sylhet City on the basis of a small scale questionnaire survey. Dhaka, the capital of Bangladesh is a densely populated and largest city of Bangladesh and Sylhet is the fourth largest city. A small scale questionnaire survey is performed on both cities dwellers. From the study, the dreadful scenario of noise pollution is drawn. From the study, it is found that all residential areas have noise level above the maximum permissible limit set by Department of Environment (DOE). Even it reaches as much as higher value like 80 dB in Sylhet and 77 dB in Dhaka, where DOE acceptable limit for residential area is 50 dB during day time. In commercial area of Sylhet, highest 87 dB is observed during evening as well as in the morning the maximum value obtained as 86 dB in Dhaka. Among the industrial areas, Tejgaon in Dhaka is more likely to be noise polluted, it shows exceeding the limit of DOE along the day. Bus station is observed to have $L_{A\,eq}$ of 87 dB in Sylhet and 86 dB in Dhaka. The noise level at kamalapur railway station is highest and obviously irritating for residents of adjacent area. Construction sites are a nuisance in residential areas specifically brick crushing, cast-in-situ piling and power generators deteriorates the environmental stipulation. Science noise have significant health effects so, it is the right time to take necessary steps for controlling noise pollution.

**Key Words:** Environment, dreadful scenario, permissible limit, questionnaire survey, noise level.

## 1. INTRODUCTION

Noise pollution is a serious and neglected issue in Dhaka, and throughout Bangladesh. It is time for NGOs, the media, and the Government of Bangladesh to work together to reduce the problem, and increase the quality of life in this country [2]. We are responsible for generating sounds more than we persist. From that point, the issue of 'noise pollution' comes into being. The word Noise comes from the Latin word 'Nausea' which is referred to 'Sea sickness' [1].

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Noise is having a variety of harmful effect over the society. Noise pollution can cause annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects [3]. Noise can have a detrimental effect on animals. Noise pollution is measured in decibels (dB). Noise is recognized as a controllable pollutant that can yield to abatement technology.

Noise produces direct and cumulative adverse effects that impair health and that degrade residential, social, working, and learning environments with corresponding real (economic) and intangible (well-being) losses. It interferes with sleep, concentration, communication, and recreation [5]. Noise pollution is greatly felt in big cities and emergent towns. In Bangladesh, its capital Dhaka is one of the megacities which are until expanding and Sylhet is a fast growing city. These two cities are chosen for noise pollution study. Dhaka, having a very convenient geographic position, attract people to stay there as permanent resident and now suffers being over-populated. It is having two parts; namely, Old Dhaka and New Dhaka. The narrow roads(especially in older part), high rise buildings, heavy traffic loads in each of the roads and streets, presence of industries in residential areas, lack of pure residential areas make the capital unhealthy and endlessly turning it to a dome of all possible type of pollution. The Sylhet carries each criteria of a rising city. The city is expanding all around. New roads are be constructed, new apartment houses, schools and colleges, shopping malls are seen to be build and are the signs of increasing population. The number of vehicle are getting larger with time, crowd is now an obvious scenario of the city. Half of the residents in the Bangladeshi capital Dhaka will be losing their hearing capacity by 30 decibels in the next 20 years, if immediate steps are not taken to control noise pollution here [6].

## 2. OBJECTIVES OF THE STUDY

The study aims at not only to determine noise level but also to make a comparison within the cities through which the research are conducted. Briefly the aims are to determination the noise level of sampling points in different three period of times during working hours (8am to 8pm), make a comparison of the received results between Dhaka and Sylhet city as well as identify dominating noisy area for both of the cities.

## 3. METHODOLOGY

For this study, noise levels of different public places, Government and private properties of Dhaka and Sylhet city were monitored. This includes – Residential Area, Commercial area, Industrial area, Bus station, Rail Station, Launch terminal, Power Station (Sylhet) and Building Construction site.

All the measurements were made manually on ‘A weighting’ scale and the sound level meter (NL-04) was switched to fast response position. During each half an hour interval, sound level has been measured for ten minutes. The average values of these measurements have been recorded as the sound level of the corresponding location at a specific time. The integrating sound level meter NL-04 allows not only conventional sound pressure level measurement, but also in-corporate processing functions which make it possible to determine: equivalent continuous sound pressure level $L_{Eq}$, sound exposure level $L_E$, percentile sound pressure level $L_X$, maximum sound pressure level $L_{max}$ and all the measurement is done in decibel (dB) units.

### 3.1. Sampling points

The sampling points are selected on the basis of importance of the area, traffic volume and the quantity of people can be subjected to direct noise pollution. The name of the sampling points of this study are a) residential areas such as Basabo, Dhanmondi, Gandaria, Gulshan, Mohammadpur of Dhaka and Amberkhana housing estate, Paira, Raja Deuri, Tilagar ,Topoban, Uposhohor of Sylhet, b) Commercial Area**s** such as Banani, Bangla Motor, Chawk Bazar, Mohakhali, Motijheel of Dhaka and Amberkhana, Bandor Bazar, Stadium ,Uposhahar, Zindabazar of Sylhet, c) Industrial Areas like as Postogola, Tejgaon in Dhaka and Khadim nagar in Sylhet, d) Bus Station i.e. Mohakhali Bus Stand, Saidabad Bus Terminal, Shyamoli Mohammadpur Bus Terminal in Dhaka and Kadamtali Bus Terminal, Kumargaon Bus Stand in Sylhet, e) Railway Station as for example Kamalapur Railway station of Dhaka and Kadamtali Railway Station of Sylhet and f) Construction Sites from several suitable local over Dhaka and Sylhet city.

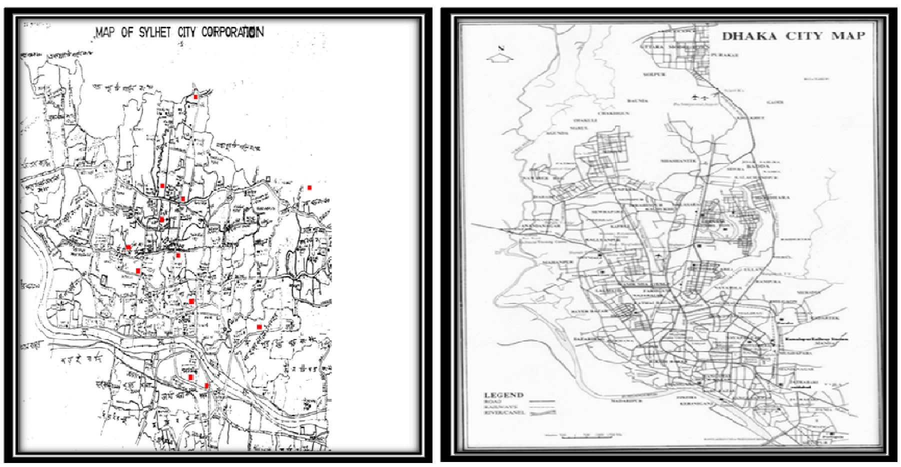


Fig 1: Map of Sylhet and Dhaka City showing sampling points locations.

### 3.2. Sampling freuency

Noise level is measured in each of the sampling location in working days during a)8 am to 10 am at morning, b) 1pm to 3 pm at noon and c) 6 pm to 8pm at evening. It is considered that the selected interval will represent a scenario of whole day noise level that people are to be exposed.

### 4. RESULTS AND DISCUSSION

All the data are tabulated in the separate tables for Residential Area, Commercial area, Industrial area, Bus station, Rail Station, Launch terminal, and Building Construction site from Dhaka and Sylhet. Table-1 shows the existing noise level of different residential areas of Dhaka and Sylhet city, from where it is cleared that all the values are exceeded the standard level set by the Department of Environment (DOE), Bangladesh. Generally at the time period of 1-3pm is the time for people to take rest at home but at that time the maximum noise level become more than double of the standard value (103dB) in both cities and it would be mentioned that all the data are collected from both cities are more or less similar.

Table 1: Comparison of Noise Level in Dhaka and Sylhet Residential Area.

| | Dhaka | | | Sylhet | | | Standard Set by DOE |
|---|---|---|---|---|---|---|---|
| Maximum Level of | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | |
| $L_{A\,Eq}$ (dB) | 76 | 76 | 77 | 74 | 78 | 80 | 50 |
| $L_{np}$ (dB) | 87 | 88 | 94 | 86 | 91 | 94 | 50 |
| $L_{A\,max}$ (dB) | 101 | 103 | 108 | 103 | 105 | 106 | 50 |

Table 2 shows the noise level of commercial areas from where it is found that average equivalent level of noise exceed standard level not only that $l_{np}$ at 6-8pm in case of sylhet, reach up to 116dB which may cause permanent loss of hearing, change of pulse rate as well as vomiting for the human being who are exposed in these areas [3]. In contrast, Dhaka shows much higher noise level at whole day long for all categories of noise. At morning and evening noise level is largest (over 100dB) in both of the cities. Whereas DOE set maximum acceptable sound level for commercial area as 70 dB, the violation of rule is visible but no law is enforced against this violation.

Table 2: Comparison of Noise Level in Dhaka and Sylhet Commercial Area.

| | Dhaka | | | Sylhet | | | Standard Set by DOE |
|---|---|---|---|---|---|---|---|
| Maximum Level of | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | |
| $L_{A\,Eq}$ | 86 | 85 | 84 | 81 | 84 | 87 | 70 |
| $L_{np}$ | 104 | 94 | 99 | 91 | 92 | 116 | 70 |
| $L_{A\,max}$ | 102 | 104 | 108 | 104 | 107 | 107 | 70 |

In the following table 3 industrial zones of both Dhaka and Sylhet city produce average level of 50dB noise specifically in Dhaka at 6-8pm but maximum level reaches at 107dB which is also alarming threat. From the tabulated data a difference in noise level of industrial areas at morning can be recognized. Industrial areas in Dhaka are most noisy all the day as each of the noise parameter is higher than that of Sylhet. Acceptable Noise level in industrial area is 75 dB, Dhaka remains far above the noise level and Khadim Nagar is just to cross it. all the three periods of time within 8am-8pm at the morning creation of noise in Dhaka is much higher than that of Sylhet (88dB and 77dB respectively) but both the cities have more than 100dB of $L_{A\,max}$ and Sylhet is highest in this case.

Table 3: Comparison of Noise Level in Dhaka and Sylhet Industrial Area.

| | Dhaka | | | Sylhet (Khadim nagar) | | | Standard Set by DOE |
|---|---|---|---|---|---|---|---|
| Maximum Level of | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | |
| $L_{A\ Eq}$ | 88 | 89 | 50 | 77 | 78 | 89 | 75 |
| $L_{np}$ | 97 | 98 | 94 | 75 | 85 | 88 | 75 |
| $L_{A\ max}$ | 102 | 104 | 107 | 99 | 103 | 107 | 75 |

From the table 4 which is shown below, it can be said that comparatively the bus stations of Dhaka are noisier than sylhet. Though value shows lower values of noise level at morning but from afternoon it rises up and remains high for rest of the time.

Table 4: Comparison of Noise Level in Dhaka and Sylhet Bus Station Area.

| | Dhaka | | | Sylhet | | | Standard Set by DOE |
|---|---|---|---|---|---|---|---|
| Maximum Level of | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | |
| $L_{A\ Eq}$ | 79 | 86 | 50 | 87 | 81 | 80 | 70 |
| $L_{np}$ | 90 | 94 | 89 | 95 | 90 | 92 | 70 |
| $L_{A\ max}$ | 107 | 106 | 106 | 109 | 106 | 107 | 70 |

There is no acceptable limit set for Bus stations, if it is considered as commercial area, the noise level should be limit within 70 dB. There are some residential hotels suited at or near by the bus stations in both cities so extra precautions are required for external or internal constructions of those hotels to support comfortable rest for the client.

Table 5: Comparison of Noise Level in Dhaka and Sylhet Railway Station Area.

| | Dhaka | | | Sylhet | | | Standard Set by DOE |
|---|---|---|---|---|---|---|---|
| Maximum Level of | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | 8 am-10 am | 1 pm – 3pm | 6 pm -8 pm | |
| $L_{A\ Eq}$ | 92 | 79 | 82 | 83 | 84 | 80 | 70 |
| $L_{np}$ | 91 | 91 | 93 | 93 | 90 | 90 | 70 |
| $L_{A\ max}$ | 115 | 92 | 103 | 108 | 105 | 104 | 70 |

In case of table 5 it is a little bit complex task to draw comparison. The values are close to one another.
Comparing values, Kamalapur Railway Station can be said noisy at morning than that of Sylhet. At afternoon Sylhet becomes noisy. At evening Kamalapur Railway Station becomes noisy again. It is expected that at railway yards the noise will be high, but it is also not expected there will be residential buildings closed to Rail station.

Table 6: Noise Level in Dhaka and Sylhet at Construction Sites.

| Noise at Construction Site(combined Dhaka and Sylhet) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crushing | Drilling | Framing | Hammering | Iron bar straighteni | Mixing aggregate | Mosaic Smootheni | Piling | Tiles Cutting |
| $L_{A\ Eq}$ | 90 | 88 | 96 | 95 | 99 | 92 | 100 | 84 | 99 |
| $L_{A\ max}$ | 102 | 90 | 101 | 99 | 96 | 100 | 107 | 94 | 105 |

Table 6 shows above, the recorded level of noise at or near the construction sites in both Dhaka and Sylhet city. Usually any Construction site is a noisy one. It generates high noise and dissipates it to surrounding area. The neighbors suffer from starting to finishing work of a building. By the available noise meter the effects of impact of noise (i.e. all type of Hammering etc.) cannot be recorded perfectly. So the noise level of relevant field carries some error. Each noise level is raised above 80 dB and maximum up to 107 dB.

## 6. CONCLUSION

The study reveals the existing noise pollution status of Dhaka and Sylhet city. The whole scenario is clamorous. There is hardly any place in both cities which can be suited to DOE acceptable limit. From the study results it is found that residential areas of both of the Sylhet and Dhaka are under the threat of noise pollution. The highest $L_{A\ eq}$ at Dhanmondi is 76 dB (A) in Dhaka and 74 dB (A) at Tilagar in Sylhet in morning from 8 am to 10 am. Even the lowest value found from this study is much greater than permissible limit set by DOE. In Dhaka, $L_{A\ max}$ reaches up to 103 dB in two sampling points during experiment which reaches up to 105 dB in Sylhet. Moreover Sylhet is observed to have 4 values of $L_{A\ max}$ above 100 dB. Sylhet is showing a tendency of having less frequency in lower ranges and greater frequency in higher ranges in comparison to Dhaka. In Dhaka, the highest value of $L_{A\ max}$ is 108 dB and exceeds above 100 dB for twice during experiment. Sylhet is smaller in aspect of area than Dhaka, but shows high level of noise than Dhaka in many sampling points. In Sylhet, Bondor Bazar is dominantly noisy business area having all of the parameter highest. No dominating silent area is found in Sylhet as well. In Sylhet 4 sampling points are observed to exceed even 100 dB. The maximum noise, $L_{A\ max}$ is observed 107 dB at Stadium area and second highest in Amberkhana (106 dB) as well as Bondor and Uposhohor both have 105 dB during experiment. During the experiment maximum noise level, $L_{A\ max}$ reaches above 100 dB at all sampling locations in both of the cities. In industrial zone, maximum noise level, $L_{A\ max}$ in Dhaka is 103 dB at Tejgaon and 107 at Postogola. In Sylhet, maximum noise level, $L_{A\ max}$ is observed as 107 dB in Khadimnagar, only industrial zone located in the periphery of Sylhet. In Dhaka, the maximum noise level, $L_{A\ max}$ from motorized vehicles is observed to be 107 dB at Saidabad bus terminal, 104 dB at Mohakhali and 100 dB at Shyamoli during this time period. In Sylhet, the maximum noise level $L_{A\ max}$ from motorized vehicles reaches up to 109 dB at Kumargaon bus station and at Kadamtali it is observed 105 dB. There is no acceptable limit set for bus station. If it is considered as commercial area, its maximum acceptable limit should be 75 dB. From the chart of bus station, it can be observed that the energy equivalent continuous noise level, $L_{A\ eq}$ is ranges from 76 dB in Dhaka and Sylhet during experiment. The maximum noise level ranges from 103 dB in Dhaka and Sylhet is observed. Almost un-noticeable difference is observed in all noise parameters of Sadarghat BIWTA terminal in different time period. It has a high $L_{A\,eq}$ value ranges above 80 dB. At all point commonly each noise parameter is highest. $L_{A\,eq}$, $L_{np}$ each exhibits a threshold of existing noise pollution. It is observed that most of the maximum high noise level occurs during evening time from 6 pm to 8 pm. This time may be termed as vulnerable for noise pollution. There is the number of people who felt annoyed by the noise.

In brief, the results of the study show that the level of noise pollution in both Dhaka and Sylhet city far exceeds the acceptable limits set by the Department of Environment, Bangladesh. Every densely populated area is posing noise induced health hazard and a large number of people are living at risk. Vital measure should be taken to control the level of noise pollution in Dhaka and Sylhet city.

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# IMPLEMENTATION OF RWH IN SYLHET CITY TO SAVE POWER & COST

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## ABSTRACT

As the world population increases, the demand increases for quality drinking water. The harvesting of rainwater has the potential to assist in alleviating pressures on current water supplies and storm water drainage systems. In most urban areas, population is increasing rapidly and the issue of supplying adequate water to meet societal needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by decision-makers. This study investigates the water saving reliability and financial performance of a potential RWH system for buildings in Sylhet city, the north-eastern divisional city of Bangladesh.

**Key Words:** rain water harvesting, rainfall, geological Log, electricity, cost etc.

## 1. INTRODUCTION

The world environment is changing day by day and various environmental problems are arising .Bangladesh is a developing country and suffering also, as the population is increasing in a rapid growth. Water supply and energy source has become a headache to all. Sylhet a north-eastern divisional city of Bangladesh is now facing fresh water scarcity, only one third of the demanded water is supplied by the authority to the city dwellers. The ground water table in this area is declining. The depth of potable water table has already been crossed 500ft and so far in some areas. A major portion of the total power supply is now been using to collect water from this depth. Indiscriminate use of ground water without proper recharge is also promoting desertification in some areas. So with respect to the physical alternatives to fulfill sustainable management of ground water and minimizing power use, an analysis has been done to develop a power & cost saving rain water harvesting system for Sylhet city.

## 2. STUDY AREA

Sylhet is one of the rapidly growing metropolitan areas, located in the northeast region of Bangladesh and situated at 24.85° latitude and 91.80° longitudes. Sylhet was changed to a city corporation from a municipal board in 2001and in 2002 the city was administrated by the Sylhet City Corporation (SCC) and finally was granted metropolitan city status in 31st March

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2009(4).SCC occupies a total area of 26.5 sq. km with a population of around 0.5 million. Population density is 17,479/km$^2$.

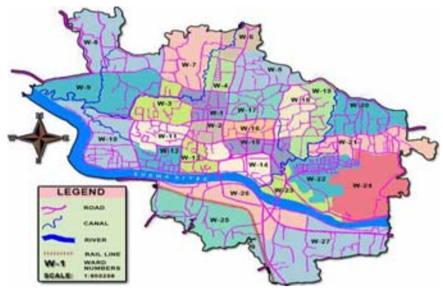

Fig01: Sylhet City Corporation.

## 3. METHODOLOGY

The rooftops being built significantly with hard material, large quantities of rainwater runoff and loss due to evaporation and percolation are very minimal. Thus, rooftop rain water harvesting can be put to good use by storing rooftop water on (a) roof itself (b) ground level (c) below the ground, by using storage devices like masonry tanks / Ferro cement tanks / plastic or metal containers. The collection of rainwater can be done by as following -

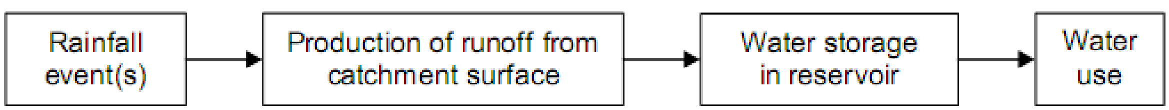


Fig02: Flowchart demonstrating fundamental rainwater harvesting Processes.

For a low cost rain water harvesting system for Sylhet city only the staircase of the buildings with existing water storage tank is taken under the consideration. To demonstrate the study the analyses were done with the collected data as -

**A. Calculation of collected water in a month from staircase catchment:**

The minimum area A (m$^2$), required for the collection of rain water for N no. of people supplied with q lpcd of water can be derived from the following equation:

$$A = (0.365*q*N)/(CI) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where C=runoff coefficient

I=rainfall intensity (mm)

As we worked with the staircase only we consider this area in further calculation. Usually staircase is provided to protect indoor area from rainfall and open expose to environment. We will take 100ft$^2$ areas for a typical staircase.

The amount of water received per month by a catchment may be computed as

$$V= (f*A*R)/1000 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where V=Volume of water received from catchment (m$^3$)

f=Catchment efficiency (0.75)

R=rainfall (mm)

**B. Electricity:**

Assuming 1000 liters water tank is filled in 15 minutes

The required discharge, Q=1.1 liters/s=0.001m$^3$ /s

The water horse power can be calculated from the following equation

$$p = \frac{wQH}{\eta} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,

w=9.81, Q=discharge, H=total head, $\eta$ =efficiency of the motor=0.65.

Work done by this HP, $W = Pt \ldots\ldots\ldots\ldots\ldots (4)$

Where p=power in KW and t=time in hour.

**C. Cost**:

Cost=W*unit price ………………(5)

**4. DATA COLLECTION**

Mainly three types of data were collected to complete the study-the rain fall distribution, depth of ground water table and the demand of electricity in Sylhet city. Bangladesh Meteorological Department is responsible for the rainfall distribution data. They keep all Meteorological related information. For this study Total Rainfall (mm) in Monsoon over Sylhet Division And monthly rainfall were collected from Bangladesh Meteorological Department. Ground water depth data were collected from Department of Public Health

Engineering (Aquifer Database Inventory Program, DPHE-JICA, 2010 DPHE Groundwater Circle, Dhaka) from where average depth were found as 150m and the electricity demand were collected from the power distribution company Sylhet but Specific demand for the Sylhet city was not found from them as they can not provide this.

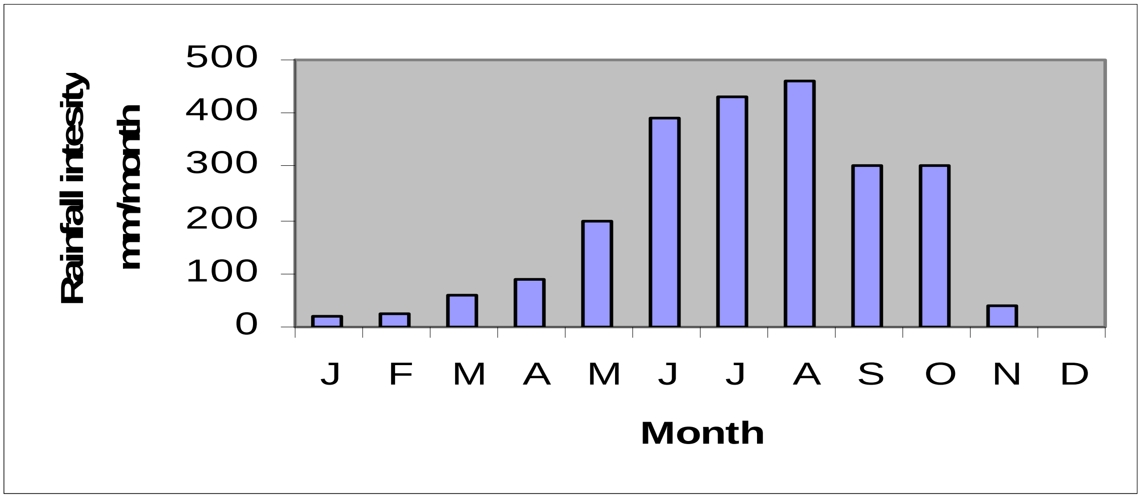


Fig03: Monthly distribution of rainfall in Bangladesh

Table 01: Monthly Normal Rainy Day in Sylhet

| stations | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sylhet** | **2** | **4** | **9** | **16** | **20** | **22** | **25** | **22** | **18** | **8** | **2** | **1** |

Table02: Geological Log Record of Sylhet

***General Information***

| | |
|---|---|
| Data Source: | GOB-5 |
| Year of Installation | 2007 |
| Total Depth Drilled (m): | 173.74 |
| Depth of Screen Centre (m): | 169.62 |

Table03: Average monthly rainfall in Sylhet

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 15.9 | 41.5 | 93.9 | 320.9 | 592.4 | 1005.3 | 771.0 | 685.3 | 469.1 | 237.8 | 29.5 | 6.5 | 4401.6 |
| inches | 0.6 | 1.6 | 3.7 | 12.6 | 23.3 | 39.6 | 30.4 | 27.0 | 18.5 | 9.4 | 1.2 | 0.3 | 173.3 |

Source:http://www.worldclimate.com/cgi-bin/data.pl?ref=N24E091+2100+4189

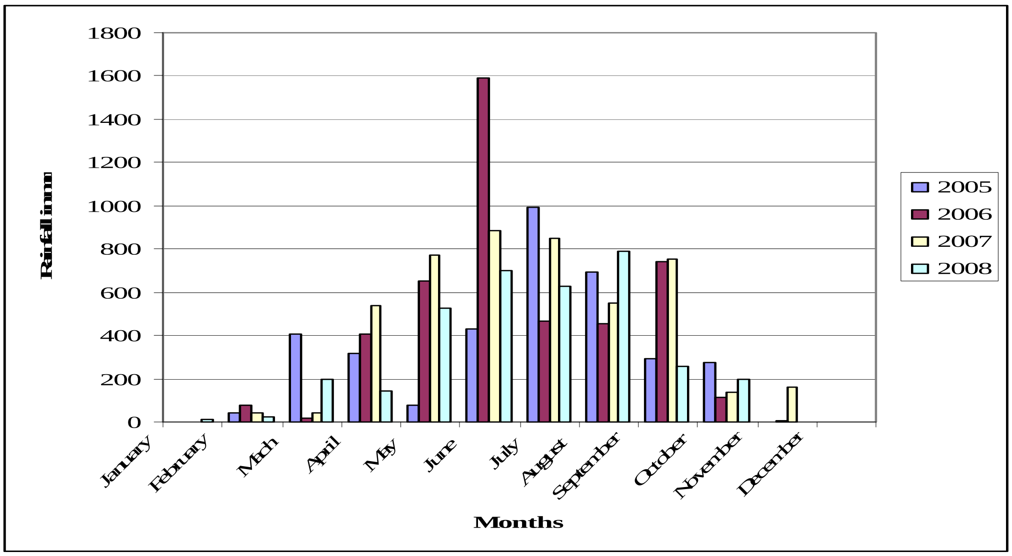


Fig04: Total Rainfall (mm) in Monsoon over Sylhet Division

## 5. RESULT

Considering 1000 domestic building in the study, the following table gives the relevant information regarding the study (one season basis)-

| Month | April | May | June | July | August | Septembe r | October | Total |
|---|---|---|---|---|---|---|---|---|
| Rainfall(mm) | 320.9 | 592.4 | 1005.3 | 771 | 685.3 | 469.1 | 237.8 | 4081 |
| Water($m^3$) | 2166.08 | 3998.7 | 6785 | 5204 | 4625 | 3166 | 1605 | 27550 |
| Electricity (kW.h) | 1383.8 | 2554.7 | 4334.9 | 3324.8 | 2954.9 | 2022.7 | 1025.4 | 17596 |
| Cost(tk) | 5396 | 9960 | 16902 | 12963 | 11522 | 7885 | 3997 | 68625 |

Unit price were taken as tk.3.9.This information revels that rain water harvesting only from the existing staircase can save a considerable amount of power supply in the monsoon. The demand of the electricity is increasing rapidly. Now a day's power scarcity has become a mess. This amount can be saved almost using existing resources.

## 6. CONCLUSION

In Bangladesh the main problems in water supply are surface water contamination, arsenic, salinity and iron problems, ground water lowering and non availability of suitable water source in hilly areas. The most potential alternative water supply option are rainwater harvesting. Rain water harvesting offers a possible source of drinking water. Many agencies, including the Water and Sewerage Authority (WASA), are studying feasibility of rainwater harvesting in Bangladesh.

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# ARSENIC CONTAMINATION OF GROUND WATER IN OUR CITIES: SCREENING OF ALL THE TUBE-WELLS IN NORTH HALISHAHAR WARD, CHITTAGONG

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***Abstract***

*National Hydro-Chemical Survey of well water in Bangladesh done in the year 1998 and 1999 found alarming rate of Arsenic contamination in our ground water. Major cities in Bangladesh like Dhaka and Chittagong were not covered by the survey, though ground water is extensively used in these two cities. To give an example, Chittagong Water & Sewerage Authority (CWASA) can supply water to only 1/3$^{rd}$ of the city dwellers. Rest of the people is depending on shallow tube-wells for their daily supply of drinking water. In 2008, under a joint research project, the Institution of Engineers Bangladesh, Chittagong Centre (IEBC) and Chittagong University of Engineering & Technology (CUET) conducted a sample survey in 41 Wards, administrative sub-divisions, of the city. Contrary to the popular belief that groundwater in Chittagong City is free from Arsenic, Arsenic was found in shallow tube-well water in 13 city Wards. Seven Wards out of these 13 Wards had Arsenic concentration exceeding Bangladesh standard limiting value of 0.05mg / litre. The situation is so grave that the screening of all the tubewells in the Arsenic affected Wards warrant our immediate attention. In the present paper, North Halishahar--a city ward is taken as the study area. This particular Ward is one of the worst affected Wards in the city where Arsenic contamination exceeding 0.05mg/litre was reported. Since CWASA is not having any water distribution network in North Halishahar, tube-wells, some of which are contaminated with Arsenic, remain the most widely used alternative source of drinking water in that area.*

*All the tube-wells in North Halishahar were tested for Arsenic concentration. A total of 426 tubewells were identified and located. Water samples from all these tubewells were tested in the field by using Wagtec Arsenic Field Test Kit. Out of a total of 426 tube-wells tested, 168 tubewells in the Ward, about 39% , were found to be contaminated with Arsenic. 18% of all these tubewells have Arsenic concentration exceeding Bangladesh standard limiting value of 0.05mg/litre. Arsenic contaminated tubewells were marked with colour paint for future reference. Contamination was found only in shallow tube-wells. Deep tubewells were found to be free from Arsenic. Amongst these contaminated 168 tube-wells, all endeavours were made to collect information on the duration of its use. Information on duration of use could be obtained for 141 tubewells only. Eighty one tube-wells amongst these 141 tubewells are in use for five or more years. Users of the tubewells which are in use for five or more years may have visible signs of*

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*Arsenic related diseases. These people are to be identified and their medical needs assessed. Immediate medical intervention in this area is necessary before it becomes too late..*

## 1. INTRODUCTION

### 1.1 Background Information

A vast majority of shallow tube-wells providing pathogens free drinking water in Bangladesh are found to be contaminated with Arsenic. These tube-wells, once lauded for saving lives by preventing or reducing the intensity of water borne diseases are now blamed for killing people by slow poisoning them with Arsenic. What was once considered a blessing is now considered a curse in disguise.

British Geological Survey (BGS) and Department of Public Health Engineering (DPHE), Bangladesh conducted a national hydro-chemical survey of well water in Bangladesh in the year 1998 and 1999. The survey found that 46% of all the tube-wells in Bangladesh, sunk to a depth of 150 meters and less in 61 districts excluding the three hill districts of Rangamati, Khagrachari and Bandarban, were contaminated with Arsenic exceeding the World Health Organization (WHO) permitted limiting value of 0.01mg/litre in drinking water. More conservatively, Bangladesh allows 0.05mg/litre of Arsenic in drinking water. If limiting value of Arsenic as accepted by Bangladesh is taken into consideration, 27 % of all shallow tube-wells in 61 plain districts of Bangladesh could be termed as contaminated with Arsenic. The corresponding figures for deep tube-wells sunk to a depth of 150 meters and above were 5% and 1% for Arsenic contamination of 0.01mg/litre and 0.05mg/litre respectively (1). Forty million people in Bangladesh are now exposed to Arsenic concentration exceeding the Bangladesh limiting value of 0.05mg/litre.

### 1.2 Scenario within the city of Chittagong

The aforementioned BGS-DPHE study did not conduct any survey within the major cities of the country including the city of Chittagong. Chittagong Water Supply & Sewerage Authority (CWASA) is responsible for supplying safe water to the city dwellers in Chittagong. So far, they have not conducted any study for investigating the Arsenic contents of shallow tube-well water within the 41 Wards, administrative sub-divisions, of the city. About 50% of the CWASA supplied water comes from the deep tube-wells located in the central part of the city and the rest 50% comes from surface water drawn from the river Halda at Mohra point. Most of the CWASA deep tube-wells have a depth varying between 80m to 168m (2). CWASA has not found Arsenic exceeding World Health Organization (WHO) limiting value of 0.01mg/litre in water from these tube-wells. NJS Consultants in their Feasibility Report for the extension of Mohra Water Treatment Plant, published in the year 2000 reported that CWASA could supply water to 44.7% of city population (3). Remaining 55.3% of the city dwellers depend on shallow tube-wells for their drinking water. Since 2000, the situation has aggravated further; CWASA could not add a drop of water to its existing generation and distribution network. It can supply water to only one third of the total estimated city population of about four million people.

## 1.3 Questions raised regarding the quality of drinking water

1.3.1 Though reports of Arsenic contamination for deep tube-wells in Bangladesh are less frequent, question remains, what is the situation in those areas of the city where CWASA does not have any shallow or deep tube-well? CWASA does not have any deep tube-well in the northern and southern part of the city. There is no documented information on Arsenic content in tube-well water used in these areas.

1.3.2 In the absence of water supply from CWASA, two third of the city dwellers depend on shallow tube-wells or privately sunk deep tube-wells as their source of drinking water. How safe is this tube well water used by the city dwellers? Is it free from Arsenic?

## 1.4 Research Initiative

To find an answer to the questions raised regarding the suitability of tube-well water for drinking purpose, the Institution of Engineers Bangladesh, Chittagong Centre (IEBC) and the Department of Civil Engineering, Chittagong University of Engineering & Technology (CUET) agreed to pool their resources for conducting a joint research programme considered very essential for ensuring the well being of the residents of Chittagong City.

Commencing in the year 2008, the IEBC- CUET research team conducted a sample survey in all the 41 Wards of Chittagong City Corporation (CCC) and published a report titled, "Arsenic Screening of Ground Water from Tube-wells Located within Chittagong City" (4).

## 1.5 Findings of the IEBC-CUET study 2008

IEBC-CUET study 2008, field-tested 401 randomly selected water samples from tube-wells distributed within the forty-one wards of the city. Out of the total samples, 282 were taken from shallow tube-wells and the rest 119 were from deep tube-wells. Sample density was one tube-well for every 0.39 sq. km of the city area. The study team did not find Arsenic above allowable limit in the water samples from the deep tube-wells. It may be mentioned here that CWASA, too, did not find Arsenic in the deep tube-wells used by them for the city water supply system. Shallow tube-well water was found to be contaminated with Arsenic in thirteen city Wards. The details of the findings are given in Table-1. The Arsenic affected city wards are further illustrated in Figure-1.

**Table- 1. Wards with Arsenic Content Exceeding WHO Standard Value (0.01mg/l)**

| Ward No. | Ward Name | Maximum Arsenic Concentration in mg/litre | Percentage of tube-wells found contaminated |
|---|---|---|---|
| 6 | East Sholashahar | 0.4-0.5 | 40% |
| 11 | South Kattali | 0.1-0.2 | 20% |
| 17 | West Bakalia | 0.3-0.4 | 40% |
| 18 | East Bakalia | 0.06-0.08 | 20% |
| 19 | South Bakalia | 0.3-0.4 | 30% |
| 24 | North Agrabad | 0.06-0.08 | 10% |
| 26 | North Halishahar | 0.4-0.5 | 20% |
| 27 | South Agrabad | 0.05 | 60% |
| 35 | Boxir Hat | 0.05 | 10% |
| 37 | North Middle Halishahar | 0.02-0.04 | 10% |
| 38 | South Middle Halishahar | 0.02-0.04 | 20% |
| 39 | South Halishahar | 0.02-0.04 | 20% |
| 40 | North Patenga | 0.02-0.04 | 10% |

Source: IEBC-CUET Joint Research Project 2008

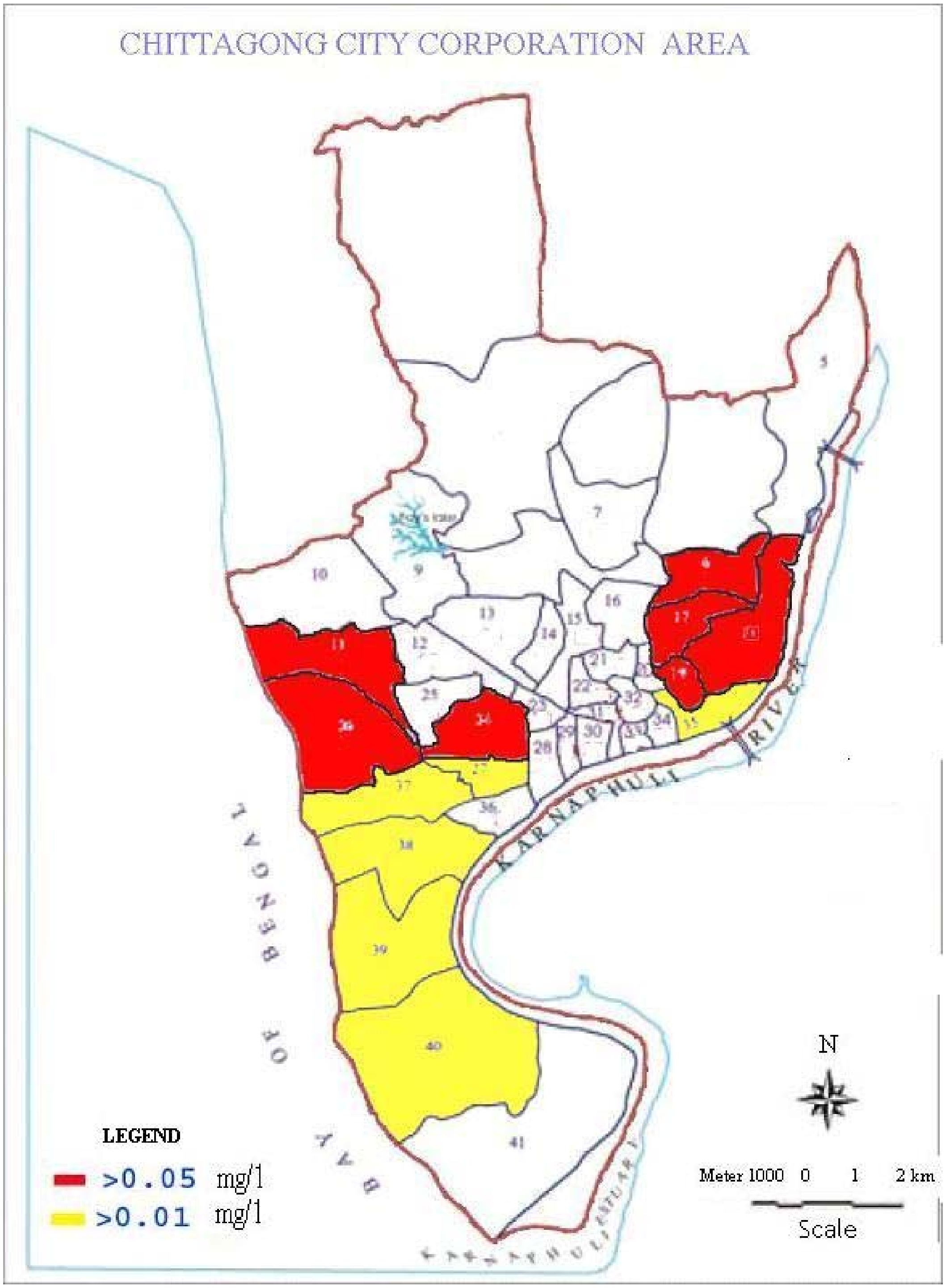


**Figure-1. City Wards Affected with Arsenic Contamination**
Source: IEBC-CUET Joint Research Project 2008

Wards, coloured red in Figure-1 above, are the worst affected areas where Arsenic concentration exceeds Bangladesh standard limiting value of 0.05mg/litre. Wards coloured yellow are areas where Arsenic concentration is above WHO limiting value 0.01mg/litre but less than Bangladesh standard limiting value of 0.05mg/litre. Some of the wards had Arsenic concentration forty to fifty times more than the WHO limiting value of 0.01mg/litre.

## 2. OBJECTIVE OF THE PRESENT STUDY

Considering the looming health hazard faced by the city dwellers, all the tube-wells within the 13 Arsenic affected city Wards are to be screened for Arsenic concentration. The present study aims at examining all the tube wells within North Halishahar, a city Ward with reported Arsenic concentration exceeding 0.05 mg/ litre. Arsenic contaminated tube-wells are to be identified and marked. The findings are to be communicated to the general public who might become a victim of Arsenic related diseases in the absence of appropriate information on the quality of ground water they are consuming. It may be mentioned here that IEBC-CUET sample survey done in the year 2008 found Arsenic concentration in the range of forty to fifty times of the WHO limiting value of 0.01mg/litre in the shallow aquifers of Ward 26, North Halishahar.

## 3. STUDY AREA

The study area comprises of ward-26: North Halishahar. The Ward is located in the central core of the city where high concentration of Arsenic was found in ground water. Location of the Ward comprising the study area is illustrated in Figure-2. According to last census held in 2001, North Halishahar had a population of 39,792. Number of households in the Ward was 7552 (5). Current population is estimated at 67,360 for North Halishahar. Corresponding number of estimated households is 13,208. Because of proximity with the Chittagong Export Processing Zones (CEPZ) and Patenga Industrial Area, once predominantly rural North Halishahar Ward is experiencing rapid population growth.

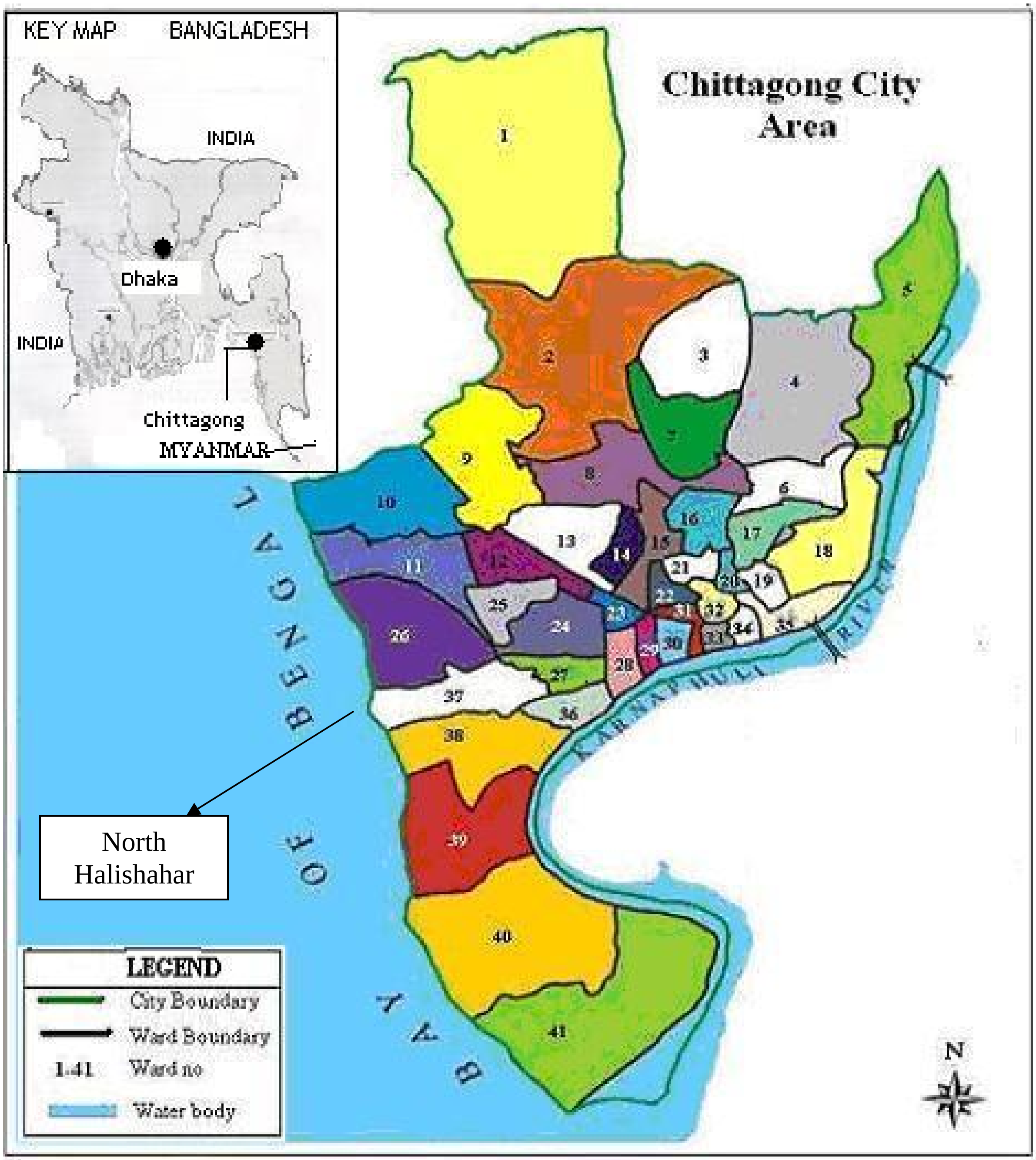


**Figure-2. Location of North Halishahar: Ward 26 within the city**

## 3.0 ALLOWABLE LEVEL OF ARSENIC IN DRINKING WATER

**Table 2. Allowable Level of Arsenic in Drinking Water**

| Country/ Agency | Allowable Arsenic concentration in mg / litre | Country/ Agency | Allowable Arsenic concentration in mg / litre |
|---|---|---|---|
| USA (2001) | 0.01 | India | 0.05 |
| Great Britain | 0.05 | Russia | 0.05 |
| Canada | 0.025 | Bangladesh (1997) | 0.05 |
| Japan (1993) | 0.01 | Srilanka | 0.05 |
| Australia (1996) | 0.007 | Zimbabwe | 0.05 |
| WHO (1980) | 0.05 | China | 0.05 |
| WHO (1993) | 0.01 | Indonesia (1990) | 0.05 |
| European Union (1998) | 0.01 | Philippines (1978) | 0.05 |
| Jordan (1991) | 0.01 | Vietnam (1989) | 0.05 |

Allowable limit of Arsenic in drinking water for Bangladesh is 0.05 mg per litre. The corresponding limiting value accepted by World Health Organization (WHO) is 0.01mg / litre. In Table-2, limiting values of Arsenic accepted by some other countries are compiled (6).

## 4. METHODOLOGY

### 5.1 Shallow & Deep Tube-Wells Defined

Local people in general consider a tube-well as shallow, when the well diameter is about 1.5 inch (about 38 mm) and the depth is less so that water from it can be extracted manually by hand pump. Tube-wells sunk in deep aquifer, having a diameter greater than 1.5 inch, depth greater than the average tube-well and when motorized pumps are used for extracting water, the tube-wells are generally termed as deep tube-well.

In Chittagong, generally, shallow tube-wells find water within a maximum depth of 150 ft. (about 46 meters). Deep tube-wells sunk in deep aquifer, on the other hand, have a varying depth of about 200 feet to 700 feet (about 60 to 215 meters). Since all the shallow tube-wells tested in the field, within the study area, were reported to be sunk within the depth of 150ft (about 46 meters), tube-wells in this study, exceeding the depth of 150ft and having a diameter above 1.5 inch, some-what arbitrarily, were considered as deep tube-wells. The earlier IEBC-CUET Report

“Arsenic screening of ground water from tube-wells located within Chittagong City” published in 2008, used the above criteria for differentiating shallow from the deep tube-wells.

In the BGS-PHE national survey in 1998 & 1999, tube-wells below the depth of 150 metres (about 492 feet) were considered as shallow tube-wells. If 150 meter is considered as the controlling criterion for shallow tube-wells than most of the tube-wells tested in this study will fall into the shallow tube-well category including most of the deep tube-wells operated by CWASA.

### 5.2 Collection of water samples

IEBC-CUET sample survey done in 2008, found 20% tube-wells in Ward-26: North Halishahar contaminated with Arsenic concentration above Bangladesh standard limiting value of 0.05mg /litre. Considering the gravity of the problem faced by the local residents, it was decided to taste water from all the tube-wells in this worst affected Ward within the city. Water samples were collected in 500 ml mineral water bottles. The empty bottles were collected, washed and dried. The bottles were washed again with the sample water before collection of the sample.

### 5.3 Field testing of water samples

The water samples were tested in the field by using Arsenic-Testing Kit. As in the earlier IEBC-CUET study, Wagtech Arsenic Test Kits were used for field-testing of water samples from the tube-wells. The findings of the field investigations are given in Table-3.

### 5.4 Arsenic Field Test Kit

Wagtech Arsenic Kit box shown in Figure-3 was used for testing of water samples in the field, collected from the shallow and deep tube-wells within the North Halishahar Ward. While using the test kit, procedures and instructions given by the manufacturers were followed.

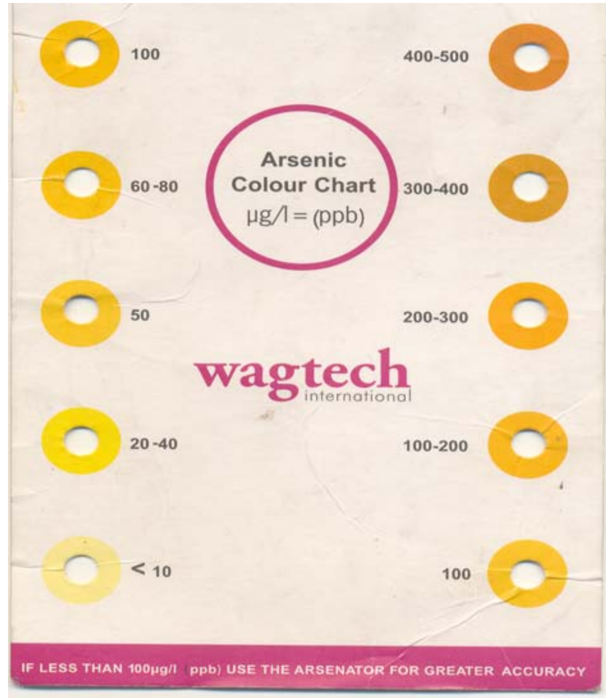


**Figure-3. Wagtech Arsenic Kit Box and Colour Chart**

## 5. FINDINGS

### 6.1 North Halishahar : Ward Number-26

The survey team tried to locate all the tubewells, both shallow and deep, in the area. A total of 426 tubeweels were identified. Water samples from all these tubewells were tested in the field by using Wagtec Arsenic Field Test Kit. The findings of the field tests are tabulated as under in Table-3:

**Table-3. Findings of Arsenic screening of all the tubewells in Ward-26: North Halishahar**

| Total number of tubewells tested | Arsenic content in water exceeding 0.05mg / litre (Bangladesh Standard) | | Arsenic content in water exceeding 0.01mg / litre (WHO Standard) | | Remark |
|---|---|---|---|---|---|
| | No.of tubewells | Percentage | No.of tubewells | Percentage | |
| 426 | 78 | 18.31 | 168 | 39.44 | The tubewells were claimed to have been sunk to a depth varying between 70 to 320 feet. |

Source: Field investigations done in May & June 2010

About 39% of all the tube-wells in this Ward are contaminated with Arsenic. Of the Arsenic contaminated tube-wells, 18.31% are having contamination above the Bangladesh standard value of 0.05 mg per litre. Quite a number of tubewells are found to be having contamination in the range of two to six times the Bangladesh limiting value of 0.05mg per litre. Affected areas of the ward are illustrated in Figure-4. Sadek Colony near railway track, Abdul Hamid Chowdhury Lane, Khondakar Bari, Barnighata Lane, Idris Commissioner Bari, Chowdhury Bari Lane, Ful Chowdhury Para, Nath Para, B-Block-Housing etc. are the worst affected areas in North Halishahar. Tubewells, sunk below the depth of 150 feet in deep aquifer and termed as deep tube-well in this report, were not found to be contaminated with Arsenic above the allowable limit.

Out of a total of 426 tube-wells, 168 tubewells in the Ward were found to be contaminated with Arsenic. Eighty one tube-wells out of these 168 contaminated tube-wells are in use for more than five years. Remaining contaminated tubewells are in use for less than five years. Majority of them, in fact, are in use for about three years. Sinking of any new tubewell in the recent past was not reported. The details of these tube-wells are given in Table-4.

Whole of the Ward is not densely populated. There are pockets of uninhabited low lying areas in the Ward. The areas found to be contaminated with Arsenic are located near khal and often gets inundated during the rainy season. Worst affected areas like Golichipa Para,Full Chowdhury Para, Nath Para, B-Block Housing etc. are low lying areas. Part of these areas remain submerged under water for a few days in every year.

The area is not covered by CWASA water supply network. For quality and safe water people are depending on tube-well. Since 39% tubwell in the area are contaminated with Arsenic, the residents are in great danger of sufferring from Arsenic related disorders. People using Arsenic contaminated water for more than five years, may have visible signs of Arsenic related disorders like skin lesions, keratosis, Melanosis etc.

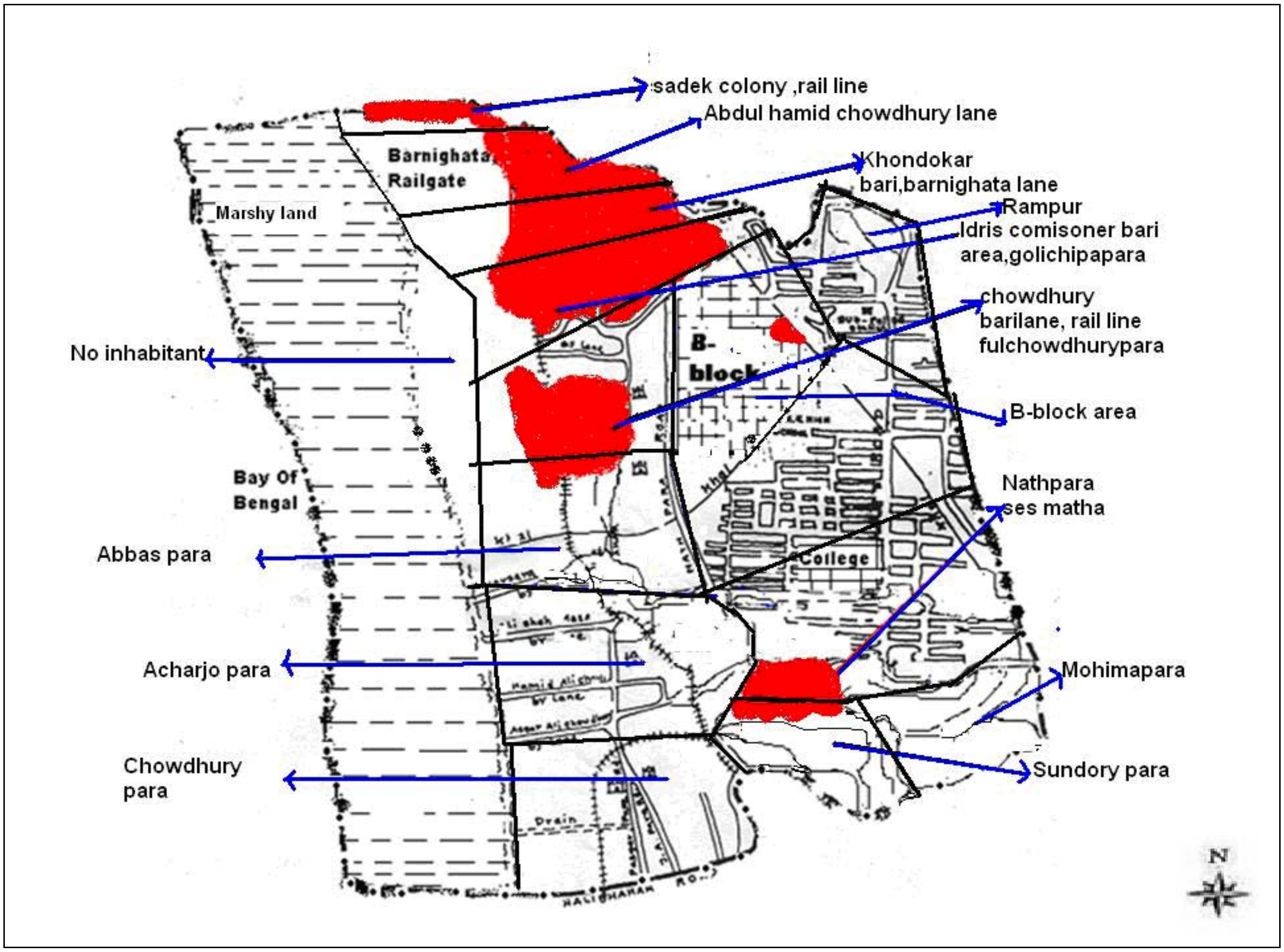


**Figure-4. Arsenic contaminated areas of Ward-26: North Halishahar.**

**Table-4. Duration of Tube-well Use (Ward-26: North Halishahar)**

| No. of Arsenic contaminated tube-wells | No. of tubewells with known years of use | No.of tubewells in use for 5 years and more | Percentage | No.of tubewells in use for one year and less | Percentage |
|---|---|---|---|---|---|
| 168 | 141 | 81 | 57. 45 | NIL | NIL |

### 6.2 Discussion on findings and recommendations

Arsenic contamination of tubewells in the North Halishahar Ward were found to be more severe than it was thought of after the IEBC-CUET sample survey in the year 2008. Thirty nine percent tube-wells in North Halishhar were found to be contaminated compared to the earlier findings of 20% in the aforementioned IEBC-CUET study.

Considering the severety of the hazard, all the tubewells in the remaining wards, identified as Arsenic affected in the IEBC-CUET study 2008, are to be screened for Arsenic content. Chittagong City Corporation (CCC), Chittagong Water & Sewerage Authority (CWASA), Chittagong Development Authority (CDA) and NGOs working in the environmental sector can arrange the necessary finance for the proposed detailed study of the remaining eleven Arsenic affected Wards.

## 4.0 LIMITATIONS OF THE PRESENT STUDY

7.01 Though testing of water samples from all the tube-wells in the North Halishahar Ward were aimed at, it is possible that some of the tubewells might have been left out of this survey. Since it is illegal to sink deep tubewells without approval from CWASA and since an hefty amount is charged by CWASA for granting that approval, some people, if not all, has a tendency to sink deep tube-wells without appropriate approval. The tubewell owners without approval, generally, avoids disclosing their identity for fear of retaliation by CWASA. A few locations of shallow tube-wells may have gone un noticed during the field survey. As a result, there is a possibility that water from all the tube-wells were not tested. However, we still feel that majority of the tubewells were tested and the percentage of tubewells left-out of the survey will be very less.

7.02 There may be seasonal variation of concentration of Arsenic in tube-well water. Water samples were collected and tested in the month of May & June only. Samples were not separated taking drought and rainy season into consideration. There may be variation in Arsenic cocentration depending on the age of the tube-well.

## 5.0 FUTURE AREAS OF RESEARCH

8.01 Now that all the tube-wells in North Halishahar are screened for Arsenic content, and the tubewells which are in use for five or more years are identified, researchers can now go for investigating the health conditions of the users who are expposed to Arsenic contaminated water for five or more years. Arsenicosis patients can now be identified and given appropriate medical help.

8.02 Most of the tube-wells in North Halishahar were found to be located near latrine. Because of close proximity of these latrines with the water source, tube-well water may get contaminated with foecal content and bacteria. The tubewell waters may be screened for bacteria and foecal content.

## 6.0 ACKNOWLEDGEMENT

The Institution of Engineers Bangladesh, Chittagong Centre (IEBC) and Chittagong University of Engineering & Technology (CUET) financed this research jointly. We gratefully acknowledge their contribution and support in initiating this research project. Two final year civil engineering students of CUET, Md.Toufiqul Islam & Md.Asfauddulla were involved in collecting and testing of water samples at site.

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# SOLID WASTE MANAGEMENT IN SUB-URBAN AREA: A CASE STUDY ON SAVAR MUNICIPALITY

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## ABSTRACT

Savar municipality has been facing rapid population growth, urbanization and industrialization. Solid waste generation had reached to the value 51, 016 kg/day on the basis of per capita waste generation 0.40 kg /day. Savar Municipal Authority is the only responsible organization for solid waste management (45% of total generated wastes) of its nine wards (17.15 km$^2$). Questionnaire survey and interview were conducted to collect primary data regarding solid waste generation and its management. GIS technique was used to define the current solid waste management practice of Savar municipality. About 80% of food wastes were calculated from the collected samples. Lack of waste bins and improper installment and lack of disposal sites were the main causes of improper solid waste management. An adequate and integrated SWM was suggested in for efficient solid waste management of Savar municipality. Waste minimization, segregation of wastes, door to door waste collection, participation of Community Based Organizations (CBOs), composting, energy generation and sanitary land filling were integrated to manage about 75% of the total generated solid wastes.

**Key Words:** Community, Disposal, Dumping, Municipality, Solid Wastes

## 1. INTRODUCTION

Rapid population growth, urbanization, industrialization and changing consumption patterns are generating amounts of solid wastes. Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services [1]. The issue of solid waste is not only because of the increasing quantities but also largely because of an inadequate management system. Waste management policy without considering integrated management plan along lack of appropriate technology is making the situation threatening to the environment and public health. Inadequate disposal of waste can contribute contamination of surface water with the spillage and ground water with the percolation of leachate. The aims of this study were to understand the present solid waste management (SWM) system and to identify possible options for efficient waste management for sub-urban areas, like, Savar municipality.

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Savar municipality has been experiencing a rapid growth of population and urbanization from the beginning of the 1990s. According to the Population Census Report (BBS 2001), population-density is about 7,435 persons per square kilometer [2]. Over the last decade, urbanization followed an upward trend for Savar municipality. The daily waste generation is projected to be 51,016 kg per day on very rough per capita basis considering 0.40 kg/capita/day. Proper management of this solid waste is now one of the prime concerns for Savar municipality. Savar municipal authority has a small number of trucks (5 trucks) and waste collecting vans (50 vans) for collecting more than 50% of generated wastes in municipality. An integrated SWM technique was highlighted in this study for the effective management of SWM of sub-urban area considering all the stakeholders, governmental or non-governmental, formal or informal, profit or non-profit oriented groups.

## 2. METHODS AND METHODOLOGY

Reconnaissance field survey was conducted to collect solid waste samples (3 kg) from different wards. Participatory questionnaire survey (120) was conducted at different wards of the study area. Explorist 200 was used to collect Global Positioning System (GPS) locations of waste bins, disposal sites and illegal dumping sites. Spatial data were generated using collected GPS locations and Google Earth software. Relevant secondary information regarding solid wastes and other relevant information: demographic and economic data were collected from relevant governmental and non-governmental institutions.

## 3. STUDY AREA

Savar municipality is located about 26 km far from the north western side of Dhaka city and the municipality is bounded by Turag on the east, Dhalashwari and Bangsi on the west and Buriganga on the south.

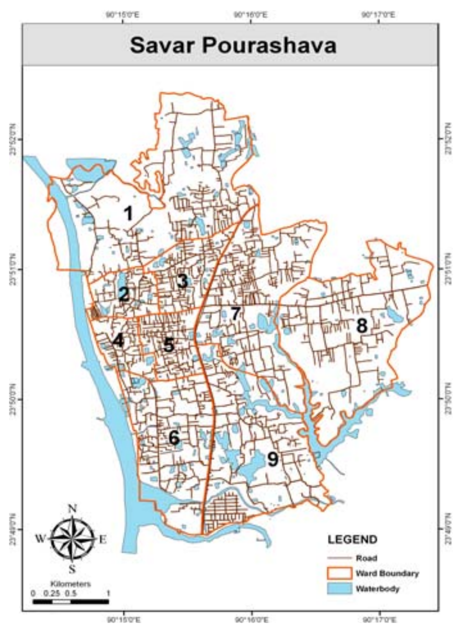


Fig 1: Savar municipality (Pourashava)

The municipality lies between 23°44' and 24°02' N latitude and 90°11' and 90°22' E longitude. Total area of Savar municipality is about 17.15 $km^2$ (Fig 1). Savar municipality consists of about 9 wards and 55 mahallas with total population about 1, 27,540 [2].

## 4. RESULTS

### 4.1. Composition of Solid Waste in Savar Municipality

Solid wastes in Savar municipality can be characterized as highly biodegradable and contain high moisture content. It was observed that, more than 90% of the total waste contains biodegradable materials, 5% of plastics and polythene, 0.5% glass and ceramics and 0.5% metals (Fig 2).

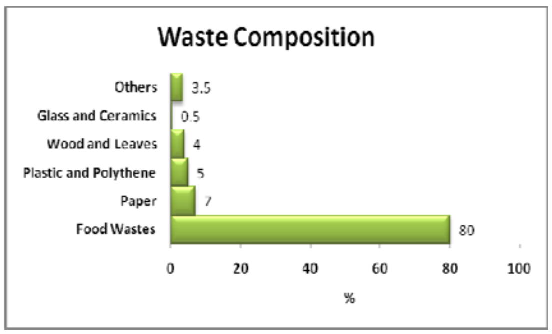


Fig 2: Solid waste composition of Savar municipality

### 4.2 Current Solid Waste Management System of Savar Municipality

Savar municipal Authority is the only responsible organization for management of generated solid wastes with its infrastructures for collection, separation and disposal of solid waste generated within the municipal area. According to the reconnaissance field visit about 40 waste bins were found within the municipality area (Fig 3).

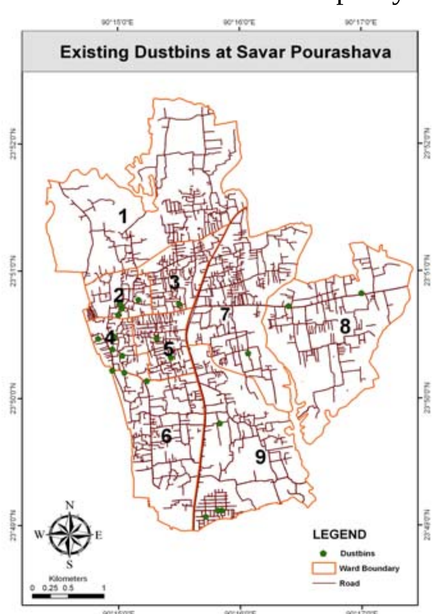


Fig 3: Existing dustbins at Savar municipality

Savar municipal conservancy department has about 147 staffs including 1 inspector, 2 supervisors and 67 cleaners. The Conservancy department has 50 vans and 5 trucks for waste management of nine wards of Savar municipality. Municipality collects waste from 40 bins and from roadside illegal dumping areas and finally dumps the wastes in several areas close to Dhaka-Aricha highway. Savar municipal authority has one official disposal site at Karno Para in Ward No 7. Beside this Savar municipality dump solid waste in Bank town (Ward 9), Ulail (Ward 6), Ganda, Near Savar bus-stand (Ward 7) and Radio colony (Ward 3) along the Dhaka-Aricha highway (Fig 4).

Waste generation rate of nine municipal wards were found irregular in manner. Amount of solid waste generation of nine several municipal wards are varying with ward waste generation rate and population (Fig 5).

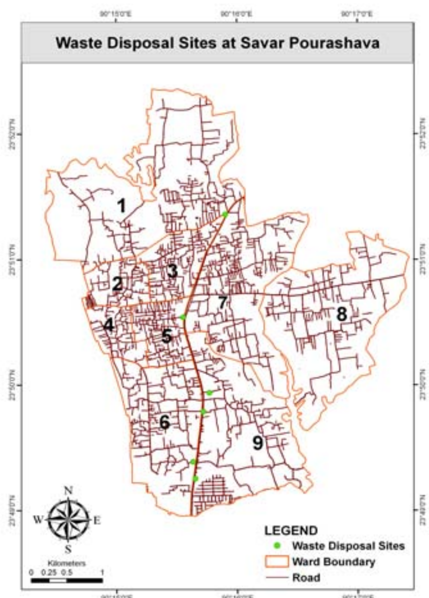


Fig 4: Waste disposal sites at Savar municipality

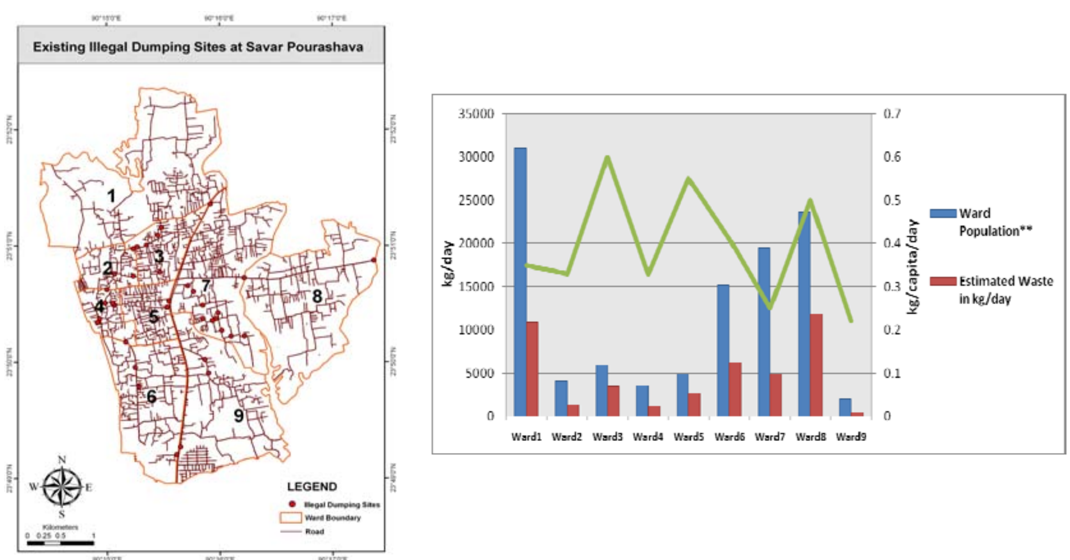


Fig 5: Ward based population and waste generation rate

Maximum solid waste was generating in Ward 8, where the population was about 23,617 and total estimated waste generation was about 11808.50 kg/day on the basis of per capita waste generation rate of 0.5 kg/cap/day. The lowest solid waste generating rate was in ward 4, where the population is 3,519 and total estimated waste generation is 1161.27 kg on the basis of per capita waste generation of 0.33 kg/cap/day (Figure 2). Most of the waste bins and illegal roadside dumping were seen in Ward 7. Illegal roadside dumping was also seen in Ward 3, 4 and 5 in Savar Municipality Area (Fig 6).

The roads of the municipality area were not wide enough to move waste collecting trucks and only vans can collect wastes from the congested area of Savar municipality. There were a few number of municipal workers were working in populated wards (Ward 3,4 and 5) due to the lack of waste bins and disposal sites and irregular waste collections household waste remains on the street for many days (Fig 7).

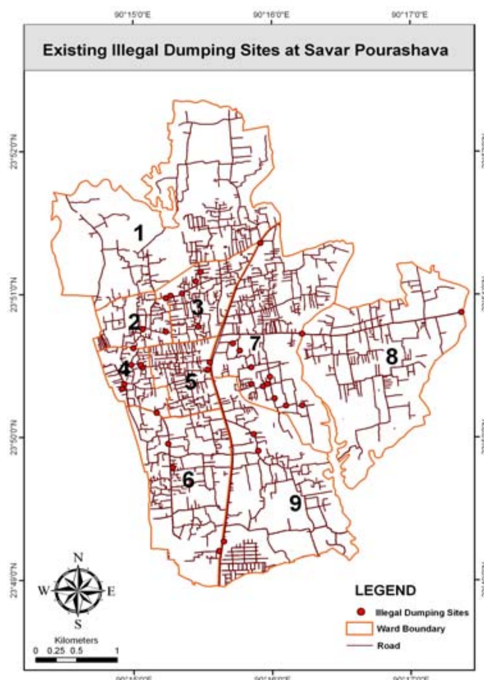


Fig 6: Illegal dumping sites at Savar municipality

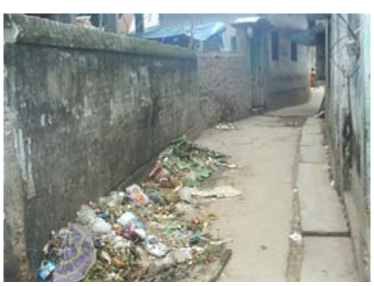

Fig 7: Road side illegal dumping

Fig 8: Illegal disposal site

Ward 1, 2, 3, 4, 8 and 9 were fully residential area and Ward 5, 6 and 7 were mixed area. Among the nine wards of Savar municipality, minimal solid waste management initiatives were seen in Ward 3 and 4. Some illegal disposal sites were seen along the Dhaka-Aricha highway (Fig 8).

**4.3 Efficient Solid Waste Management Options for Savar Municipality**

Efficient solid waste management can be attained with managing solid wastes in environmental friendly, economically cost effective and socially acceptable way. Integrated and participatory SWM practices are required for efficient SWM system in Savar municipality considering future population growth, urbanization and development. Many municipalities of Bangladesh like Savar have taken several steps to ensure efficient SWM, with the participation of Non Government Organization (NGOs) and Community Based Organizations (CBOs). Waste management hierarchy shown in Fig 9 should be followed to attain 75% efficiency in solid waste management [3].

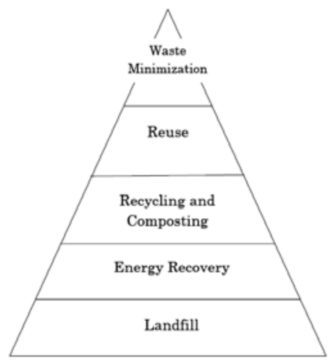


Fig 9: Waste management hierarchy

Household level waste minimization technique with a fixed bin for every household was implemented in Khulna City Corporation through CBOs and was found working effectively [4]. The household should have paid a fixed amount of money for generated solid wastes in monthly basis.

Integrated source separation, collection, transfer and disposal approach can be a better choice for congested wards of Savar municipality. Community Based Organizations (CBOs), Non Government Organizations (NGOs) and municipal authority should work together for better management of generated solid wastes in residential areas (Ward 1, 2, 3, 4, 8 and 9) of Savar municipality. In the proposed way, dwellers will separate their waste as biodegradable waste, recyclable waste and non recyclable waste. CBOs and NGOs will provide manual vans with separate compartment of different colors to collect separated waste from door to door and will transfer in a primary collection point. Primary collection point will be made in such a way that biodegradable, recyclable and non recyclable waste can be stored separately (Fig 10).

Primary collection point will place in area from where municipal waste transfer truck can collects them easily. For placing primary collection point, the Savar municipality can divided into several block on the basis of generating solid wastes from the wards. Finally, the biodegradable waste will be transferred for composting and non-recyclable wastes and some remaining biodegradable wastes will then be transferred to the sanitary landfill sites and the recyclable waste will be relocated to the recycle industries. This integrated concept can be a useful option for better management of solid wastes of Savar municipality.

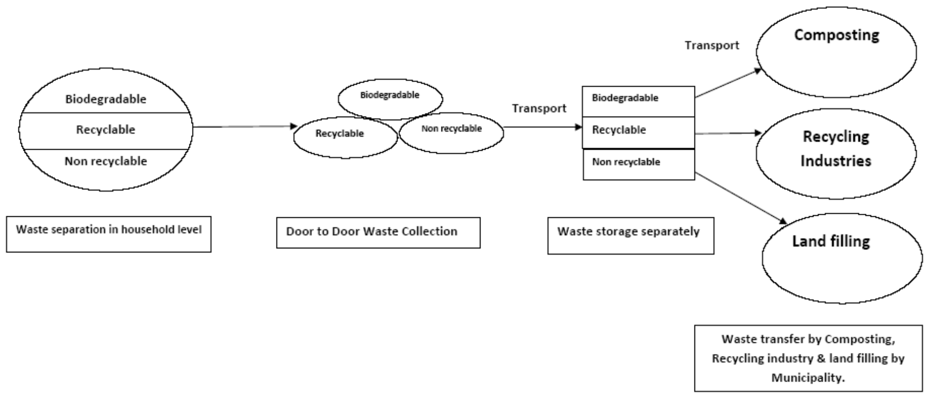


Fig 10: Proposed flow chart for effective SWM in Savar municipality

Most of the generated wastes in sub-urban area were biodegradable wastes. According to Ahsan et al. (2009), slum dwellers of KCC motivated to dispose their organic wastes in the yellow barrel provided by the CBOs and it was found that from a 200 liter barrel we can get Tk. 900-1000 [4]. This is not only beneficial for the environment but also a source of extra income with minimizing wastes. The organic portion of solid wastes in Savar municipality was found above 80%.The final product after biodegradation of organic materials can also be used as soil fertilizer. Composting can be integrated with other mentioned options for effective solid waste management of Savar municipality. Composting reduce the required area for landfill. It is environmental friendly and economically beneficial.

Daily about 51, 016 kg solid waste is generated in Savar municipality. Among this, above 80% solid waste is biodegradable. By the anaerobic digestion a huge amount of biogas can be produced. This biogas can use for electricity generation. A feasibility study on Dhaka city solid waste by Waste Concern in 2003 depicted that gas production per kg waste in the open dumping site may vary from 25 to 40 liters [5]. So energy generation from solid waste of Savar municipality will give a big economic and environmental output.

A sanitary land fill is a managed, controlled site equipped with system to reduce leachate and land fill gas migration into the surrounding environment [4]. Sanitary landfill was found an effective management option of solid wastes of Savar municipality. Sanitary landfill sites can be built in the open places of Ward 1, 8 and 9.

Better management of generated solid wastes requires integrated approach, household waste minimization ensuring reuse and recycling, integrated source separation, collection, transfer and disposal approach, biodegradation and composting, sanitary landfill, compilation of community based SWM system, incorporation of Clean Development Mechanism (such as, Energy Generation) should be incorporated in waste management strategy of Savar municipality [6]. As the area is not uniform in nature and with its population, it will not be possible to manage efficiently generated solid wastes following one or two techniques.

Considering the future demand of Savar municipality, all the possible environmental friendly and economically feasible measures should be incorporated in waste management plan of Savar municipality. The efficiency of Savar Waste Management Authority was about 45% which reflected that maximum portion of the generated solid wastes was still unmanaged. Integrating above mentioned options in a waste management framework can improve the solid waste management of the municipal area up to 75%. The other sub-urban area can also replicate these techniques into an integrated waste management framework for better management of generated solid wastes.

## 5. CONCLUSIONS

Rapid urbanization and development are responsible for increasing solid waste generation in Savar municipality. Inadequate management system, improper planning and lack of waste management infrastructure were found the main obstacles of efficient solid waste management in Savar municipality. Only 55 waste collecting vans and 5 trucks were found operating to collect wastes in nine wards of municipal area ensuring 45% management of generated solid wastes. Communal bins were not adequate in number for storing solid wastes so roadside dumping were seen frequently in crowded sites of the municipality area. Wastes remain on street for few days, creating unhealthy environment all around such as bad odor, encroachment of street and create aesthetical problems. In Savar municipality, source separation, reduce; recycle and reuse practices were absent.

For efficient SWM (75%), proper planning, adequate management skill, public awareness and community participation in SWM system is the pre-requisite. Integrated approach of Municipality Authority, CBOs and participation of private sectors is an important factor to ensure efficient SWM system in Savar municipality. Integrated source separation, collection, transfer and disposal approach should be incorporated in waste management plan for better management. Community based information system (COMMIS), Clean Development Mechanism (such as, electricity generation, biogas generation from solid wastes) should be incorporated in municipality planning for better management of generated solid wastes in sub-urban areas.

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# PLASTIC WASTE MANAGEMENT AND FEASIBILITY OF FUEL PRODUCTION- A CASE STUDY IN SYLHET

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## ABSTRACT

The accelerating rate of urbanization and economic development in Bangladesh results to a rapid increase in waste generation. Due to increase in generation, waste plastic; particularly PET bottles, plastic shopping bags and other scrap of plastic goods are becoming a major stream in solid waste, which are being littered on landscape of Bangladesh. In this paper, the research has been carried out to study the feasibility of plastic waste conversion in Sylhet, Bangladesh. The government has enforced a few numbers of policies to address this severe littering problem. These policies have been analyzed with particular references to Sylhet as a case study to find out an effective and sustainable way of plastic waste management. The analysis of the existing policies and activities of related organizations to get rid of this long term littering problem. The weakness, lacking and missing links of the existing policies can be eliminated by the chemical process of converting plastics into hydrocarbon fuel with unlimited application. The output of present study on proper plastic waste management and proposed energy production can be suggested to the concerned authorities that would assist them to take comprehensive plan.

**Key words:** Plastic waste, waste management, fuel, cost estimation, environment, recommendation, Sylhet

## 1. INTRODUCTION

Sylhet , the north eastern divisional city in Bangladesh is located at 24°53 N latitude and 91°53E longitude with an estimated population of 0.6 million and a high migration rate especially a population growth rate of 4% per annum (Rahman & Islam, 2000) in comparison to the annual average growth rate of 2.01% in Bangladesh (Ahmed, 1994). This increasing population results rapid and mushrooming expansion of waste products in the city. Now-a-days the waste generated per day throughout the city is approximately 190-200 tons containing more than 4-5% organic plastic wastes (sylhet city corporation, SCC 2011). A little fraction of plastic waste is being recycled and rest of them are thrown to landfill or incinerated. Landfill waste plastics remain non-degradable through a long passage of time that results the loss of soil fertility which is environmentally unsafe for its inhabitants. Emission of toxic gases results from incineration; blast furnace and gasification have adverse effects such as acid rain ozone depilation and green house effect etc. Moreover the un-used plastic shopping bags get clogged in city causes severe sewerage problem. As Sylhet is on the bank of river Surma, floating plastic waste causes a tremendous threat for aquatic life.

Even though a certain amount of recycled plastic waste being converted to plastic goods, create jobs and save millions of dollars of foreign currencies spent for importing virgin plastic, it still remains as an ultimate threat for both environment and health.

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In this back ground, the present study is conducted to evaluate the existing waste management system including the demand and fulfillment of the people involved here. Besides, this study has been carried out also to propose a specific way to covert waste to wealth by fuel conversion from plastic waste.

## 2. METHODOLOGY

The research was carried out in four phases:

1) Questionnaire survey and face to face conversation with the people involved in plastic waste collection and recycling system to realize the present condition.

2) Literary survey to guess the plastic sector in Bangladesh with existing policies.

3) Getting ensured about the existing policies defines viewpoints on the problems and plausible solutions as well as suggests a new policy for fuel production from plastic waste.

4) Questionnaire survey among the concerned people to evaluate the acceptance for proposed fuel production policy rather than ordinary plastic re-production.

Location and types of the surveyed plastic factories are shown in table-1. Some disposal spots within the city, as well as the only damping site at Lalmatia, near the Sylhet - Fenchuganj road and some colonies of waste collectors were visited.

Table 1: Plastic factories where study has been conducted

| Name | Location | Type |
|---|---|---|
| Ripon plastic | Kodomtoli | Granulating and Re-producing factory |
| Vuya plastic | Bi-pass road | Re-producing factory |
| Shahjalal plastic | Mominkhola | Re-producing factory |
| Khaja plastic | Khadim | Re-producing factory |
| Dipu cut and molam plastic | Jholopara, Kodomtoli | Granulating factory |
| Babu plastic | Bi-pass road | Granulating factory |
| Sumaya plastic | Bi-pass road | Granulating factory |
| R.k plastic | Bi-pass road | Granulating factory |

## 3. RESULT AND DISCUSSION

### 3.1. Present Waste Management Scenario in Sylhet

A survey on solid waste generation rate and physical composition analysis found that per capita solid waste generation rate in Sylhet city is .321 kg/cap/day with the 190.11 tons/day of solid waste generation. On average 4-5% of the total waste generated in Sylhet city is plastic materials. The pre-dominant source of post consumer plastic waste is municipal source including residential household, markets, small commercial establishments, hotels and hospitals. The growth rate of plastic waste materials over last 5 years in SCC area is shown on figure-1 (according to SCC waste report)

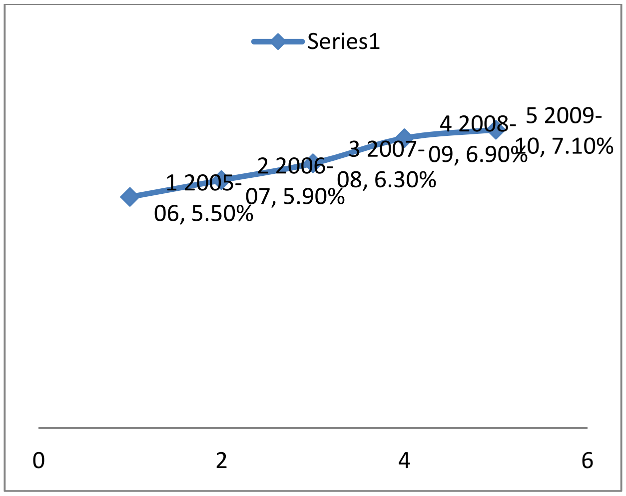



Figure 1: Growth rate of plastic wastes for last 5 years

It is evident from the above graph that average increase in plastic waste is 7.1% during the last year, which is the maximum growth rate for last five years. The average growth rate is estimated as 6.34%. The nature of the plastic waste in Sylhet is law-calorific value, excessive moisture content with high quantity of non-combustible contents. The raw classification of plastics is shown on figure-2 with their percentage

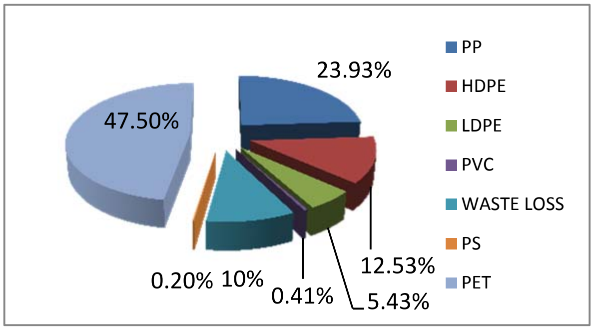



Figure 2: Present recycled plastic composition.

The rise in PET (poly ethylene tetra-chloride) is mainly associated with the non-availability of pure mineral drinking water. Lack of pure drinking water in Sylhet city causes water borne diseases which force the residents to bottled water and cold drinks packed in PET. Its amount also varies from summer to winter depending on the necessity of pure drinking water. Even though PET includes the major part of Sylhet city, it is gone to Dhaka and China for processing as here no access is available to be recycled. PET bottles are separated initially by the waste-pickers from rest of the plastics. In this survey, we got near about 350 tons of PET each year exported from Sylhet. PET along with other raw plastics are partially used to recycle and rest are thrown to landfill and street side and remain un-used for a longer time. This amount is shown in figure-3.

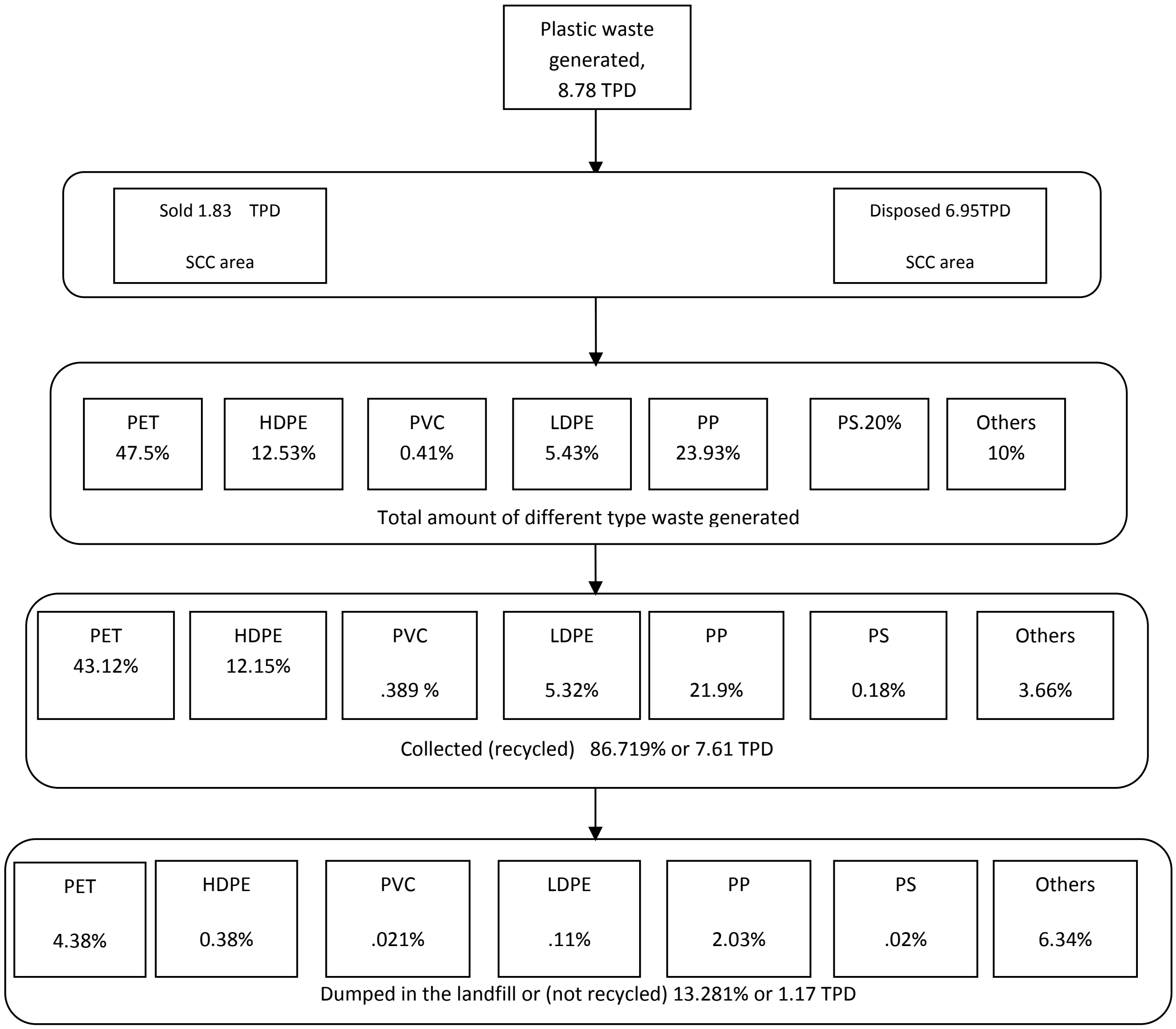



Figure 3: Amount of plastic waste recycled and non-recycled in Sylhet city

***The waste management system in Sylhet city***

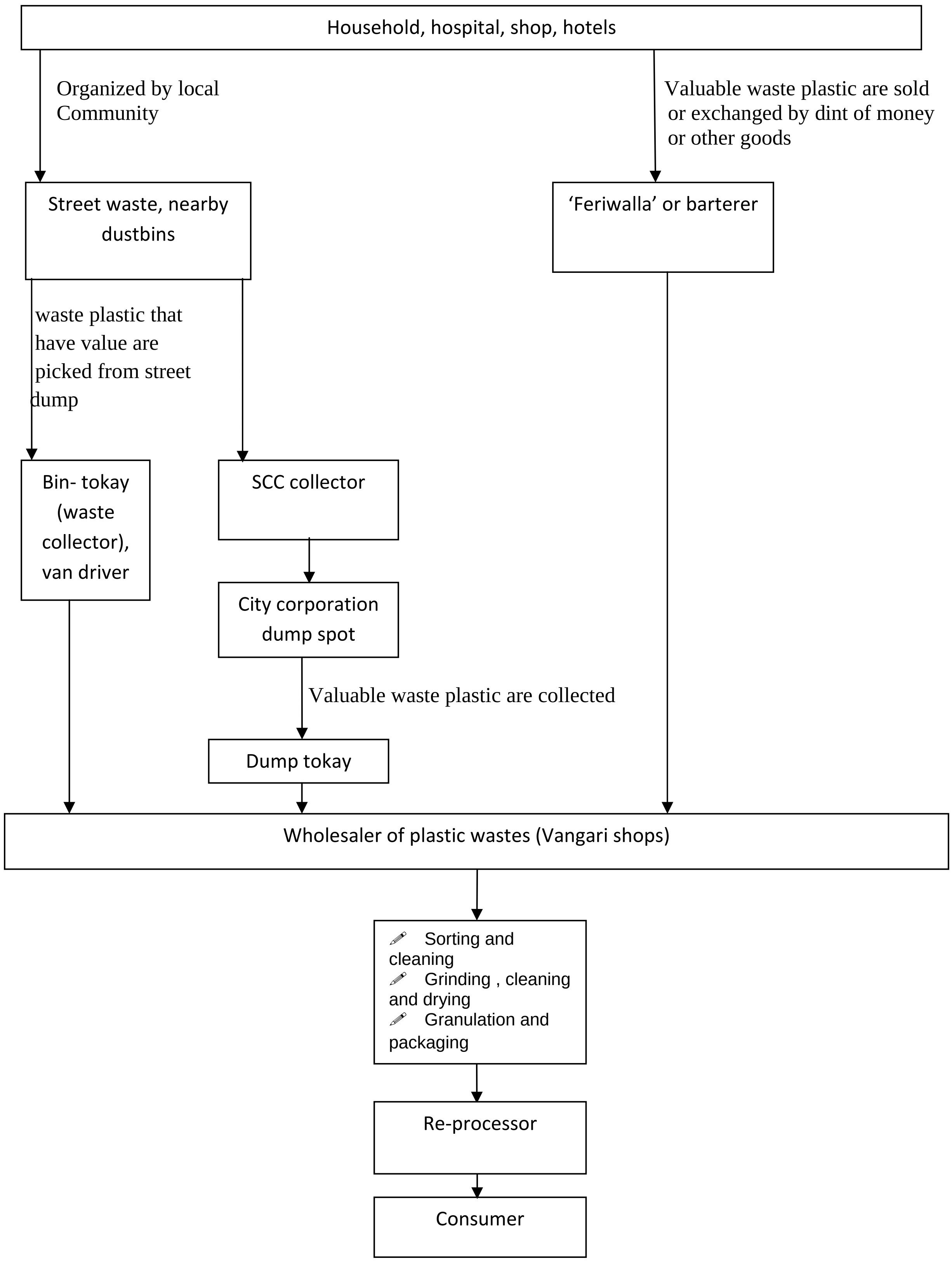



Figure 4: Plastic waste management system diagram in Sylhet city

From the figure-3, it is seen that 1.17 tons of plastic waste in each day are kept on the dumping spot and remain not-recycled. Rest of the part is being processes where the total amount of waste plastic generated in each day are 8.78 tons. This is collected by different types of collector involved in this process.. Then it is going to be recycled through several steps. After competition of this steps it again goes to the consumer as a finished product. The steps involved up to the finished product from waste plastic are mentioned in figure-4. It is often referred as a cradle to grave of a plastic material. The waste management system in Sylhet city is also shown on figure-4.

The overall system involves two steps,

1) plastic waste collection system

2) plastic waste recycle system

### 3.1.1. Waste Plastic Collection System

The waste plastic management system mentioned in figure-4 can involve the waste collectors into following categories.

Barterer, van-driver → Primary collector (from house to house)

SCC collector, bin-tokay → Secondary collector (From roads and dustbin)

Dump Tokay → Tertiary collector (from final disposal)

A large number of people are involved with waste plastic collection in various stages. From the table-2 it can be observed that total female involvement is about 19.85%

Table 2: People involved in collecting process (source: SCC and owner of vangary shops)

| post | Male | Female | Total | % of female |
|---|---|---|---|---|
| Feriwalla | 1200 | 100 | 1300 | 7.69% |
| Van-collector | 165 | 0 | 165 | 0.00% |
| Bin tokay | 250 | 150 | 400 | 37.50% |
| SCC collector | 147 | 105 | 252 | 41.60% |
| Dump tokay | 177 | 140 | 377 | 37.13% |
| Total | 1939 | 495 | 2494 | 19.85% |

### 3.1.2. Waste Plastic Recycling System

The reprocessing sectors can be divided into the granulators and the convertors. The granulator makes granules from plastic scrap and sell granule only. The sorting of plastic scrap is done on the basis of color, transparency, hardness, density and opacity. The granules they make have some ordinary market names and categories described in table-3.

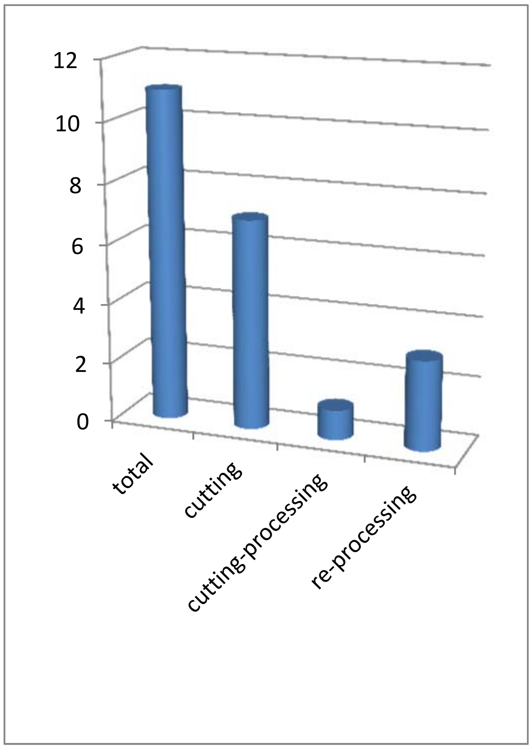
Table 3: Types of plastic with their market name and product

| Names by granulator | Actual group | products |
|---|---|---|
| Molam | Raw plastics | |
| Hyboroze | High-density polyethylene | Milk, detergent oil bottles, toys, container used outside parts and plastic bags,i.e,bodna,chalni,gallon |
| pp | Poly-propylene | Refrigerated container, some bags, most bottle tops ,household containers,i.e,bowl,balti |
| Red-hyboroze/marlex | High-density polyethylene | Red colored HDPE product |
| Blue hyboroze/marlex | High-density polyethylene | Blue colored HDPE product |
| Green | High-density | Green colored HDPE product |

| | | |
|---|---|---|
| hyboroze/marlex | polyethylene | |
| Red-pp | Poly-propylene | Red colored PP product |
| Blue-pp | Poly-propylene | Blue colored PP product |
| Red-hard-elkatin | Stronrg polypropylene | Red colored strong plastic containers |
| Green-hard-elkatin | Strong polypropylene | Green colored strong plastic containers |
| Pran | marlex | Cross tee |
| Paracchute | Strong High-density polyethylene | High quality HDPE product |

However these granules are partially sold in the local re-processing factories to produce the above product and rest of them is gone to Dhaka for processing with some uncrushed plastics also. Distribution of different forms of plastic is shown on figure-4.

A survey to the local recycling process in Sylhet city shows the involvement of 11 factories. Four of them do the job up-to conversion and rest of them is engaged with granulating. Three of the four plastic productive factories meet up their granule demand from the local granulator shops and the rest one involves both conversion and production. A present look on plastic recycling factories is shown in figure-3



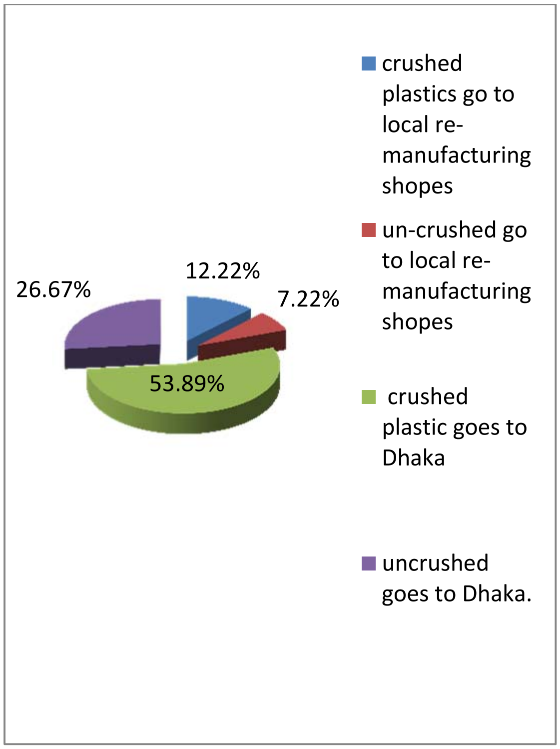




Figure 3: Catagories of plastic recycling factories in sylhet city

Figure 4: different forms of plastic distribution

From the figure-4, we see the major amount of plastic (80.56%) generated in Sylhet city is sold to Dhaka or outside for processing. This portion involves both crushed and un-crushed plastics according to the demand. A very small fraction remains here to be processed in local manufacturing factories.

Figure 5: Traditional system of separating different types of plastics in a local granulator shop

At present, the number of jobs created by the plastic waste recycling process has been analyzed in table 4:

Table 4: people involved in recycling process (Source: local plastic factories)

| actor | male | Female | Total | % of female |
|---|---|---|---|---|
| Vangari shop | 413 | 87 | 500 | 17.4% |
| broker | 90 | 160 | 250 | 64% |
| Wholesaler | 32 | 45 | 77 | 58.44% |
| manufacturer | 37 | 19 | 57 | 33.33% |
| Total | 572 | 311 | 884 | 35.18% |

This analysis of table-3 and table-4, show a large participation of female worker in plastic recycling sector rather than collecting sector by 15.33%.

### 3.1.3. Health Hazard Involvement

Health risk is involved for both plastic waste collector and re-cycler, such as,

1) The chemical migration from plastic waste
2) Chance of cut-injury, punctured wound, swelling or accident.
3) Germs of infectious waste.

During collecting plastic waste, collectors may fall into severe injuries by pierced. As they are involved for a longer period, they may face inhalation problem, cancer, genetic change, chronic bronchitis, skin diseases and so on. During manufacturing plastic waste are washed away, it may results wear and tear, breast & uterine cancer and risk of decreasing testosterone level(3). Again plastic waste is associated with clinical waste in dumping spot. The chemical poisons in hospital waste can affect different parts of the body: for instance, hepatoxic agents (e.g. carbon tetrachloride, tetra chloroethane) affect the liver; nephrotoxic agents (e.g. halogenated hydrocarbons) affect the kidneys; haematopoietic toxins (benzene, phenols) affect blood; and neurotoxic agents (e.g. methanol, metals,organometallics) and ana-esthetic agents (e.g. ethyl ether, esters, acetylene hydrocarbons) affect nerve systems and consciousness, respectively (4).Moreover a large number of children are involved here in both sector which is more hazardous and vulnerable for them.

### 3.1.4. Financial Aspect of Waste Management in Sylhet City

The total budget of local Government on waste management is around 29000000TK each year where the waste collectors are provided 140 tk per day and 30 tk per day for the sweepers.

The value addition at different stages from cradle to grave of plastic wastes is shown on figure-6.

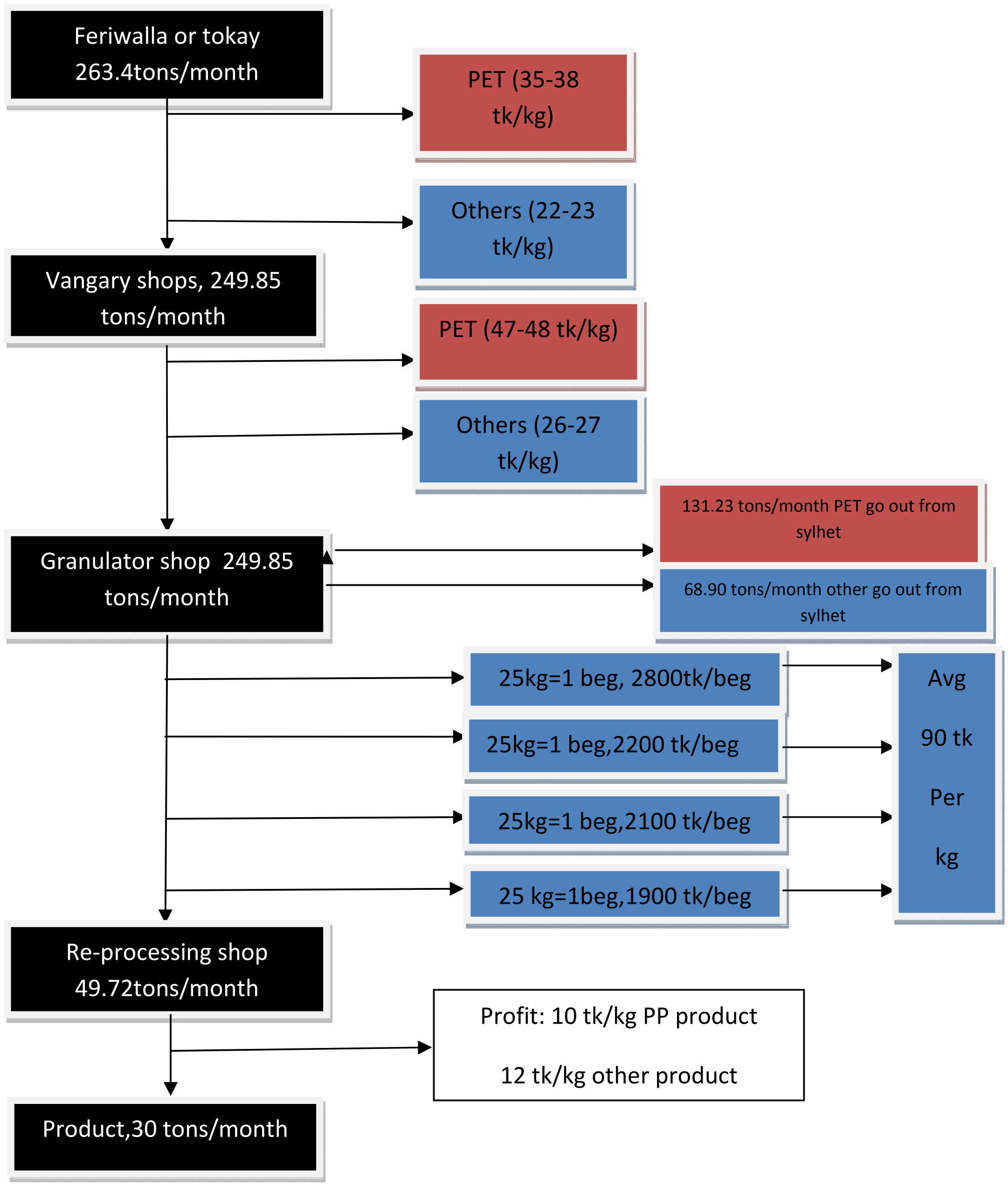



Figure 6: Value addition diagram for different stages of plastic waste

## 3.2. Proposed Fuel Conversion of Plastic Wastes

### 3.2.1. Background for the Fuel Production Purpose

Waste plastics are one of the most promising resources for fuel production because of its high heat of combustion and due to the increasing availability in local communities. The conversion methods of waste plastics into fuel depend on the types of plastics to be targeted. Additionally the effective conversion requires appropriate technologies to be selected according to local economic, environmental, social and technical characteristics.

### 3.2.2. Process Involved In Fuel Production

Chemical process such as pyrolysis and de-polymerization can be used to safely convert plastics into hydro-carbon fuel that can be used for several purposes.

Pyrolysis is the chemical decomposition of condensed organic substances by heating. The pyrolysis process for plastic takes the long chain polymer molecules and breaks or cracks them into shorter chains through heat and pressure. The pyrolysis process does this with intense heat in a closed system in a short amount of time. Conditions for producing pyrolysis oil are more likely to include virtually no oxygen. The pyrolysis of plastics produces a liquid product, pyrolysis oil or oil that can be readily stored and transported (7). Pyrolysis oil can be used directly as fuel or further refined into diesel or jet fuels. (5)

The production method for the conversion of plastics to liquid fuel is based on the pyrolysis of the plastics and the condensation of the resulting hydrocarbons. Pyrolysis refers to the thermal decomposition of the matter under an inert gas like nitrogen. For the production process of liquid fuel, the plastics that are suitable for the conversion are introduced into a reactor where they will decompose at 450 to 550 C. Depending on the pyrolysis conditions and the type of plastic used, carbonous matter gradually develops as a deposit on the inner surface of the reactor. After pyrolysis, this deposit should be removed from the reactor in order to maintain the heat conduction efficiency of the reactor. The resulting oil (mixture of liquid hydrocarbons) is continuously distilled once the waste plastics inside the reactor are decomposed enough to evaporate upon reaching the reaction temperature. The evaporated oil is further cracked with a catalyst. After the resulting hydrocarbons are distilled from the reactor, some hydrocarbons with high boiling points such as diesel, kerosene and gasoline are condensed in a water-cooled condenser. The liquid hydrocarbons are then collected in a storage tank through a receiver tank. Gaseous hydrocarbons such as methane, ethane, propylene and butanes cannot be condensed and are therefore incinerated in a flare stack. This flare stack is required when the volume of the exhaust gas emitted from the reactor is expected to be large. Figure-5 presents a schematic diagram of a liquid fuel production plant.

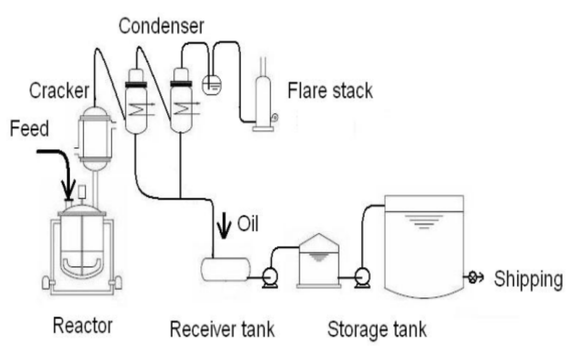



Fig 5: schematic diagram of a liquid fuel production

### 3.2.3. Present World and Plastic Fuel

The present world is very much concerned about the acceleration of waste plastic and taking suitable steps to get rid of it. Fuel conversion is becoming much popular in this aspect. For example, About 300 million barrels are obtaining from 300 million ton of waste plastic generated each year in US, This could replace up to 9% of fossil fuel depending in the US

Companies worldwide are making good use of this abundant source of waste plastic some of them are mentioned in table-5.

Table 5: world recognized technologies of fuel production from plastic waste

| Company/person Name | procedure | purpose | location | uses | Amount of production |
|---|---|---|---|---|---|
| Ozmotech | pyrolysis, catalytic breakdown and controlled distillation | waste plastic to diesel fuel | Australia | can run any diesel engine. | 350 million liquid fuel from 400000 tons P.W |
| Unique plastic waste management and research co pvt ltd | low temperature melting process with degasification and de-polymerization | waste plastic sulfur free industrial crude oil | India | used for in furnaces and electrical purpose | Convert 85% fuel and 15% gas from 100% P.W |
| Envion Oil Generator co pvt ltd | | waste plastic into light or medium oil. | China | Solve the growing problem of trash | 3-5 barrel Light oil Per ton p.w |
| Umesh Zadgaonkar of the G.H. Raisoni College of Engineering, Nagpur, Maharashtra | Random de-polymerization and Fractional Distillation | a) Solid Fuel Coke<br>b) Liquid Fuel<br>c) Gaseous Fuel LPG range gas | india | 1) for running a four-stroke/100 cc motorcycle<br>2)as an alternative clean fuel in boilers and other heating systems | 3 kgs of plastics produce about 2 litres of Liquid Fuel in about 3 hrs |

### 3.2.4. Advantages of Fuel Production from Plastic Waste

1) Almost all kind of plastic wastes including bio-medical plastic waste can be used to ensure the maximum conversion and to obtain cheaper and quality fuel.

2) Raw materials are readily available and easy to make a perfect solution

3) Sometimes valuable by-product can be obtained such as coke and LPG in some technologies.

4) It ensures environmental safety as well as decrease in foreign oil dependency, which would help stabilize the price fluctuation of the global marketplace and the expense of operating vehicles.

### 3.3. Fuel Production: Sylhet Perspective

The dominant types of plastic wastes in Sylhet city required to make fuel are shown on the table-6

Table 6: Product types of some plastics pyrolysis

| Main products | Type of plastics | available In ton/month | As a feedstock of liquid fuel |
|---|---|---|---|
| Liquid hydrocarbons | Polyethylene (PE)<br><br>Polypropylene (PP)<br><br>Polystyrene (PS) | 47.9<br><br>71.7<br><br>5.31 | Allowed.<br><br>Allowed.<br><br>Allowed |

From the data of table-6 and table-5, it is seen that in total 124.91 TPM of plastics are found suitable for fuel production in Sylhet city. These 124.91 tons of plastic waste can be converted into 109296.25 L of fuel following ozmotech process [6] which can meet up the local fuel demand with a excellent profit. Sylhet may be the suitable one for fuel production. It has sufficient resources to convert plastic waste into fuel. Moreover a good number of industries including two largest fertilizer and cement industries are located here. So it has a good probability to meet up the demand of their furnace oil from local plastic waste. The transportation need for fuel has also a rapid increase in Sylhet. That's why its probability is at arm's length for us.

In fuel production plastics are vaporized rather than burning in re-production. After a certain period of recycling some plastics become unsustainable for further plastic re-processing but still eligible for making fuel. polyethyne shopping bags have no further use for plastic re-production. That's why it becomes a great threat for environment. But for fuel production these poly-bags are good to use again. Different diseases concerned with plastic recycling are not observed in fuel production. In plastic re-production system, the major part of granules is exported abroad for processing. But the price of granules in international market fluctuates rapidly which causes uncertainty in this business resulting mental stress. But our local demand for fuel in industrial and transportation purpose can easily be fulfilled by the plastic waste generated here and it results a mental relief and more economical solvency to the people. This survey studies the job satisfaction for the present plastic re-production system and also what will the acceptance rate be in case of fuel production. It is compare on the fig-5 and fig-6.

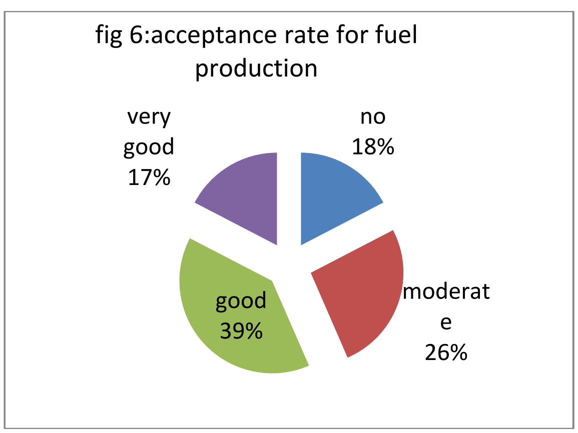



Figure-5: acceptance rate for fuel conversion to the proprietors and manager of local plastic factories

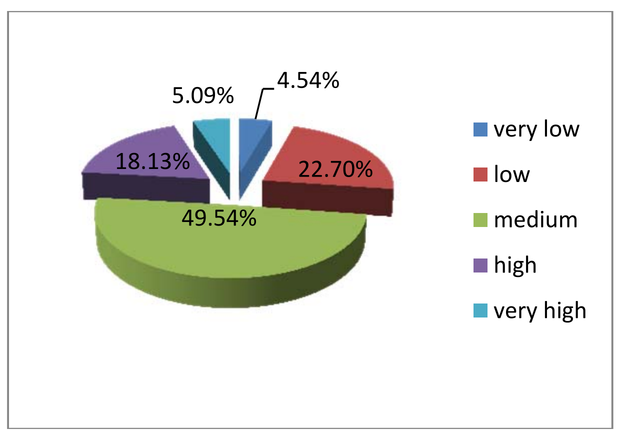



Figure-6: Business satisfaction of persons involved in plastic recycling process

## 4. CONCLUSION AND RECOMMENDATION

plastic waste results a tremendous threat for environment, as well as health. This hazard must be eliminated by utilizing the waste in a proper manner. This survey got the following treatment that should be studied.

1) Introducing fuel converting plastics to be used in a large number
2) Keeping emphasis on separation of different types of wastes at their sources
3) The concerned authorities should treate different types of wastes separately
4) waste-pickers should be trained and permanently involved in SCC
5) The waste loss during collecting period should be minimized.
6) Gathering mass people to inspire them for using fuel converted from plastics waste.

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# ENVIRONMENTAL AND GEOTECHNICAL ASPECTS OF CHAPTIR HAOR SUB PROJECT AND ITS PROPOSED REHABILITATION

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## ABSTRACT

Chaptir Haor has a great importance among all wetlands of Bangladesh which supports a rich ecological, economic, commercial and socio-economic resource base. Fresh water of Chaptir Haor contains a great bio-diversity of flora and fauna including diversity in agriculture crops as well as a large number of endangered species of international interest, provides habitat for a variety of resident and migratory waterfowls and potentials to support eco-tourism. The Flood Control and Drainage Project implemented by BWDB is working well but not as planned due to various problems. From field observation some serious problems are evaluated and some mitigating measures are recommended. The main problem is the poor operation and maintenance of the implemented project. Chaptir Haor faces acute drainage congestion during the monsoon causing damage to the Aman rice in the lower areas and sometimes also faces short term congestion during pre monsoon flash floods which damage the ripe High Yielding Variety of rice “Boro”. About 60~70% of the embankment length was in bad shape prior to the monsoon flood.

**Key Words:** Ecological, Socio-Economic, Flora and Fauna, Water

## 1. INTRODUCTION

Wetlands are of great importance in Bangladesh. About two-third of the country consists of wetland and 80% of all animal protein consumed, consists of fish. Haor is one kind of wetland which is bowl-shaped large tectonic depression (a low-lying area) surrounded by higher ground and having no natural outlet for surface drainage; usually deeply flooded during wet season and no or less water in dry season (Paul and Yesmin 2008). The Sunamganj Haor area occupies the northwestern and central and western part of the Meghna Depression, which forms a unique physiographical feature of Bangladesh. Drainage of the Haor Area is affected by the principal rivers, the Surma, Kangsha, Someswari, Baulai and the Kushiyara. Chaptir Haor sub-project lies between longitudes 91 °21.5'E and 91 °27'E and latitudes 25°44.4'N and 24°50.3'N, about 304 km north-east of Dhaka and 114 km west of Sylhet town by road. Chaptir Haor is bounded by the Champti Nadi to the east, the Kalni River to the west and by the Kamarkhali Nadi to the south. The haor is also rich in other faunal species such as: 1 butterfly species, 34 mammal species, 11 amphibians, and 34 reptiles (Alam 2005). The haor also provides safe haven for breeding and spawning many fresh water species. A total of 200-300 plant species in Bangladesh are judged to be wetland species for all or part of their life spans (Nishat, 1993). Tanguar Haor-a large floodplain lake area in the north-eastern part of the country lies mainly within the two upazilas of Sunamganj

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and Sylhet district has been listed as an internationally important wetland. It is also one of the country's most productive inland fisheries sources. Similarly Chaptir Haor, Zilkar Haor, Hail Haor, Hakaluki Haor play important role in fish production. Chaptir haor area is located within the haor basin of Sunamganj which comprises a vast alluvial plain with a mosaic of wetland habitat including numerous rivers, streams and large areas of seasonally flooded cultivated plains (Farzana and Islam 2006). Chaptir Haor sub-project is one of the ten submersible embankment projects in the Sunamganj area proposed for rehabilitation under System Rehabilitation Project (SRP).

In this study existing water supply, environmental and sanitation condition, socio-economic condition as well as the condition of the embankment and its causes of failure was observed and some recommendation for rehabilitation was given. The aim of this study was to analyze various problems in Chaptir Haor sub project. During survey a lot of problems in water supply and sanitation sector, causes of failure of embankment was identified.

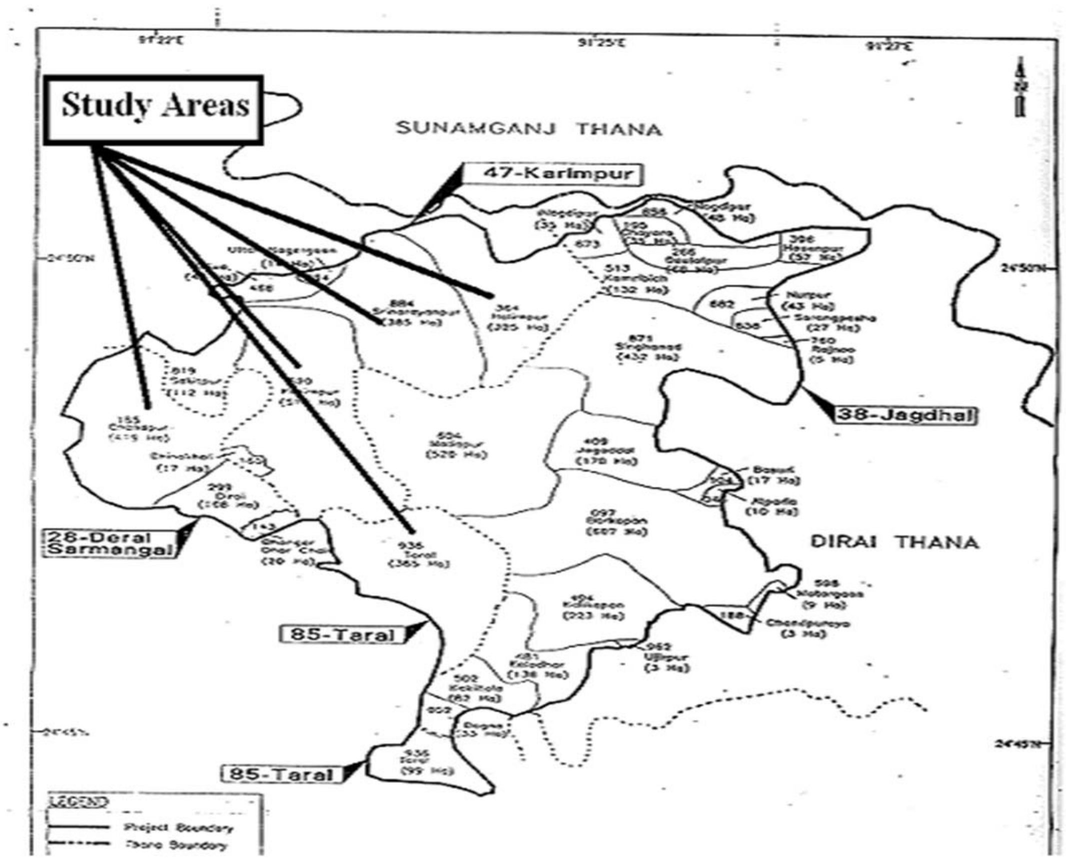


Figure-1: Location of study areas

## 2. METHODOLOGY

For the purpose of assessment, at first study areas were selected. Five different low income areas were randomly selected depending upon population density, deteriorated sanitation condition, professions, income status etc. These are Chandpur, Karimpur, Srenarayanpur, Halimpur and Tarol. To observe the physical condition of embankment four places were surveyed. These are Tarol, Boishakhali, Atrai and Chandpur. Figure-1 represents the study areas. During survey PRA method was followed. Study was done in each zone separately with various environmental parameters. In every study area at least 20 persons were randomly surveyed by questionnaire survey and field inspection.

## 3. RESULTS AND DISCUSSION

### 3.1. Observation of Environmental Condition:

#### (i) Water Supply

In every study area twenty families were randomly surveyed by questionnaire survey and visual inspection. From survey work, it is observed that most of the people (99%) of the study areas using tube-well water for drinking purposes. They are aware that tube-well water is better than other sources of water for drinking purpose. They all use river water for cooking. The ground water table is very low at that area and it is difficult to install tube-well without government aid. So they have a great scarcity of tube-well. There are no disinfection practices available to treat the water that they drink.

#### (ii) Diseases and Hygienic Condition:

Due to unhygienic sanitary conditions and inadequate water supply facilities, many water borne diseases such as diarrhoea, amoebic dysentery, bacillary dysentery, typhoid, jaundice etc are commonly occurred in all study areas. It may be noted that children are more sensitive to these diseases. Due to poverty and lack of proper sanitary knowledge the people of these areas are not accustomed with sanitary practices. The unhygienic sanitary condition of these areas is shown in the figure-2. It is found that about 14% respondents practice open defecation whereas in Chandpur the percentage is highest (20%). 32% of respondents uses hanging latrines for defecation whereas no hanging latrines were observed in karimpur and Tarol. From the observation, it is also found 27% people use sanitary latrines in chapter haor. The highest sanitary latrines users found in Karimpur (60%) which is followed by Tarol (50%).

#### (iii) Life Constraints:

After the baseline survey, it was seen that the present condition of the people of Chaptir Haor was not well enough. They are suffering a lot of problems which are listed below:

a) Unemployment problem
b) Deficiency in irrigation system
c) Lack of treatment facilities
d) Undeveloped communication system
e) Flash flood
f) Water congestion
g) Drainage congestion
h) Lack of education facilities

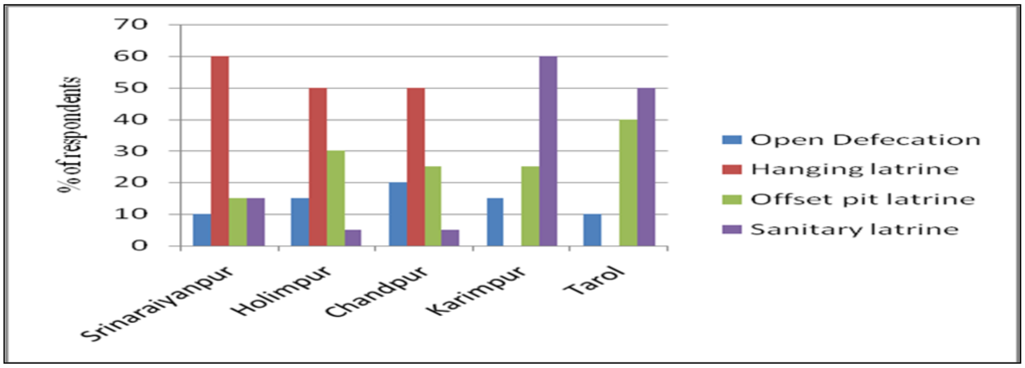


Figure-1: Distribution of latrine used in different study areas

### 3.2. Observation of Embankment

To observe the condition of embankment four places were surveyed and the causes of the failure were identified which are as follows;

**Causes of failure of embankment**

1. Faulty design of regulator: The space for passing the boat through the regulator is not sufficient. The operation of regulator is not user friendly. That's why; people break the embankment for boat passing.
2. Soil characteristics: After analyzing the characteristics of soil sample of different embankments, it was observed that the percentage of sand is higher. Because of this, the failure of embankment occurs very quickly due to flood.
3. Role of union chairman: According to the opinion of general people, the role of chairman in constructing the embankment is not satisfactory.
4. Role of leaseholders: According to the opinion of general people, leaseholders break the embankment every year because if the cropland is immersed under flood water then suitable environment for fish culture is created.
5. Inefficiency in allotment: The people of the haor area said that, the allotted money that is provided by the Govt. is not sufficient. Beside this, the allotted money is not used properly. When some portion of the embankment is broken down due to sudden flood, emergency action is not taken by BWDB.
6. Navigability of rivers: The navigability of river Surma, Kalni is low. The bank of river is comparatively lower than the river so that it cannot capture the flood water.
7. Unconsciousness of people: The people take the soil from Embankment for constructing their houses. They also take the soil to use it as fuel from just beside the embankment. That's why holes are created around the embankment, and the embankment becomes unstable. Again they break the embankment to short their way.
8. Improper maintenance of Embankment: The contractors use the soil from the crop land beside the embankment for resectioning to reduce the cost. For this reason the slope of the embankment become steeper which make it unstable.
9. Problem in discharge of river water: The water of the river Kalni can't discharge properly due to lack of space. That's why the water is overflowed and the embankment is damaged.

**Embankment slope and level analysis:**

Slope and reduced level were measured at various sections of the embankment. The findings are given by the Table 1.

Table-1: R.L and slope of various sections

| Name of the Area | Reduced level (m) | Slope | |
|---|---|---|---|
| | | Country side | River side |
| Boishakhali | 7.25 | 1:2 | 1:1 |
| Chandpur | 6.87 | 1:2.39 | 1:1.70 |
| Atrai | 6.75 | 1:2.8 | 1.2 |
| Tarol | 6.5 | 1:2.6 | 1:1.5 |

**Embankment soil analysis**

To determine the characteristics of soil of the embankment, the particle size distribution was determined by Sedimentation analysis and for experimental procedure Sieve analysis was done. The percentage of sand is 72% and silt is 28% found at Chandpur. In Boishakhali the percentage of clay, fine silt and fine dust was 32% and percentage of sand was 68%.

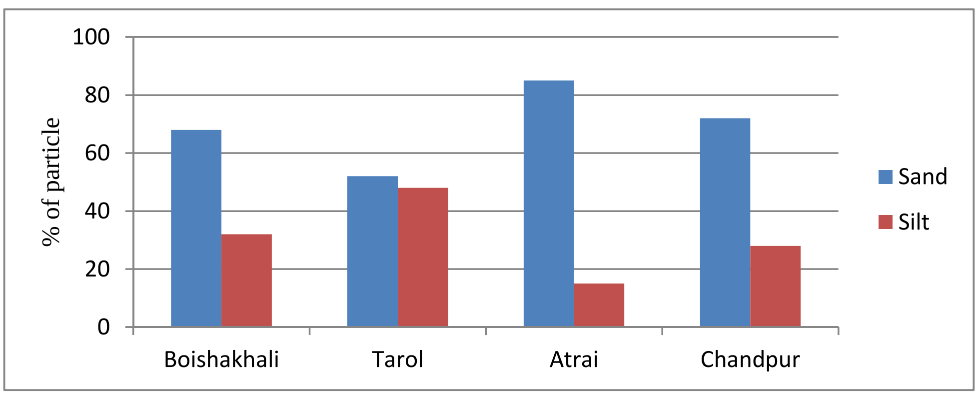


Figure-3: Result of soil analysis of the study area

**3.3. Field Observation**

It was observed form the field observation that a branch of the river Kalni is blocked for enhancing flow through the new sluice gate. So the direction of natural flow of the river is hampered and that is why the flow during flood creates pressure on the embankment and causes damage to it. This damage occurs almost every year.

The submersible part of the embankment is regularly damaged during submersion also. The height of the embankment is decreased every year. These have not been repaired for a long time. As a result pre monsoon flood water easily enters into the haor. About 60~70% of the embankment length was in bad shape prior to the monsoon flood. The top width has been reduced by wave action and rain cuts, severely damaging the side slopes and making the embankment weaker at several locations.

## 4. CONCLUSION

After analyzing the present situation, the study has come to its decisive remarks as follows:

- People are not aware about proper sanitation practices and use of safe water for different household purposes.
- The authority designs the embankment on the basis of experience rather than calculation. This experience is often gained by the trial and error method and it is still continuing.
- Accountability of implementation, operation, maintenance and supply of materials is less pronounced after and before the work.
- Soil classification and characteristics is less assessed before design.
- Long term management has not been taken.
- In the soil of the embankment, the percentage of sand is higher.

## 5. RECOMMENDATION

1. Community health education program should be arranged to improve domestic health a widespread program should be commenced to construct more sealed sanitation facilities.
2. Regular monitoring of water quality should be given priority.
3. The drainage system should be improved. The existing drainage (khal) can be excavated and enlarged as they can drain out the flood water.
4. The existing regulators are not sufficient to drain out the water swiftly. In selecting the location for a new drainage regulator; the spot should be on the full flood embankment.
5. Disaster preparedness education & flood proofing should be available in the unions.
6. Local station for measuring discharge, water level & velocity should be set up.
7. More research should be performed on the river Kalni and individual formula should be developed. Physical modeling can also be done to simulate flow pattern before designing the embankment work.
8. The slope of the embankment should be maintained properly during construction.
9. Community participation should be encouraged to develop the sense among people about the structure's overall objective.
10. Improved drainage operation requires better maintenance & design of structures, regulator gates need to be sealed culverts be closed properly. Local needed project committees need to be geared up for proper management. Regular periodic inspection should be made after the embankment stabilization measures have been installed.

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# COASTAL GEOMETRY AND STORM SURGE MODEL FOR THE BAY OF BENGAL

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## ABSTRACT

Bangladesh is situated at the northern tip of the Bay of Bengal. The Bay of Bengal is surrounded by coasts all around except in the south where there is open sea. The coasts are curvilinear in nature and the bending is very high along the coasts of Bangladesh. The long continental shelf, shallow bathymetry and complex coastal geometry with lots of kinks and islands of the Bay of Bengal are well-known features of the highest storm surge of the longest duration. It was verified that the storm surge is very sensitive to the basin depth. The future impact of sea level rise and climate change on the coastal zone of Bangladesh will depend on the vulnerability and resilience of its physical and biological systems. The main objective of this paper is focusing on coastal zone and providing information as a basis of storm surge model for the Bay of Bengal. Finally, determine the amount of impact in correspondence to storm surge and sea level rise for coastal people and economic region of Bangladesh. IIT Kharagpur Model (Domain: 18 - 23° N, 83.5 - 94.5° E) is used for numerical simulation of storm surge. The results obtained from the model are in good agreement with the reported data.

**Key Words:** Bay of Bengal, coastal zone, storm surge, simulation, bathymetry, sea level rise, geo-reference.

## 1. INTRODUCTION

The coastal geometry of the Bay of Bengal is so complex. There are lots of kinks, inlets and islands of the Bay of Bengal. Depending on its character, the coastal zone can be divided into three main parts: west, central and east coasts (Fig.1). For geometrical structure of the Bay of Bengal, of all the countries surrounding the Bay of Bengal, Bangladesh suffers most from storm surges (Fig.2). For example about 300,000 lives were lost in one of the most severe cyclone that hit Bangladesh (then East Pakistan) in November 1970 [S.K. Dube *et al*.]. The most of the world's greatest human disaster associate with tropical cyclones have been directly attributed to storm surges. There are a lot of studies on cyclone track forecasting and simulation. Debsarma (1994, 1995) developed "Storm Track Prediction (STP) Model" and "Steering and Persistence (STEEPER) Model" for the Bay of Bengal. Rao *et al.* (2003) observed mesoscale characteristics of tropical cyclones and made some preliminary numerical simulations of their kinematics features. Mohanty *et al.* (2004) made simulation of Orissa super cyclone (1999) by using PSU/NCAR mesoscale model. Rama Rao *et al.* (2005) made further evaluation of the Quasi-Lagrangian Model (QLM) for cyclone track prediction in the north Indian Ocean. Goswami *et al.* (2006) made advance forecasting of cyclone track over north Indian Ocean by using Global Circulation Model (GCM). Debsarma (2007) made numerical simulations of storm surges in the Bay of Bengal. Lin *et al.* (2008) studied warm ocean anomaly, air sea fluxes, and the rapid intensification of tropical cyclone Nargis (2008). Debsarma (2009) made 3-D simulations of storm surges in the Bay of Bengal. There are two parts of the study:

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## 1.1 Coastal Geometry

This section focuses the coastal zones of the Bay of Bengal.

***(a) West Coastal Zone:***The western boundary of the west coastal zone is the Bangladesh/India border at the Hariabhanga River. The eastern boundary is the west bank of the Tetulia River and the northern limit is taken as the landward limit of the coastal districts of Khulna, and part of Barisal. The west coastal zone has three distinct sub-zones defined by distinctive physio-geographic characteristic the Sundarban mangrove forest, the saline tidal floodplain, and the non-saline floodplain (Fig.1). The far western part of the zone is the relatively inactive area of the Gangetic deltaplain. The tidal floodplain areas are low-lying, with an intricate network of river channels. Salinity affects the soils and groundwater of the north-west and south-east of the zone. Extensive areas in thesouth and west have been embanked to create polders which protect land against tidal flooding with saline water [S.Paul *et al.*, 1993].

***(b) Central Coastal Zone:*** The western boundary of the central zone is drawn along the west bank of the Tetulia River (Baru, 1991). The eastern boundary of the zone is drawn through the Sandwip channel and meets the coast at the mouth of the Feni River. The northern limit is taken as the landward limit of the coastal districts. The central coastal zone is more dynamic of the three coastal zones. The sediment-laden rivers of the Ganges, Brahmaputra and Meghna deposit vast amount of sediment into the Bay of Bengal at the mouth of the lower Meghna estuary. These sediments have accreted to form the fertile and densely populated estuarine floodplains and offshore islands of the central coast. This sediment is moulded by strong tidal and fluvial processes, by moderate wave energy, and high waves and surges produced during cyclones.Tidal flows are strongest in the eastern part of the zone, whereas river flows are strongest in the western part. The relative strengths of tidal and river flows have been used to divide the zone into ‘’ river dominated”, “fluvio –tidal dominated” and “tidal dominated” sub-zones (Barua, 1991). Each sub-zone might be expected to respond differently to future sea-level rise and climate change.

***(c) East Coastal Zone:***The southern boundary of the east zone is the border of Bangladesh with Myanmar (Burma). The north-western boundary is drawn through the Sandwip channel and meets the coast at the Feni River. The inland limit is taken as the landward limit of the coastal districts. The east coastal zone is the non-deltaic coast of Bangladesh and is characterized by a narrow coastal plain. The zone can be divided into southern and northern sub-zones at the Karnafuli River. Each sub –zone is distinctive. The northern sub-zone contains a smooth, nearly level, estuarine mud coast in its northern-most reaches, whereas further south there are gently sloping sandy beaches with low (1 to 3) dunes. The coastal plain varies in width from one to 12 km (Siddique, 1967). Although non-deltaic, this coastline is influenced by the dynamic forces operating in the adjacent Meghna estuary.

South from Chittagong to the Naaf River on the Bangladesh/ Myanmar border, the shoreline of the southern sub-zone is a wave-dominated sandy coast with a narrow coastal plain and 145 km of gently sloping sandy beaches backed by irregular sand dunes. In addition there is 15 km of rock cliffs. The coastal plain is backed by hills. In the far south of the southern sub-zone, Teknaf peninsula, which is 75 km long, separates the Naaf estuary from the sea. This peninsula has some hills reaching up to 300 m high, but is generally a low sand spit with an average width of 160 m at high tide (GOB, 1991), with 2 km wide sand flats exposed at low tide containing rock boulders.St. Martin’s Island, or Jinjiradwip, is the only island with living coral in Bangladesh. It is 8 km off the coast of Bangladesh. The island is approximately 8 $km^2$ in area, with numerous surrounding small islands. The island is founded on sandstone and is generally 3 m high, with a maximum elevation of 10 m (GOB, 1991).

## 1.2 Storm Surge Model for the Bay of Bengal

Storm surge is an extreme overflow of sea water on coastal region by the force of strong winds due to low pressure weather system. The storm surge is a long wave which increases the sea water level during the

Table 1: Classification of tropical storms

| Sl. No | Disturbance | Wind speed Km/hr | m/sec |
|---|---|---|---|
| 1. | Depression | 32-50 | 9-13 |
| 2. | Deep depression | 51-60 | 14-16 |
| 3. | Cyclonic storm | 61-89 | 17-23 |
| 4. | Severe cyclonic storm | 90-119 | 24-31 |
| 5. | Severe cyclonic storm with a core of hurricane wind | >120>32 | |

Source: G.D. Roy (1984)

cyclone as well as tide. It may exist from few minutes to several days depending on the cyclone size and speed of movement. Classification of tropical disturbance in the Bay of Bengal (Bangladesh perspective) is shown in Table 1. Of all the countries surrounding the Bay of Bengal, Bangladesh suffers most from storm surges. The main factors contributing to disastrous surges in Bangladesh may be summarized as (Ali 1979)

(a)shallow coastal water,
(b) significant pressure fall,
(c)coastal geometry and convergence of the bay,
(d)high astronomical tides,
(e)thickly populated low-lying islands,
(f)favourable cyclone track, and
(g)numerous number of inlets including world's largest river system (Ganga–Brahmaputra–Meghna).

Bangladesh is suffered by Tropical Cyclones almost every year. Eighty percent of the global causalities occur in Bangladesh due to complex coastal geometry of the northern tip of the Bay of Bengal. A review of the data shows a colossal loss of lives in Bangladesh from cyclones (Table-2).

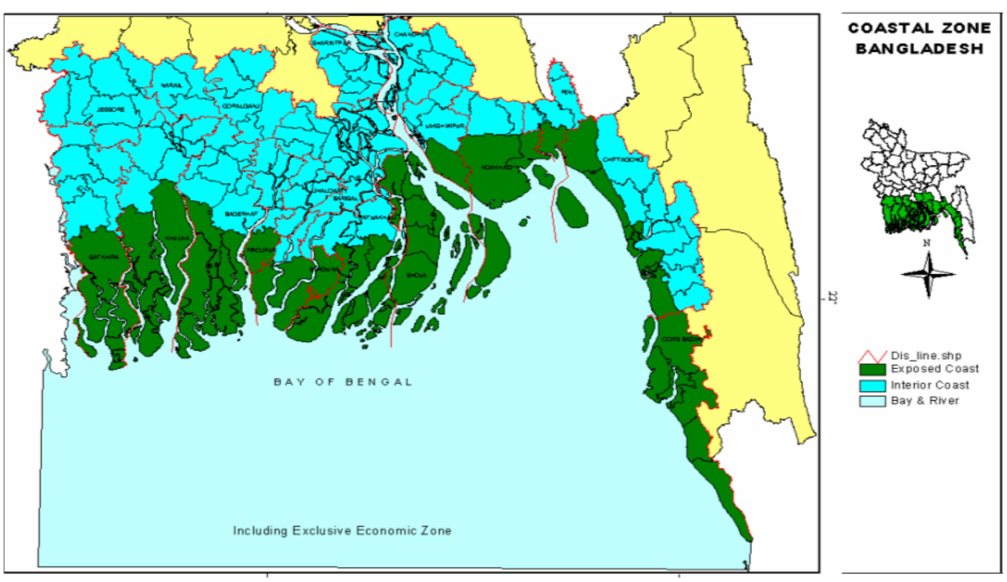


Fig.1: Coastal zone of Bangladesh (Source: Islam, 2004)

Table 2: Partial list of deaths in Bangladesh associated with severe cyclones since 1876

| Year | Country | Deaths |
|---|---|---|
| 1970 | Bangladesh | 300,000 |
| 1876 | Bangladesh | 200,000 |
| 1897 | Bangladesh | 175,000 |
| 1991 | Bangladesh | 140,000 |
| 1882 | Bangladesh | 40,000 |
| 1965 | Bangladesh | 19,279 |
| 1963 | Bangladesh | 11,520 |
| 1961 | Bangladesh | 11,466 |
| 1985 | Bangladesh | 11,069 |
| 1960 | Bangladesh | 5,149 |

Source: [S.K. Dube *el at.*]

## 2. IIT KHARAGPUR MODEL

Numerical computation has become a powerful and popular tool to study oceanographic natural disasters, coastal processes, etc. IIT Kharagpur Model is a numerical hydrodynamic storm surge model.The graphics software, GMT is used to visualize the results and Gost Script (GS) or ImageMagic is needed to install on computer for seeing postscript files. A dynamical storm model is usedfor computation of surface winds and ocean currents associated with cyclonic storms. The required meteorological andhydrological inputs are positions of the storm centre, radius of maximum wind,pressure drop and bathymetry data. Numbers of iterations depending on the time step, the latitude of the open sea, East-

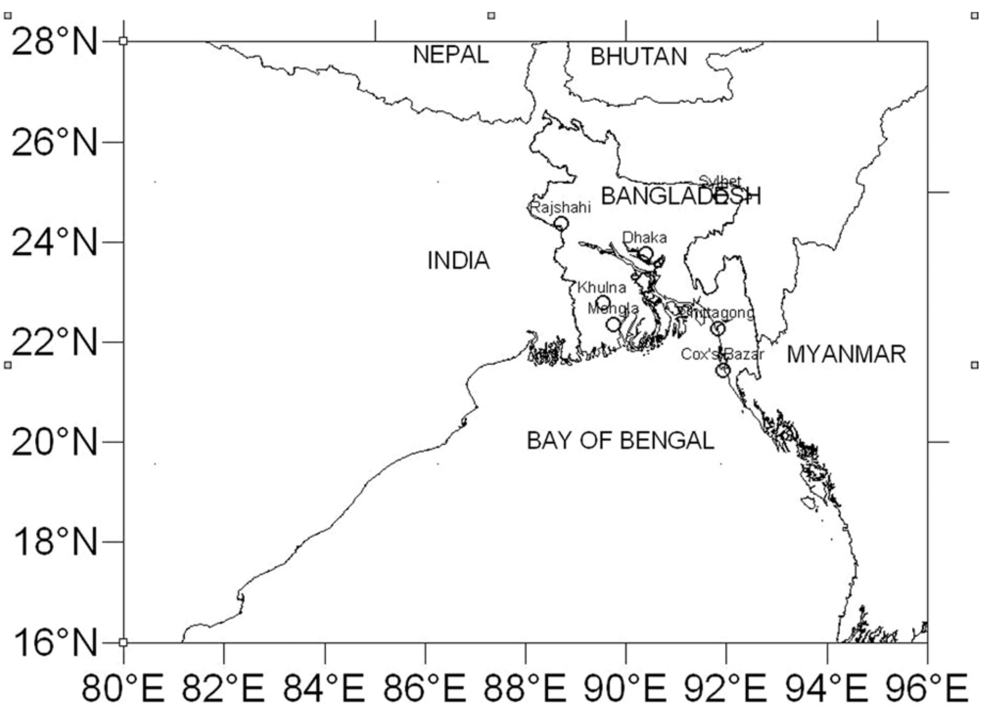


Fig.2:Map of Bangladesh showing complex coastal geometry

West and North-South extents of the area of interest and number of storm positions are also important inputs. The system can be operated on a PC or a workstation with Linux/Unix operating system. Recently Windows version of IIT Storm Surge Model is developed at IIT Delhi.

## 2.1 Procedures of Operating the Model: (Input File)

The procedures of operating the IIT Kharagpur Storm Surge Model are given below step by step
Step 1: Setup forecast domain by executing an appropriate window.
Step2: Provide arbitrary number of stations around the forecast place of landfall for peak surge display.
Step3: Input duration (Time up to landfall).
Step4: Input tropical cyclone characteristics

(a) Cyclone positions (Latitude- Longitude)
(b) Time level
(c) Radii of maximum winds (m)
(d) Pressure drop (h Pa)

Step5: Run the model.
Step6: Execute the result
Step7: Visualize the graphics in post script (PS)

## 2.2 Basic Equations

For the formulation of the model, systems of rectangular coordinates are used. The origin 'O' is denoted the equilibrium level of the sea surface, where 'Ox' point indicates the east, 'Oy' point indicates the north and 'Oz' is directed vertically upwards.

The basic hydrodynamic equation of continuity for the dynamical process in sea may be given by

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

And momentum equation

$$\frac{d\boldsymbol{V}}{dt}=-2\boldsymbol{\omega}\times\boldsymbol{V}-\frac{1}{\rho}\nabla\mathbf{p}+\mathbf{g}+\boldsymbol{F_r} \qquad (2)$$

Where $\mathbf{V} = u\vec{\imath} + v\vec{\jmath} + w\,\vec{k}$ and $\frac{d}{dt}=\frac{\partial}{\partial t}+u\frac{\partial}{\partial t}+v\frac{\partial}{\partial t}+w\frac{\partial}{\partial t}$

The above equation can be written in terms of u, v and w components, as below:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+2\,\omega v sin\varphi-2\omega\, w\cos\varphi+F_x \qquad (3)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}-2\,\omega\, u\sin\varphi+F_y \qquad (4)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}+2\,\omega u cos\varphi-g \qquad (5)$$

For large scale meteorology, $\omega \ll u, v$ so we avoid 'w' related term

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (6)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\ \frac{1}{\rho}\frac{\partial \tau_x}{\partial z} \qquad (7)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\ \frac{1}{\rho}\frac{\partial \tau_y}{\partial z} \, (8)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\ =-\frac{1}{\rho}\frac{\partial p}{\partial z}-g\quad =0 \qquad (Largescalemotion) \qquad (9)$$

Where f = 2 $\omega$ sin$\varphi$ is Coriolis parameter, and $u, v, w\ (omittingoverbar)$ are Renolds averaged component of velocity in the direction of x, y and z respectively and defined by

$u = \acute{u} + \bar{u}$ ; $v = \acute{v} + \bar{v}$ ; $w = \acute{w} + \bar{w}$ where $\acute{u},\ \acute{v},\ \acute{w}$are fluctuating (turbulence) velocity components and $\bar{u}, \bar{v}$ , $\bar{w}$ are average velocity components in x, y, and z directions respectively. Here p denotes pressure, t denotes time, ρ denotes density of sea water supposed incompressible and homogeneous, g is acceleration due to gravity, and$\tau_x$, $\tau_y$ are x and y components of frictional stress (Reynold stress) respectively.Molecular viscosity has been neglected in these equations. Using scale analysis in the vertical momentum equation (9), it reduces to the hydrostatic pressure approximation

$$\frac{\partial p}{\partial z}=-\rho g \qquad (10)$$

Let us consider the displaced position of the free surface as Z = $\zeta$(x,y,t) and position of the sea floor as Z = -h (x,y), so that the total depth of the water level is $\zeta$ + h . During a storm period the upper surface stress is generated due to circulatory wind of the storm and the bottom stress acts as the dissipation term, which is known as bottom friction. Now consider the x and y components of the surface stress as $T_x and T_y$, and the same for bottom friction as $F_x$ and $F_y$ respectively. Again consider the atmospheric pressure as $P_a$.Then the bottom and surface conditions are given by

At the bottom

$u = v = w = 0$ and $(\tau_x, \tau_y) = (F_x, F_y)$ at Z = -h (x, y) (11)

At the free surface

$(\tau_x, \tau_y) = (T_x, T_y)$ , $P = P_a$ and $w = \frac{\partial \zeta}{\partial t}+\ u\frac{\partial \zeta}{\partial x}+v\frac{\partial \zeta}{\partial y}$ at Z = $\zeta(x,y,t)$(12)

The last condition is known as kinematic surface condition and expresses the fact that the free surface is materially following the fluid.

Now integrating equations (6) - (8) in the vertical from Z = -h (x, y) to Z = $\zeta(x,y,t)$ and using boundary conditions (10) to (11) and also simplifying, one gets

$$\frac{\partial \zeta}{\partial t}+\frac{\partial}{\partial x}[\zeta\text{+h})u]+\frac{\partial}{\partial y}[(\zeta+h)v]=0 \qquad (13)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-fv=-g\frac{\partial \zeta}{\partial x}+\frac{T_x-F_x}{\rho(\ \zeta+h)} \qquad (14)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+fu=-g\frac{\partial \zeta}{\partial y}+\frac{T_y-F_y}{\rho(\ \zeta+h)} \qquad (15)$$

## 2.3 Initial and Boundary Conditions

The initial and boundary conditions take the form (For Stair-Step Method)

$u$ = 0   along y - directed boundary
$v$ = 0   along x-directed boundary and
$\zeta = u = v = 0$ for   t =0
at the open sea boundaries, the radiation type of conditions are applied which lead to ( Heaps 1973)
$u\cos\varphi + v\sin\varphi + (\frac{g}{h})^{1/2}\zeta = 0$

## 2.4 Bathymetry in the Model

Bathymetry is very essential parameter for prediction of surges. The equilibrium depth in the model is represented as the cubic interpolation functions of x and y. ETOPO2 datasets of USGS is used to calculate the bathymetry in the model.

## 2.5 Model Configuration

No. of East-West Grid Points : 331
No. of North-South Grid Points : 154
Time Step (DT) : 60 sec
No. of iterations to execute (KOUNT) : (KOUNT = DT $\times$ Hrs)

## 3. RESULTS AND DISCUSSION

The IIT Storm Surge Model is run for 18 hrs to simulate track and structure of the severe cyclone Sidr (2007) which was formed in the Bay of Bengal. The resolution of the Head of the Bay of Bengal model is high ($\Delta x$ =3.7 km, $\Delta y$ = 3.5 km, and $\Delta t$ = 60 sec). The actual track of severe cyclone Sidr (2007) is shown Fig.3 where time duration was 18 hrs and maximum value of peak surge was 5.34 m.

## 3.1 For Fast Moving Case

In this case, time duration is taken 12 hrs and simulated maximum value of peak surge for Sidr-2007 is 4.28 m which is shown in Fig.4.

## 3.2 For Slow Moving Case

In this case, time duration is taken 24 hrs and simulated maximum value of peak surge for Sidr-2007 is 6.24 m which is shown in Fig.5.

### 3.3 Land Falling at Different Coastal Zone

In this case, time duration is fixed (18 hrs) but changing the location (Three different coastal zones) and find the different values of maximum peak surge .In eastern coastal zone, examine point location (22.50 ° N, 91.80 °E), coastal shape is convex and simulated maximum value of peak surge is 3.84 m (Fig.6). In central coastal zone, examine point location (22.20 ° N, 90.70 °E), coastal shape is concave and simulated maximum value of peak surge is 4.20 m (Fig.7).In western coastal zone, examine point location (21.90 °N, 89.20 °E), coastal shape is complex and simulated maximum value of peak surge is 3.85 m (Fig.8).

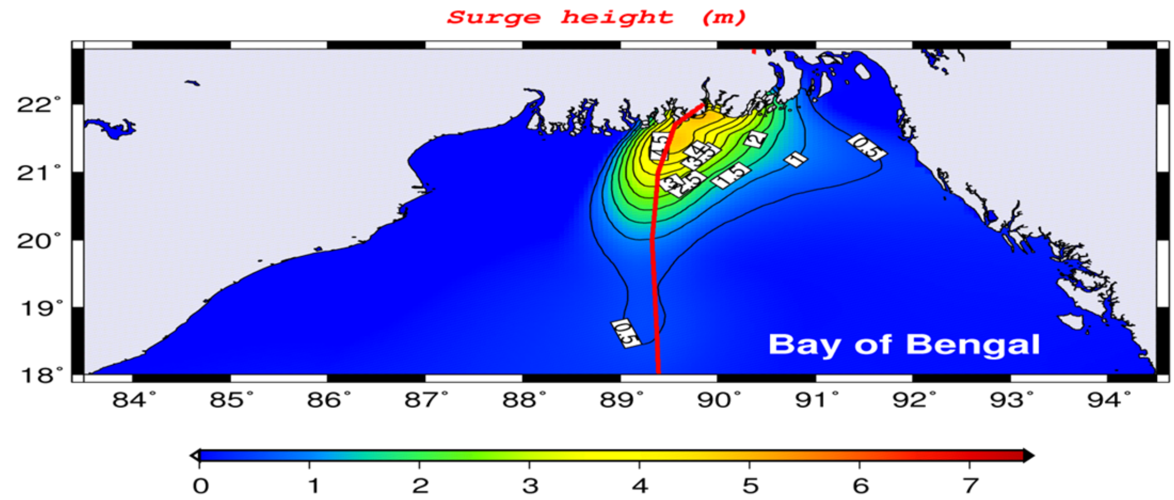


Fig.3: Storm surge from severe cyclone Sidr-2007

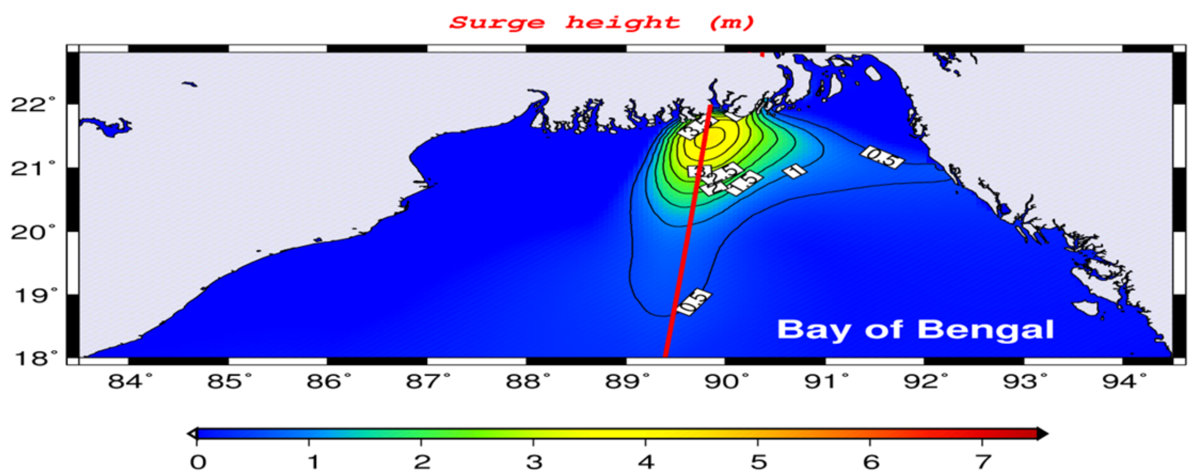


Fig.4: Storm surge of Sidr-2007 for fast moving

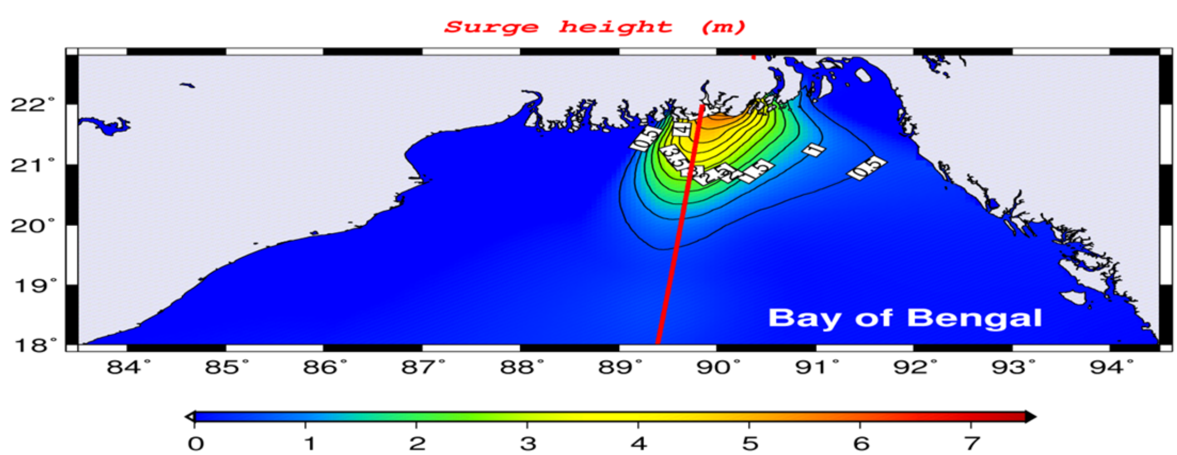


Fig.5: Storm surge of Sidr-2007 for slow moving

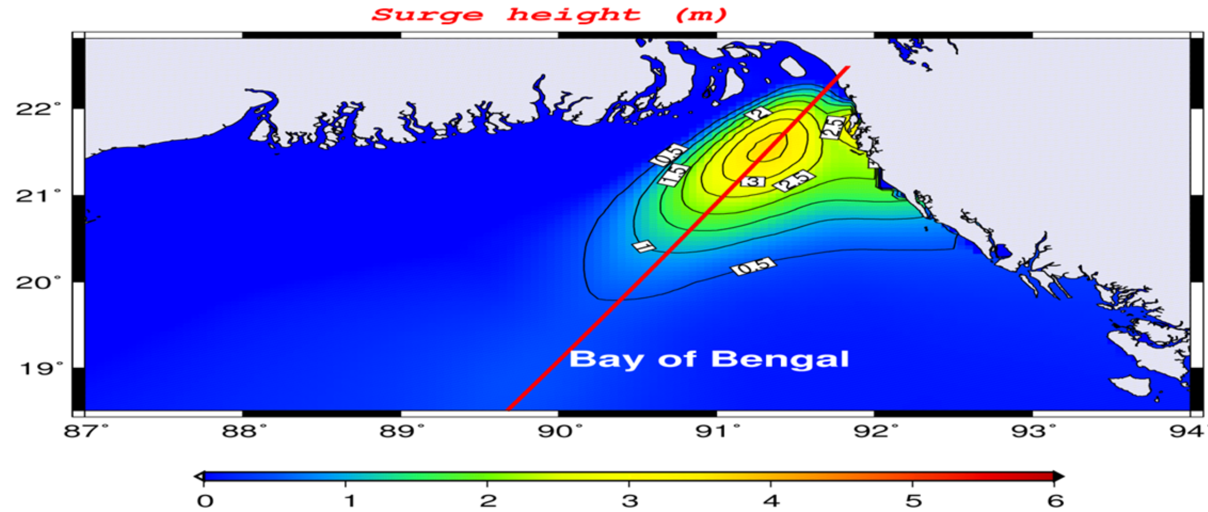


Fig.6: Storm surge of Sidr-2007 in eastern coastal zone

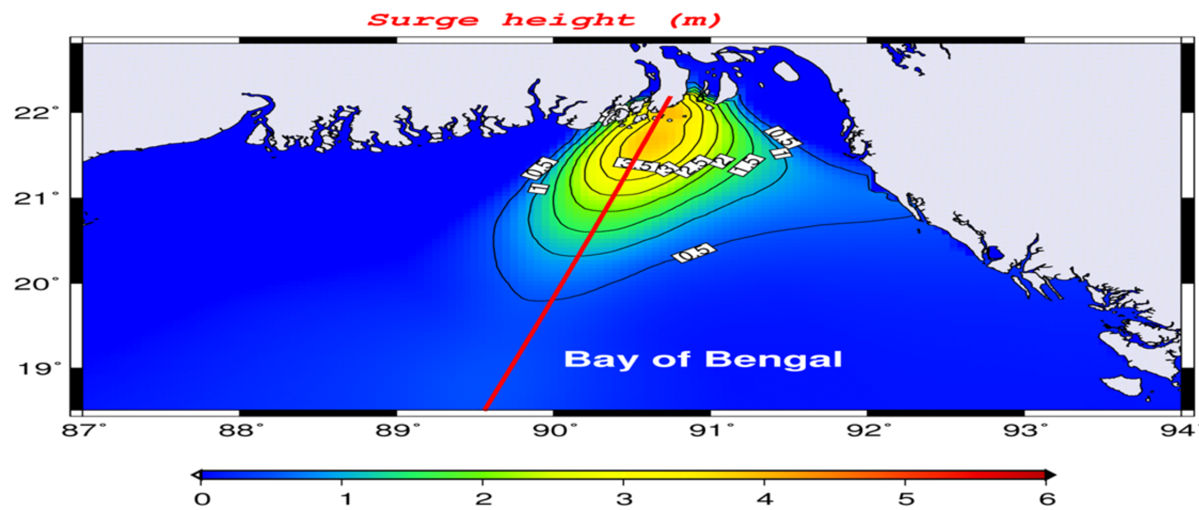


Fig.7: Storm surge of Sidr-2007 in central coastal zone

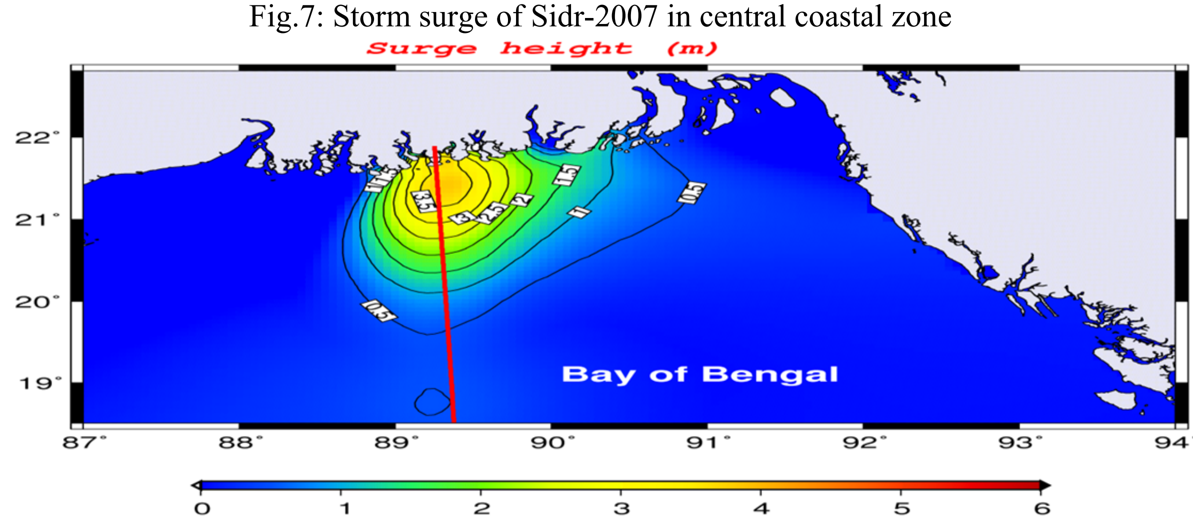


Fig.8: Storm surge of Sidr-2007 in western coastal

## 4. CONCLUSION

The location of the highest storm surge depends on the time duration and the angle of landfall for the Bay of Bengal which is shown in this paper. By this experiment it is shown that central coastal zone isthe most vulnerable region for storm surge in Bangladesh for its physical shape. It is also shown that storm surge height is more for slow moving case than the real case and less for fast moving case than the realcase.

## ACKNOWLEDGEMENT

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# SOL-GEL SYNTHESIS OF PHOSPHOROUS DOPED $TIO_2$ THIN FILMS AND ITS APPLICATION IN THE DYE DEGRADATION AIMING ENVIRONMENTAL PROTECTION

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## ABSTRACT

The sol-gel process is a wet-chemical technique (chemical solution deposition), which has been widely used in the fields of materials science, ceramic engineering, and especially in the preparation of photo catalysts. The electrons and holes photo generated from $TiO_2$ materials have strong reduction and oxidation power. This property allows them in the efficient decomposition of air and water pollutants. But the problem is that $TiO_2$ shows catalytic activity mostly in UV range light. In addition, the powder catalyst is difficult to reuse. Considering these issues we synthesized thin films of phosphorous doped $TiO_2$. Titanium (IV) isopropoxide and orthophosphorous acid have been used as titanium and phosphorous sources, respectively. Our synthesized films showed better photo-catalytic activity in the degradation of methylene blue compare to that of $TiO_2$ in the visible range. In addition, the films could simply be re-used. The synthesized film was characterized by the use of X-ray diffraction (XRD), and scanning electron microscope (SEM). Our results showed a way of low cost and re-usable photo-catalyst for environmental protection.

**Keywords:** Thin film, photo catalysts, Phosphorous, Methylene blue, Environmental protection, Sol-gel method.

### 1. INRODUCTION

An increasing interest toward sol-gel synthesis (alkoxide route) of the nanostructred oxide thin films is due the method advantages: simple and cheap technological equipment, low processing temperature for thin film densification and wide possibility to vary thin film properties by the composition of the solution. The method involves the hydrolysis of alkoxide in alcohol with a small amount of water, to form soluble intermediate species which condense, generating inorganic polymers.$TiO_2$ based vitreous films were among the first prepared ones. Recently, titanium dioxide has been extensively used for the decomposition of environmental pollutants as a possible alternative to conventional water treatment technologies. This is due to its numerous qualities: optical and electrical properties, high

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photocatalytic activity, chemical stability, low-cost non toxicity. In order to clean the water from chemically stable synthetic organic compounds, so-called advanced oxidation methods (AOMs) have been developed.$TiO_2$ photocatalysis belongs to AOMs processes that use energy to produce highly reactive intermediates of high oxidizing or reducing potential, able to destroy the target compounds [1]. Doping of metals to $TiO_2$ structures (powder and thin films forms) will promote efficient use of solar energy (i.e. to extend $TiO_2$ spectral region from UV to Visible light) in environmental protection (dye degradation, odor control and water purification).The disadvantages of conventional $TiO_2$ powder catalysts are its agglomeration property and it is difficult to separate the final particle-fluid for the catalyst recycling. To overcome the above mentioned problems, $TiO_2$ thin films would be a strong candidate as effective photo-catalyst. There are huge numbers of research efforts have been taken on the powder forms of $TiO_2$ [2].

Thin films are material layers ranging in thickness from one monolayer of atoms or molecules to several micrometers. The upper thickness limit is somewhat vague but usually thin film thicknesses are in the nanometer range, i.e. below 1μm. Thin films are all around us in everyday life. For example, all modern electronic devices rely on thin film technologies that allow the preparation of integrated circuits where a huge number of transistors or other devices are prepared simultaneously on a single silicon wafer. Thin films are used in optical components such as eyeglasses, camera lenses and filters to give scratch-proof and anti-reflection properties for example. Flat panel displays, mirrors, windows, CDs and DVDs are other examples which contain thin films. As part of the recent 'nanoboom' functional thin films in the nanometre range are often connected with nanotechnology although no real nanoscale phenomenon exists. Nevertheless, thin films are increasingly being applied to all sorts of new applications and the existence of a nanoscale effect is not really that important as long as the film has all the desired properties. One of these new application areas is photocatalysis which is the main topic of this thesis. Photocatalysis is the catalysis of a spontaneous chemical reaction where light is required for the catalyst to function. A photocatalyst can transform light energy into chemical energy by creating strong oxidative and reductive species which greatly enhance the rate of the spontaneous reaction. During this transformation the photocatalyst itself remains unchanged. Photocatalysts are heterogenous catalysts usually in the form of a powder or a thin film. Studies related to photocatalysis have increased immensely over the past few years and currently well over 1000 research papers are published annually [3].

Bangladesh is extending its economy to industrialization. Where dye degradation and odour control as well as water pollution are major problems in respect to environmental side. In response of those problems, one of the ideas to use metals doped $TiO_2$ for the photodegradation efficiency / odor control ability and purification of organic pollutants in water. It is known that solar energy could be used to get holes and electrons from $TiO_2$ with some doping by extending the spectral region from UV to visible ranges. Those doped $TiO_2$ thin films could be used specifically to the following purposes: i) photodegradation of organic dyes from industrial effluent and their odor control and ii) water purification. The experimental methods are planned to be used sol-gel coating; dip and spin coatings. It is well known that sol-gel is one of the most cheapest and easy experimental method to get nanoparticles and thin films. It does not need big and very sophisticated instrumental facilities. It is hoped that the nation would be effectively beneficial in addition to the students concerns of this university.

## 2. EXPERIMENTAL

### 2.1. Apparatus and Reagent:

Different glass wares, Hot plate, pH meter, Conductivity meter, reflux condenser, heating mantle, Centrifugal machine, Mufle furnce (80-1200°C), drier, $N_2$ gas cylinder, Rotary evaporator, Magnetic stirrer, etc. Titanium iso-propoxide (TIP), Hydrochloric acid, ethanol, orthophosphoric acid, Triethyl amine, Methylene Blue (MB) distilled water etc.

### 2.2. Titanium dioxide solution preparation:

1.0 ml, (3.42 mmol) Titanium Isopropoxide (TIP) was added to ethanol 6.075 ml(143.64 mmol) under vigorous stirring conditions and then 0.24 ml(1.7 mmol) triethyl amine was added as a stabilizer of the solution and stirred (200 rpm) for 2–3 min under an inert environment. The required inert environment was made by nitrogen gas flow through the system (solution-A). A second solution was prepared separately as follows: hydrochloric acid (0.52 ml, 16.416 mmol) and water (0.13 ml, 5.13 mmol) were added to 10 ml ethanol and mixed well by a magnetic stirrer (200 rpm) (solution-B). The two solutions were then mixed drop wise and stirred vigorously for 60 min under $N_2$ gas flow. The formed $TiO_2$ sol was transparent, quite stable and highly sensitive to the amount of triethylamine and water.

### 2.3. 2%Phosphorous doped $TiO_2$ solution preparation:

For the preparation of Phosphorous doped $TiO_2$, 0.0132ml, 0.216mmol $H_3PO_4$ was added to the mixture of solution-A and solution-B.

### 2.4. Thin film preparation:

The pure $TiO_2$ and P-$TiO_2$ thin film have been obtained by the dip coating on microscopic slide substrates, finally calcinated at $450^oC$ temperature for one hour.

### 2.5. Photocatalytic activity:

The photocatalytic activity of the samples 2× (6 cm × 1 cm) was evaluated by the degradation of methylene blue. The concentration of methylene blue was maintained at 30 mg/L for all photocatalytic reaction. The photocatalytic measurement was performed in a 60 mL beaker which was placed on the top of the magnetic stirrer, maintaining the temperature of methylene blue to about $25^o$c.they are placed at affixed distance from the lamp. A 1000 W Hg-lamp was employed as the light source. The aqueous solution of methylene blue (50 mL) and two pieces of glass of thin films were in the reactor to perform photocatalytic activity experiments. Before turning on the Hg-lamp, the solution was adjusted at pH = 9.5. After the light was turned on, a certain amount of methylene blue was retrieved from the reactor for analysis at different time intervals. The final samples were analyzed by double beam UV-visible spectrophotometer (UV-1800 Series**,** UV-Vis spectrophotometer, Shimadzu Corporation, Kyoto, Japan) at its characteristic absorption band (462 nm).

## 3. RESULT AND DISCUSSION

When $TiO_2$ is doped with Phosphorous its catalytic activity is increased under visible light irradiation. Under the same experimental conditions 50ml $1\times 10^{-5}$ M Methylene Blue solution was used.

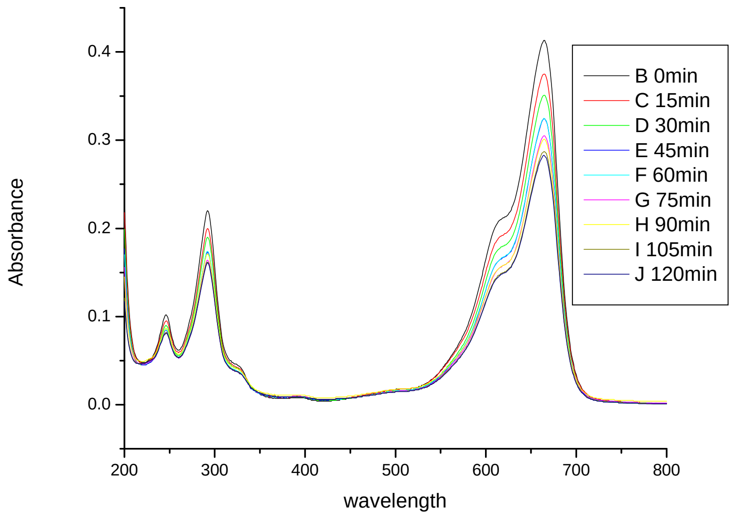


Fig 1: Photodegradation of methylene blue by pure $TiO_2$ thin film under visible light irradiation. $[MB]=1\times10\text{-}^{5}$, Time =120 min.

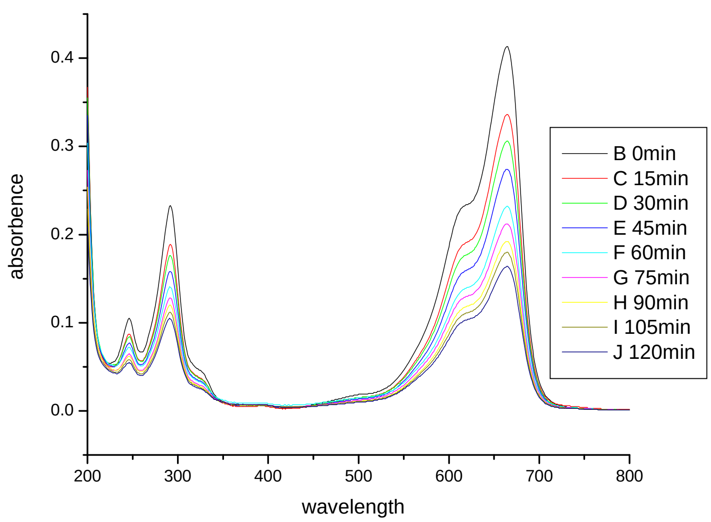


Fig 2: Photodegradation of methylene blue by P-doped $TiO_2$ thin film under visible light irradiation. $[MB]=1\times10\text{-}^{5}$, Time =120 min.

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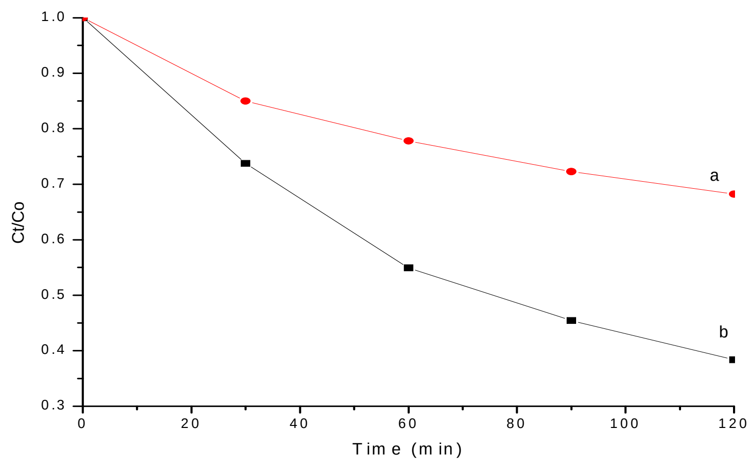


Fig 3: Photodegradation of methylene blue (MB) by catalyst (a) $TiO_2$ film (b) P-doped $TiO_2$ under visible light irradiation of MB.

## 4. CONCLUSION

Pure and S-doped $TiO_2$ nanometer films coated on glass substrates for environmental protection were prepared by the alkoxide route ot the sol-gel process. The influence of the dopant, number of coating and thermal treatment on the films sructur was established. The sol-gel was tested for the degradation of Methylene Blue (MB) organic compounds from aqueous solution. The MB removal yield is better by P-doped $TiO_2$ films than the pure $TiO_2$ thin film.

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# STUDIES OF PHOTOCATALYTIC ACTIVITY OF DIFFERENT DOPED NANO PHOTOCATALYSTS FOR DEGRADATION OF COMMERCIAL DYE

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## ABSTRACT

The present study involves the photo catalytic degradation of Methyl Orange (MO), employing heterogeneous photo catalytic process. Photo catalytic activity of various semiconductors such as sulfer doped, titanium dioxide (S-TiO2), zinc oxide (S-ZnO), stannic oxide (S-SnO2), has been investigated. An attempt has been made to study the effect of process parameters viz.,amount of catalyst, concentration of dye and pH on photo catalytic degradation of MO. The experiments were carried out by irradiating the aqueous solutions of dyes containing photo catalysts with UV and solar light. The rate of decolorization was estimated from residual concentration spectrophotometrically. Similar experiments were carried out by varying pH (2–10) and the amount of catalyst (0.5–3.0 g/l). The experimental results indicated that the maximum decolorization (more than 90%) of dyes occurred with S-ZnO catalyst and at basic pH and it required 60 min and the activity order found as S-ZnO>S-TiO2>S-SnO2. The percentage reduction of MO was estimated under UV/solar system and it was found that COD reduction takes place at a faster rate under solar light as compared to UV light. The performance of photo catalytic system employing S- ZnO/solar light was observed to be much better than S-ZnO/UV system.

**Keywords:** Photo catalysis, Decolorization, Azo Dye, Methyl Orange, S-ZnO,S-TiO2,S-Sno2

## 1. INTRODUCTION

Textile industries produce large volume of colored dye effluents which are toxic and non-biodegradable. These dyes create severe environmental pollution problems by releasing toxic and potential carcinogenic substances into the aqueous phase. Over the last decades, the increasing demand for dyes by the textile industry has shown a high pollutant potential. It is estimated that around 10-15% of dyes are lost in the effluent during the dyeing processes. Various chemical and physical processes such as precipitation, adsorption, air stripping, flocculation, reverse osmosis and ultra filtration can be used for color removal from textile effluents. However these techniques are non-destructive, since they only transfer the non-biodegradable matter into sludge, giving rise to new type of pollution, which needs further treatment.Recently there has been considerable interest in the utilization of advanced oxidation processes (AOPs) for the complete destruction of dyes. AOPs are based on generation of reactive species such as hydroxyl radicals that oxidizes a broad range of organic pollutants quickly and non-selectively. AOPs include photocatalysis systems such as combination of semiconductors and light, and semiconductor and oxidants.

Heterogeneous photocatalysis has emerged as an important destructive technology leading to the total mineralization of most of the organic pollutants including organic reactive dyes.Titanium dioxide (TiO2) is generally considered to be the best photo catalyst and has the ability to detoxification water from a number of organic pollutants. However widespread use of TiO2 is uneconomical for large scale water treatment, thereby interest has been drawn towards the search for

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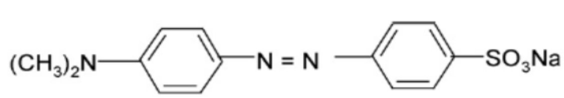
suitable alternatives to TiO2. Many attempts have been made to study photo catalytic activity of different semiconductors such as SnO2, ZrO2, CdS and ZnO. Lizama et al. reported the photo catalytic decolorization of Reactive Blue 19 (RB-19) in aqueous solutions containing TiO2 or ZnO as catalysts and concluded that ZnO is a more efficient catalyst than TiO2 in the color removal of RB-19. Daneshvar et al. reported that zinc oxide (ZnO) is a suitable alternative to TiO2 for the degradation of Acid Red 14, an azo dye, since its photodegradation mechanism has been proven to be similar to that of TiO2. The biggest advantage of ZnO is that it absorbs over a larger fraction of solar spectrum than TiO2. For this reason, ZnO photo catalyst is the most suitable for photo catalytic degradation in the presence of sunlight.

In Bangladesh being a tropical country, sunlight is abundantly available natural energy source, which can be conveniently exploited for the irradiation of semiconductor. Dyes can be degraded in the presence of photo catalyst upon irradiation with solar light because of their absorption in the visible region. Therefore, in order to shift the optical absorption of $MO_x$ into the visible region and prevent charges from the recombination on the photo catalysts surface, various attempts have been made. For example, it can be achieved by doping transitional metal ions, such as La, Ni, Mn and Fe, or by doping N and S[10-13]. Since Bangladesh being a tropical country, so to use this energy if we dope sulphur in $Mo_x$ then $MO_x$ will show maximum absorption in the visible region by decreasing band gap. Methyl Orange (MO) is an azo dye and also has a variety of uses in textiles, foodstuffs, pulp and paper, and leather industry. The release of these complex dyes and their products in the environment cause toxicity problems. So an attempt has been made to study the decolorization of this dye. In this study, various Sulfur doped semiconductor photo catalysts (S-$TiO_2$,S-ZnO and S-$SnO_2$) were compared for the decolorization efficiency of aqueous solution of the dye MO. After the selection of the most active catalyst, subsequent experiments were conducted to investigate the effects of various process parameters (catalyst loading, pH, and initial dye concentration) on the process performance.

## 2. EXPERIMENTAL SECTION

### 2.1. Materials

Titania P-25 (surface area 50m2/g) was obtained from BD, SnO2 was obtained from S.D.Fine Chemicals,India. ZnO (5m2/g) and Methyl Orange purchased from Merck and were used without further purification. Double distilled water was used for preparation of various solutions. pH of the solutions was adjusted with 1M HCl or 1M NaOH. COD (open reflux) was estimated by using standard methods

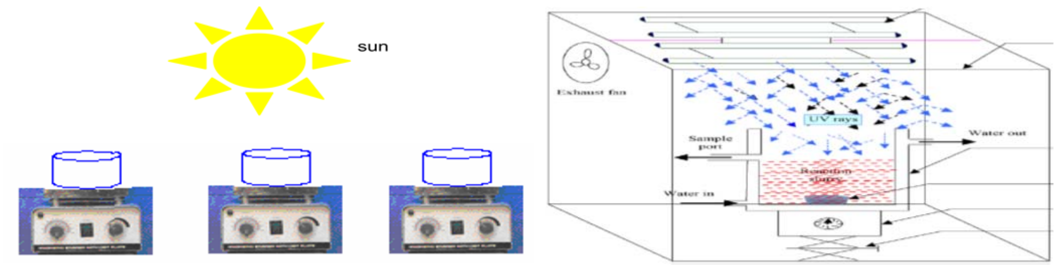


. Fig:1. structural formula of Methyl orange

### 2.2. Instruments

Photochemical degradation was carried out in the Shallow pond slurry reactor under solar light. UV experiments was carried out in specially designed double walled reaction vessels (volume 500 ml) in the UV chamber.Constant stirring of solution was insured by using magnetic stirrers. The solar experiments were performed in daytime between 10 a.m. and 4 p.m. The spectra were taken with UV–

Vis spectrophotometer (Hitachi U-2006); pH meter (Thermo Orion 920A) was used to adjust the pH of the solution.




(1) (2)

Fig 2 (1) Shallow pond slurry reactor and (2)UV chamber reactor

### 2.3. Experimental Procedures

10% TiO2 and 1% thiourea is mixed in a porceline morter and grind at 3 hours then convert these into disk and then calcinated at 650°C for 2 hours. After calcinations repeated the process again and again and prepared sulfur doped TiO2 nanoparticles(S-TiO2) of photo catalysts.By the similar way and in same percentase (S-ZnO) and (S-SnO2) prepared. To 100 ml of dye solution, photo catalyst was added and suspension was subjected to irradiation. Experiments were carried out under solar light as well as under UV light. The aqueous suspension was magnetically stirred throughout the experiment.At different time intervals aliquot was taken out with the help of a syringe and then filtered through Millipore syringe filter of 0.45_m. Then absorption spectra were recorded and rate of decolorization was observed in terms of change in intensity at $\lambda$max of the dyes. The decolorization efficiency (%) has been calculated as:Efficiency (%) =$(C_0 - C_t)/C_0 \times 100$ $\approx(A_o-A_t)/A_o \times 100$ .where C= concentration, A= absorbance,0= initial,t-at t time. Similar experiments were carried out by varying the pH of the solution (pH 2–10), concentration of dye (25mg/l) and catalyst loading (0.25–2.0 g/l).

## 3. RESULT AND DISCUSSION

Methyl Orange dye have different functional groups (Fig. 1).MO is an azo dye having sulphonate (SO3−) and azo groups.Showing absorption peak at 523 nm.The photodegradation experiments were carried out under UV light and solar light. Different catalysts viz., S - TiO2,S-ZnO,S-SnO2,and undoped Zno were investigated for their decolorization efficiency.The rate of decolorization was recorded in terms of change in intensity of characteristic peaks.

### 3.1. UV–Vis spectra of dyes

Figs. 3 show typical time dependent UV–vis spectrum Of MO during photoirradiation with S-ZnO catalyst. MO shows absorption peaks at 272 and 462 nm.The rate of decolorization was recorded with respect to the change in intensity of absorption peaks at 462 and 523 nm. The absorption peaks, corresponding to dyes diminished and finally disappeared during reaction,which indicated that the dyes had been degraded.

### 3.2. Decolorization of dyes using various photo catalysts

Investigations were carried out with different semiconductors viz., S-TiO2, S- ZnO,and S- SnO2, in order to select the most effective catalyst for degradation of dye( methyl orange). Band gap of these semiconductors are 3.2 for both TiO2,ZnO and 3.9 for SnO2.The photocatalysed decolorization of a

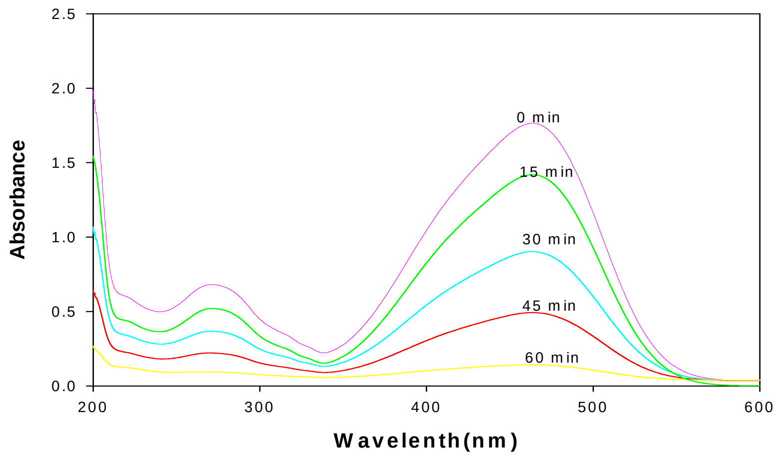



Fig 3 Absorbance spectra of Methyl Orange during the course of reaction under solar light.

dye in solution is initiated by the photo excitation of the semiconductor, followed by the formation of electron–hole pair on the surface of catalyst (Eq.(1)). The high oxidative potential of the hole (h+VB) in the catalys permits the direct oxidation of the dye to reactive intermediates(Eq. (2)):(MO/MO2)metal oxide + *hv* → (MO/MO2)(e−CB + h+VB) (1) h+VB + dye → dye•+ → oxidation of the dye (2)Another reactive intermediate which is responsible for the degradation is hydroxyl radical (OH•). It is either formed by the decomposition of water (Eq. (3)) or by reaction of the hole with OH− (Eq. (4)). The hydroxyl radical is an extremely strong, non-selective oxidant (*E*0 = +3.06 V) which leads to the partial or complete mineralization of several organic chemicals [1]:

h+VB + H2O → H+ + •OH (3)

h+VB + OH− → •OH (4)

•OH + dye → degradation of the dye (5)

Initially blank experiments were performed under visible irradiation without addition of any catalyst and negligible decolorization was observed. Then photo catalytic experiments were carried out using different catalysts, various pH values (2, 4, 8,and 10) at fixed dye concentration (25 mg/l), and catalyst loading of 1 g/l for 1h. The results indicated that S-ZnO exhibits higher photo catalytic activity than the others, especially S- TiO2 for dye. Figs. 4 depict the photo catalytic efficiency of various catalysts for MO at different pH values.The same trend was observed for undoped MOx in earlier findings with azo reactive dyes [2,3]. This was explained as ZnO is having greater quantum efficiency than TiO2 and others. On the other hand SnO2 exhibits less activity because their wide band gap and light energy is not sufficient to excite this catalyst. The order of decolorization efficiency of various photo catalysts is S- ZnO > S-TiO2 > S-SnO2 > for decolorization of MO. Besides higher efficiency, the other advantage of ZnO is its low cost. Thus subsequent experiments were carried out with S-ZnO.

### 3.3. Adsorption behavior of dyes

In order to investigate the adsorption/desorption behavior of MO at different pH values, the suspension were prepared by mixing 100 ml of dye solutions (25 mg/l) for 60 min with fixed catalyst dose (1 g/l for MO). The suspensions were kept for given times in the dark under the condition of stirring, and then filtered after being centrifuged. The absorbance of the filtrate was then measured at the maximum band 462 nm to determine the concentration of dyes.

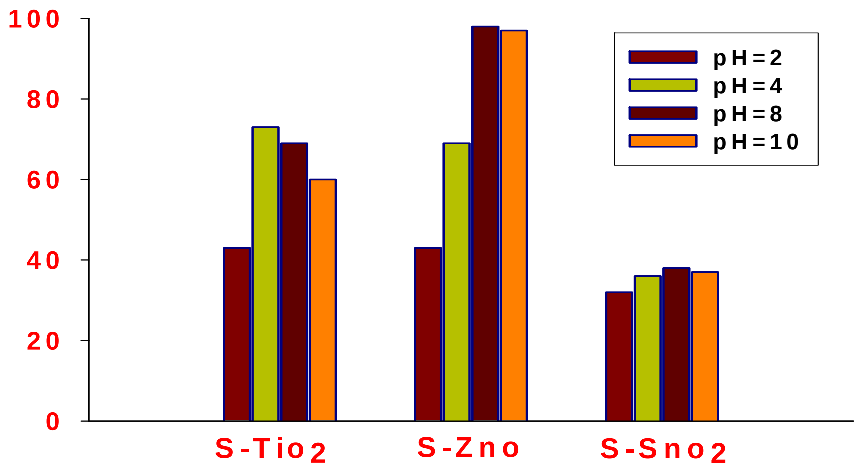



Fig :4:Photo catalytic efficiency of various catalysts for Methyl Orange at different pH (dye concentration 25 mg/l; catalyst dose 1 g/l; under solar light.

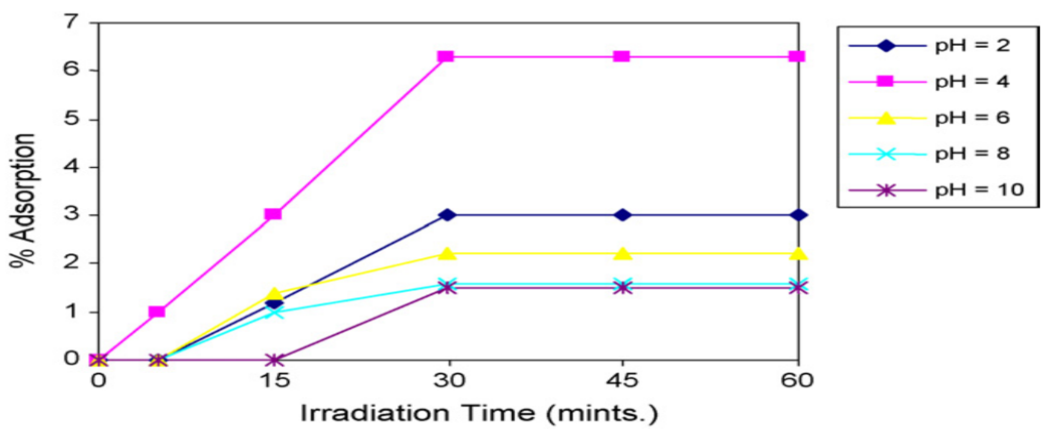



Fig. 5. Adsorption behavior of MO at different pH.

From the results, it was noticed that the adsorption/desorption equilibrium at different pH values was reached at about 30 min of equilibration time.Hasnat et al. [4] reported similar findings during comparative photo catalytic studies of decolorization of an anionic and a cationic dye.

### 3.4. Decolorization of dyes by S-ZnO as photo catalyst unde solar light:

The experiments were carried out to study the degradation of MO employing S-ZnO as catalyst under solar light.Various parameters which effect the decolorization efficiency such asbcatalyst loading (0.25–2.0 g/l), pH (2–10), initial concentration of dye (25mg/l) time (60 min) of decolorization were assessed under solar light.

#### 3.4.1. Effect of catalyst concentration

The decolorization efficiency for various catalysts loading for MO has been depicted in Fig. 6

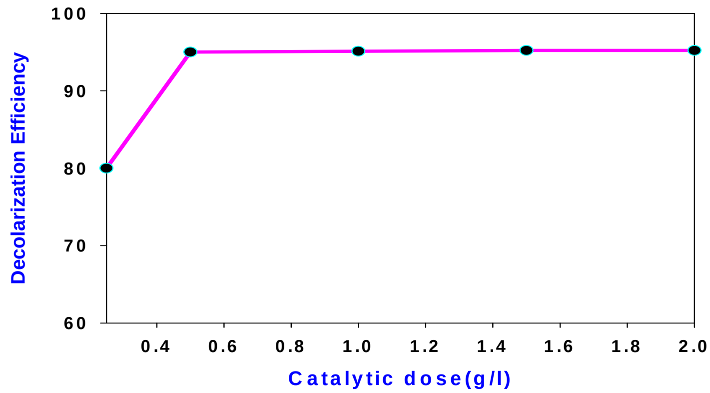



Fig. 6. Effect of catalyst dose on decolorization efficiency of Methyl Orange (dye concentration 25 mg/l; pH neutral).

Fig. 6 reveals that catalyst loading from 0.25 to 1.0 g/l, maximum decolorization is observed with 1.0 g/l.Thus it can be concluded that higher dose of catalyst may not be useful both in view of aggregation as well as reduced irradiation field due to light scattering.Therefore the catalyst dose 1 fixed for MO solution for further studies. [5,6]

### 3.4.2. Effect of pH

Wastewater containing dyes is discharged at different pH; therefore it is important to study the role of pH on decolorization of dye. To study the effect of pH on the decolorization efficiency, experiments were carried out at various pH values, ranging from 2 to 10 for constant dye concentration (25 mg/l) and catalyst loading (1 g/l). Fig. 7 shows the color removal efficiency of MO as a function of pH.

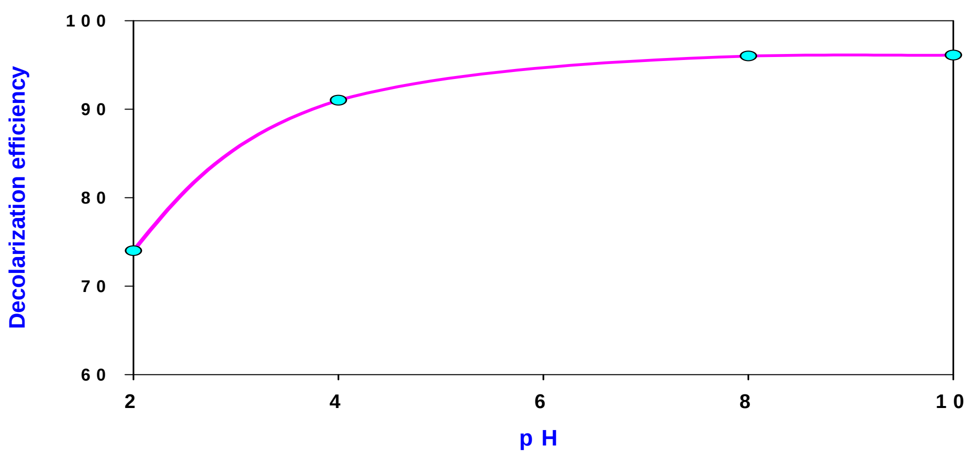



Fig. 7. Effect of catalyst dose on decolorization efficiency of Methyl Orange (dye concentration 25 mg/l; pH neutral).

It has been observed that the decolorization efficiency increases with increase in pH exhibiting maximum rate of degradation at pH 8 for MO solution. Similar behavior has also been reported for the photo catalytic efficiency of ZnO for decolorization of azo dyes [7,3,8]. The presence of large quantities of OH− ions on the particle surface as well as in the reaction medium favors the formation of OH• radical, which is widely accepted as principal oxidizing species responsible for decolorization process at neutral or high pH levels and results in enhancement of the efficiency of the process

[3].Fig. 7. Effect of pH on decolorization efficiency of Methyl Orange(dye concentration 25 mg/l).The experimental results revealed that higher degradation of the dye occurred in basic region than in case of acidic solution .For MO, rate of photodecolorization increased with increase in pH, exhibiting maximum efficiency (98.5%) at pH 8, beyond which the rate of degradation remained constant. Also 97.9% decolorization was observed at pH value 10. Although the adsorption of dye molecules are low at alkaline pH, the possible reason for this behavior may be the formation of more •OH radicals. Sakthivel et al. [9] observed similar behavior in their studies on Acid Brown 14 dye. The interpretation for the same could be amphoteri behaviors of the S-ZnO catalyst.

### 3.4.3. Kinetic study

Figs. 8 show the kinetics of disappearance of MO for an initial concentration of 25 mg/l under optimized conditions. The results show that the photo catalytic decolorization of dye in aqueous S-ZnO can be described by the first order kinetic model, , $\ln(A0/At) = kt$, where $C0$ is the initial concentration and $C$ is the concentration at any time, $t$.

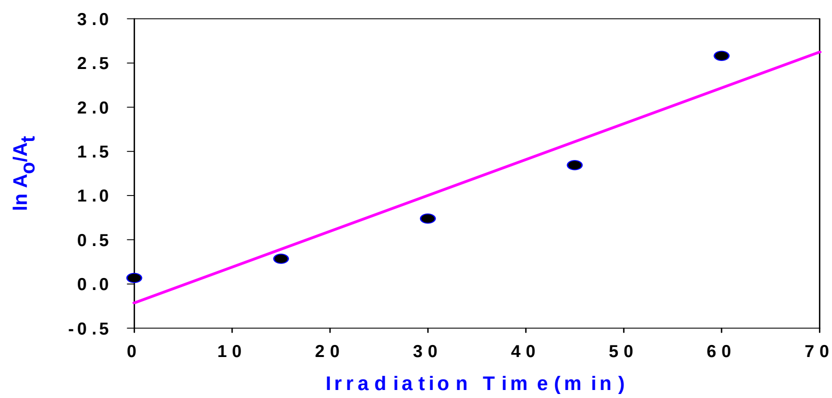



Fig. 8. Kinetic analysis of Methyl Orange under solar light.

The semi-logarithmic plots of the concentration data gave a straight line.

### 3.6. Comparison of solar/UV irradiation on photo catalytic activity for Methyl Orange.

This result indicate that MOx shows maximum absorption in the visible region.

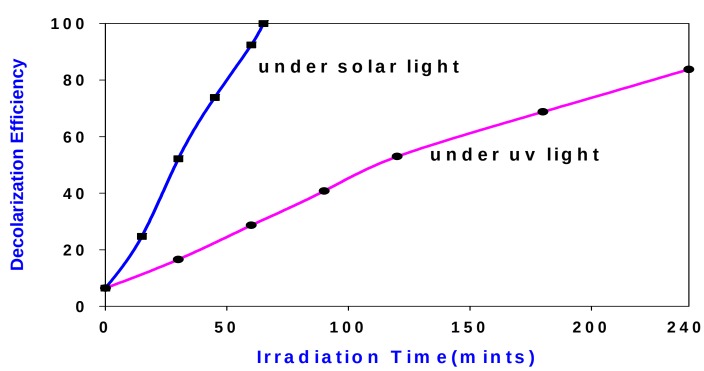



Fig. 9 Comparison of solar/UV irradiation on photo catalytic activity of S-ZnO for Methyl Orange.

### 3.7.Comparison of solar irradiation on photo catalytic activity of ZnO and S-ZnO for Methyl Orange.

This result shows that doped ZnO shows better efficiency than undoped ZnO.So doping was successful

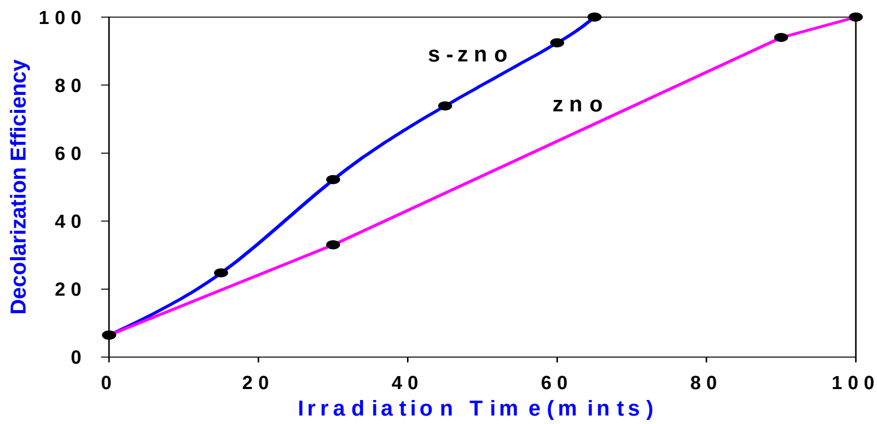
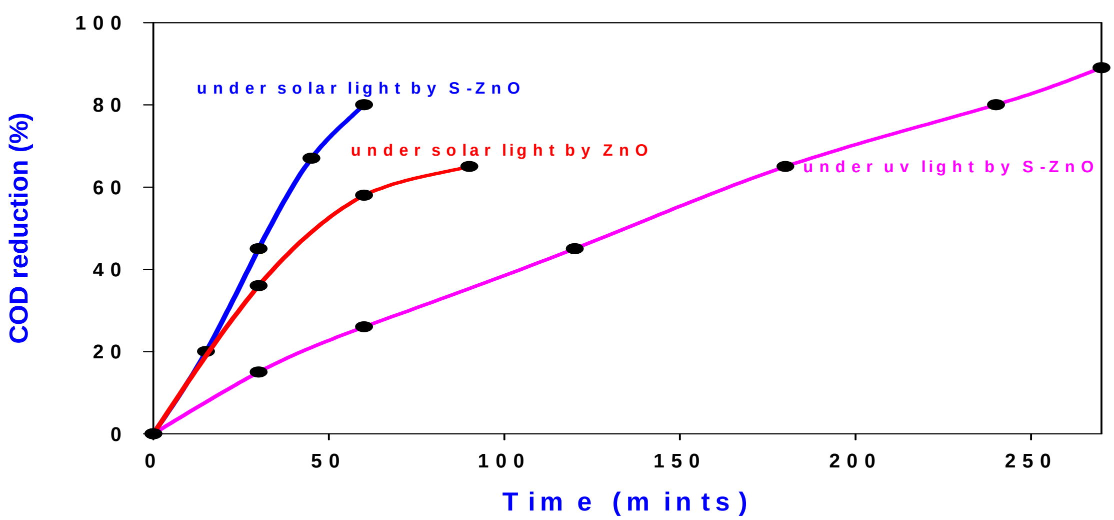



Fig:10:Comparison of solar irradiation on photo catalytic activity of ZnO and S-ZnO for Methyl Orange.

### 3.8. Mineralization studies of dye:

As the reduction of chemical oxygen demand (COD) reflects the extent of degradation or mineralization of an organic species, the percentage change in COD was studied for dye samples (initial concentration 25 mg/l) under optimized conditions (catalysts dose 1 g/l, pH 8) as a function of irradiation time using UV Solar light for S-ZnO and undoped ZnO. The results are depicted in fig20. It can be seen that under UV light, the percentage COD reduction was 89% in 270 min for S-ZnO. Whereas under solar irradiation, 80% COD reduction was achieved in 60 min for S-ZnO.Again only 65% COD reduction was achieved in 90 min by Zno.




The COD reduction is lesser than percentage decolorization which may be due to the formation of smaller uncolored products. Therefore, it seems that to achieve complete mineralization of dyes, longer irradiation time is required.

## 4. Conclusions

Comparison of photo catalytic activity of different semiconductors has clearly indicated that the S-ZnO is the most active photo catalyst for decolorization of MO than S-TiO2 and S-SnO2. Moreover,photocatalytic activity of S- ZnO is greater in the presence of solar light as compared to UV light. Experimental results indicated that the decolorization of dyes is facilitated in the presence of catalyst and were favorable in basic region. The initial rate of photodecolorization increased with increase in catalyst dose up to an optimum loading. Further increase in catalyst dose showed no effect. As the initial concentration of dyes was increased, the rate of decolorization decreased in each dye. The photo catalytic decolorization followed pseudo-first order kinetics. The COD analysis revealed that complete mineralization of dyes could be achieved in some longer irradiation times.

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# BORON DOPED TIO2 THIN FILMS FOR ENVIRONMENTAL PROTECTION

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## ABSTRACT

$TiO_2$-based systems have attracted an increasing interest for their potential uses as photo catalysts under visible-light irradiation. The electrons and holes photogenerated in the $TiO_2$ photo catalyst have strong reduction and oxidation power, being able to drive a variety of reactions. These properties allow them in efficient decomposition of air and water pollutants. The photo catalytic degradation of pollutants using $TiO_2$ photo catalysts is very attractive for applications to environmental protection, as a possible alternative to conventional water treatment technologies. Metal and nonmetal doping is one of the typical approaches to extend the spectral response of a wide band gap semiconductor to visible light, especially from UV to visible range. In these work thin films of $TiO_2$ and boron doped $TiO_2$ have been prepared by a simple sol-gel route. Titanium (IV) isopropoxide and boric acid have been used as titanium and boron sources, respectively. Finally, the photo catalytic activities of those doped and un-doped thin films have been checked for the decomposition of methylene blue. The boron doped $TiO_2$ film degrade the dye solution 50% after 2 hours irradiation, where as undoped one degrade only 30% after two hours irradiation.

**Keywords:** Thin film, photo catalysts, Methylene blue, Boron, Environmental Protection, B doped $TiO_2$, water pollutants

## 1. INTRODUCTION

Titanium dioxide ($TiO_2$) is one of the most interesting nanostructure materials because it exhibits excellent optical, electrical, photocatalytic and thermal properties. Since the reported of the photocatalytic splitting of water using rutile $TiO_2$electrodes in 1972 [1], the interest in $TiO_2$as a strategic material for environmental photocatalysis and photoelectrochemical solar energy conversion has continuously increased. They are mainly related to photocatalysis, photovoltaic devices, dye-sensitized solar cells, sensors, paintings and potential tool in cancer treatment [2–7]. The removal of organic pollutants is one of the main application fields of water photo catalytic decontamination. Industrial dyestuffs, including textile dyes, are recognized as being an important environmental warn. About 15% of the total world production of dyes is released in the textile effluents [8–10], inducing eutrophication and the generation of dangerous by-products through chemical reactions in the wastewater phase, with detrimental effects on the environment and the human health. In particular, azo compounds, representing more than half of the dyes market, are suspected to be carcinogenous agents as they form toxic aromatic amines [11, 12].Traditional physical techniques for pollutant removal (adsorption on activated carbon, ultra filtration, reverse osmosis, coagulation by chemical agents, . . .) do not result in dyes degradation, but only produce their transfer from water to another phase [13–15]. In a similar way, conventional biological treatment methods are unsuccessful for the abatement of most dyes [16, 17]. For such reasons, advanced oxidation processes (AOPs) based on the generation of reactive species, such as hydroxy radicals (_OH), are gaining a remarkable attention

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for the oxidative degradation of several pollutants. Among AOPs, $TiO_2$-based heterogeneous photocatalysis, in which both the electromagnetic radiation and the catalyst are necessary to bring out the involved chemical reactions, appears as the most promising technology [8, 18].As a matter of fact, titania are known to display excellent photocatalytic activity under UV irradiation [19,].Unfortunately, the band-gap (3.0–3.2 eV) precludes their use under visible irradiation [20]. In an attempt to exploit titania-based photocatalysts even under sunlight by altering their electronic structure, several investigations have been devoted to the study of modified $TiO_2$ systems [21] including lanthanides [22], but except for a few cases [23] the photo catalytic activities of cation-doped $TiO_2$ decreased even in the UV region. Thus, many researchers have started to use anionic nonmetal dopants such as C [24], N [24,25,26], S [27] and B [28], to extend the photocatalytic activity into the visible- light region because the related impurity states are near the valence band edge, but do not act as charge carriers . Furthermore, their function as recombination centers might be minimized as compared to cation doping .In order to enhance the photocatalytic activity in the visible region of the N-doped $TiO_2$, several studies were reported on codoped materials such as C and N [29], S and N [30], F and N [31] and N and a variety of metal ions [61], and in some cases authors underlined the synergistic effect of codoping. However, conventional TiO2 powder catalysts present the disadvantage of agglomeration and of a difficult separation of the final particle-fluid for catalyst recycling. Thus the application of TiO2 thin films has attracted much attention in the last years. In this work we have prepared $TiO_2$ thin films doped with boron by means of sol-gel route.

## 2. EXPERIMENTAL SECTION

### 2.1. Materials

Titanium (lV) isopropoxide, ≥97.0% (Sigma Aldrich). Tri ethyl amine, Microscopic glass substrate. All reagents were analytical grade and used without further purification. Methylene blue was purchased from Merck. pH of the solution was adjusted with 1M HCl and1M NaOH.

### 2.2. Instruments

Photochemical degradation was carried out in open visible light chamber. A 500w tungsten filament light was used as light source. Constant stirring of solution was insured by using magnetic stirrers. The spectra were taken with UV–Vis spectrophotometer (Hitachi U-2006); pH meter (Thermo Orion 920A) was used to adjust the pH of the solution.

### 2.3. Experimental Procedures

All chemicals used were of analytical reagent grade supllied by sigma Aldrich. All solution were prepared by using distilled and deionized water. 1.5 ml Titanium Isopropoxide (TIP) was added to 2-isopropanol (10 ml) under vigorous stirring conditions and then 0.35 ml triethyl amine was added as a stabilizer of the solution and stirred (200 rpm) for 2–3 min under an inert environment. The required inert environment was made by nitrogen gas flow through the system (solution-A). A second solution was prepared separately as follows: hydrochloric acid (0.92 ml) and water (0.15 ml) were added to 10 ml ethanol and mixed well by a magnetic stirrer (200 rpm) (solution-B). The two solutions were then mixed drop wise and stirred vigorously for 60 min under $N_2$ gas flow. The formed $TiO_2$ sol was transparent, quite stable and highly sensitive to the amount of triethylamine and water. Boron doped $TiO_2$ was synthesized by a similar preparation. 36.12 mg was dissolved in 5 ml ethanol (solution-C) and rapidly added to the mixture of solution –A and Solution-B. The pure $TiO_2$, B-$TiO_2$ thin films have been obtained by the dip coating on microscopic slide substrates. Degradation was carried out under visible light. 50 ml $1\times10^{-5}$ M methylene blue solution was taken and two catalyst film was used. The surface area of film is 6 $cm^2$. Then absorption spectra were recorded and rate of decolorization was observed in terms of change in intensity at $\lambda$max of the dyes. The decolorization efficiency (%) has been calculated as: Efficiency (%) =($C_0$ –

$C_t)/C_0 \times 100 \approx (A_o\text{-}A_t)/A_o \times 100$ ,where C= concentration, A=peak area, 0= initial, t-at t time.

Fig 1.photo degradation of methylene blue under visible light irradiation.

## 3. RESULT AND DISCUSSION

The photocatalytic activity of boron doped TiO2 thin film systems was tested in the degradation of (MB). The following figures reports the results of photocatalytic experiments, compared with those of pure TiO2 film catalyst. The rate of decolorization was recorded in terms of change in intensity of characteristic peaks.

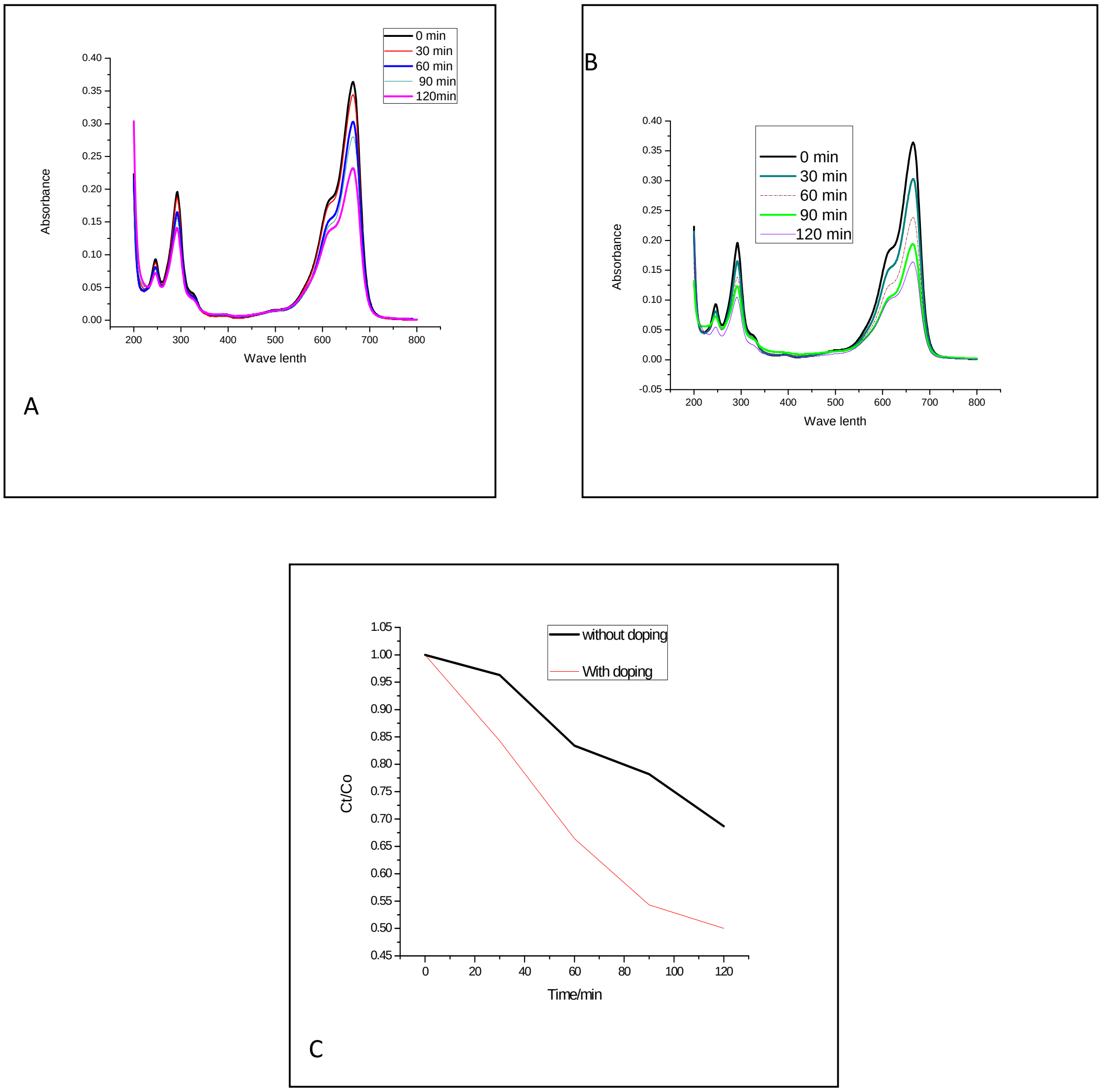


Fig 1. (A) UV-vis spectral changes of methylene blue (MB) on pure $TiO_2$ film catalyst as a function of time of exposure at room temperature, under visible light irradiation, (B) on boron doped $TiO_2$ (C) Comparative time dependence of the concentration decay of methylene blue on $TiO_2$ film ( with doping and without doping).

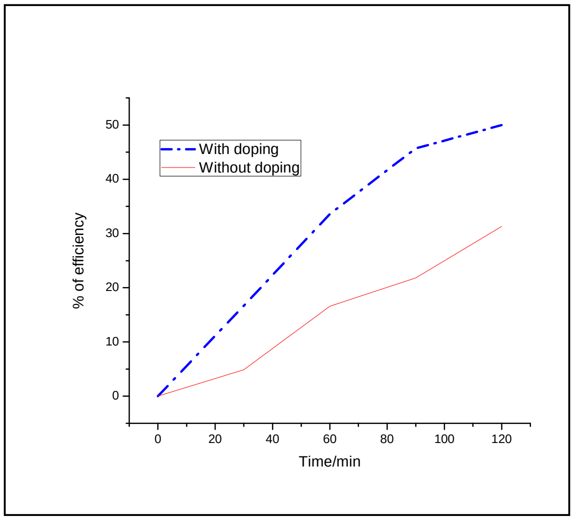


Fig.3 : Decolorization efficiency of MB on $TiO_2$ catalyst (with doping and without doping) as a function of time of exposure at room temperature, under visible light irradiation.

The figure shows the degradation efficiency of boron doped $TiO_2$ is much higher than that of pure $TiO_2$.

## 4. CONCLUSION

In this work, $TiO_2$ systems doped with boron were synthesized by the sol-gel route and employed as photocatalysts in the degradation of aqueous MB solutions. As regards photocatalytic performances, a significant enhancement in MB degradation was observed up on doping. The degradation follows pseudo-first order kinetics.

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# SYNTHESIS OF NANO-COBALT BY A WET CHEMICAL REDUCTION METHOD IN THE PRESENCE OF SURFACTANT (SDS) AND A POLYMER (PVP)

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## ABSTRACT

Nano-sized cobalt particles have been synthesized by a bottom-up approach, using hydrazine as the reducing agent in the presence of an anionic surfactant- sodium-dodecyl sulphate (SDS). The effect of adding a cationic polymer polyvinylpyrrolidone (PVP) with an anionic surfactant has been studied. These nano-aggregated cobalt particles were characterized by using SEM with EDX facilities, TEM. TEM characterization showed the presence of spherical Co particles as fine as 10nm in diameter. However, the SEM images showed a very monodispersed spherical morphology. The combination of SDS/PVP reaction produced nano-sized cobalt particles which were much finer than the reactions where the reaction without SDS and PVP. PVP has shown some dispersion power and was found to be capable of preventing cobalt particles from gradual agglomeration.

**Key words**: Bottom-up, SDS, PVP, 10nm.

## 1. INTRODUCTION

### 1.1. Background of the Study and Problem Statement

Nanoparticles are zero-dimensional nanostructures and are generally classified according to their composition: metal oxides, noble metals, transition metals, magnetic metals, etc. These nanoparticulate materials often exhibit very interesting electrical, optical, magnetic, and chemical properties, which cannot be achieved by their bulk counterparts [2]. The synthesis of discrete magnetic nanoparticles with sizes ranging from 2 to 20 nm is of significant importance, because of their applications in multi-terabit in magnetic storage devices [3]. Such magnetic nanoparticles could also find applications in ferrofluids, magnetic refrigeration systems, contrast enhancement in magnetic resonance imaging, magnetic carriers for drug targeting and catalysis [1]. In semiconductor, it is due to the further confinement of the electronic motion to a length scale that is comparable to or less than the length scale of the electronic motion in bulk semiconductors [7]. In noble metals, it results from the strong absorption of radiation within the visible region leading to the collective oscillation of the electrons in the conduction band, called surface plasmon resonance, from the surface of one particle to another [7]. In transition metals, it arises from the large surface to volume ratio resulting to high chemical activities. And in magnetic metals, it is due to finite-size and surface effects, which become increasingly important as the particle size of the magnetic material is reduced [10]. Co is a well-known ferromagnetic material which is

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commonly used as an alloying element in permanent magnets [9]. In nanosized, Co particles display a wide range of interesting size-dependent structural, electrical, magnetic, and catalytic properties. In particular, because of their large surface area, Co nanoparticles showed high chemical reactivity, which makes them suitable for catalysis [1]. Furthermore, below a critical size of 20 nm, they behave as singe-domain particles displaying quantum size effects, super paramagnetism, large magnetic anisotropies, and a maximum coercivity [9]. Thus, these previous studies prove that Co as a nanomaterial is an excellent and interesting system to study.

Future applications of Co nanoparticles in the fields of separation technology, information storage systems, catalysis, and biomedicine require the nanoparticles to be discrete, identical in size and shape, and uniform in composition and crystal structure [8]. The properties of nanoparticles are dependent on their size and shape. While the design of nano-materials endowed with size dependant functions is gaining much importance, the synthetic strategies have matched their application needs, making a “made to order” relationship possible. It is also possible to control the size and the inner structure of the resulting nano-metals. Nano-structured materials can be produced by two different approaches, namely, “top down” and “bottom up” approach. The top down approach is the process of breaking down the bulk metals and subsequent stabilization of the resulting nano-sized metal particles of colloidal protecting agents [4]. The bottom up approach on the other hand is the wet chemical nano-particle preparation, which relies on building nanoparticles from the atom level of the metal [5]. Cobalt nanoparticles in an aqueous medium is that they are highly unstable and undergo oxidation necessitating their use immediately after preparation [1]. To overcome the problem of oxidation, attempts have been made to synthesize these nanoparticles in an organic environment which is a suitable protective agent [6]. The materials covered in the current article are froth formation systems composed of isolated particles with nanometer-sized dimensions that are stabilized by surfactant molecules and a protecting agent in liquid media.

Fig 1 desribes the rapid injection of reagents at high temperature and nucleation process for the formation of desired sized nano particles [1]. Fig 2 illustrates the model for the nucleation and agglomerative growth in a homogeneous solution [6]. It should be noted however that given sufficient time for growth, uniformly sized particles can be produced by agglomeration, though the particles are normally in the submicrometer and micrometer range

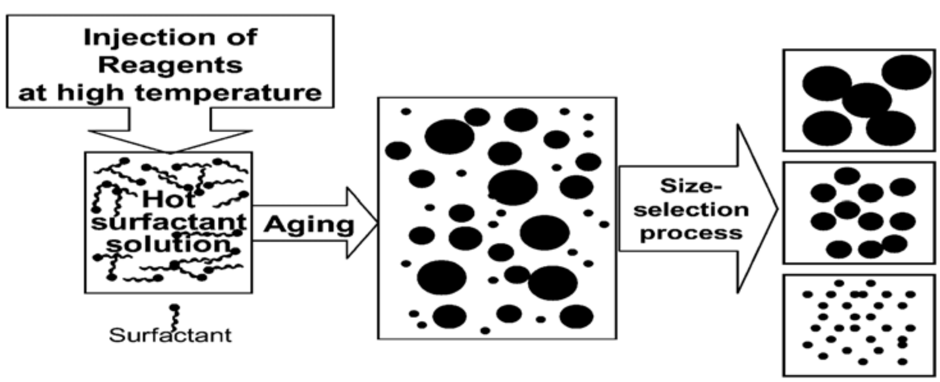


Fig 1: Generalized synthesis of monodisperse nanoparticles by the injection of reagents into hot surfactant solution followed by aging and size-selective process.

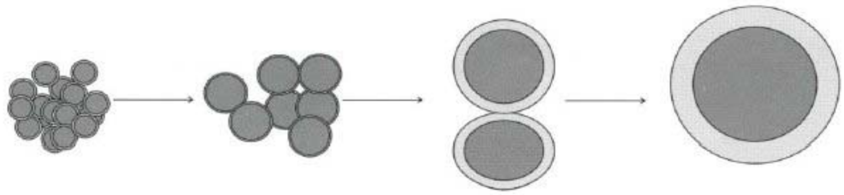

Fig 2. Scheme depicting the growth mechanism by nucleation and agglomeration

However, formation of nanoparticles satisfying these requirements prove to be difficult due to their high surface energy, their intrinsic magnetic properties, and the inherent limitations of the available processes. In addition, there are also concerns regarding the reproducibility of the existing methods. By far, liquid-phase synthetic routes are the most successful in the preparation of monodispersed Co nanoparticles. Examples of liquid-phase processes are metal salt reduction, reverse micelles, and thermal decomposition of organometallic precursor. Among these methods, direct metal salt reduction in solution is the simplest, fastest, and the least expensive, which are desirable for future attempts of large-scale production [1]. An important component of metal salt reduction processes is the protective agent. Protective agents such as surfactants that form a layer of molecular membrane around the nanoparticles and polymers that provide steric hindrance between nanoparticles are added during the reaction to inhibit particle agglomeration and to control the particle growth. However, besides posing as an additional cost to the total cost of the synthesis. Moreover, selection of the suitable protective agent for a particular reaction is a tedious task of trial-and-error, since the surface chemistry of the nanoparticles is complex due to their high surface energy and their tendency to accumulate surface charges. Thus, the interaction of the protective agent with the solvent and with the nanoparticles plus its properties, such as the solubility in the solvent, molecular weight, and the amount needed for stabilization, must be taken into account when choosing the right protective agent. Thus, in some cases, agglomeration of nanoparticles still occurred even in the presence of protective agents [8]. One way to solve the problem is by the choice of a solvent that can also act as cleaning agent. In this study, preparation of Co nanoparticles was performed using Co salt reduction technique; a suitable protective agent PVP and a surfactant SDS were used.

### 1.2 Objectives of the Study

As mentioned, the formation of Co nanoparticles is accomplished by Co salt reduction technique with a surfactant and a protective agent. The objectives of this work are:

(a) to prepare uniformly sized, monodispersed, and size-tunable Co nanoparticles using a simplified Co salt reduction process.

(b) to investigate the morphology, crystal structure, of the Co nanoparticles.

### 1.3 Project Overview

In achieving the objectives, three main experiments were conducted. The first experiment involves the reduction of Co ions in a basic medium using hydrazine, $N_2H_4$, as reductant. The size of the Co nanoparticles were tuned by varying the reaction temperature, stirring speed, precursor concentration, and amount of $N_2H_4$. However, in all samples, the particle size distribution was broad with a relative standard deviation greater than 20%. Furthermore, severe agglomeration of the nanoparticles was observed after precipitation. To obtain Co nanoparticles with narrower size distribution, a second experiment was accomplished by heating an alkaline solution of PVP/SDS containing cobalt chloride up to the boiling temperature for about one hour with reflux. Control of particle size was achieved by varying the precursor concentration and by varying the reaction temperature. A set of experiments was also performed to study the effect of PVP k15 as protective agent on the morphology and agglomeration of the nanoparticles. Furthermore, this was also done to demonstrate how addition of protective agent can complicate the synthesis and the cleaning procedure of the nanoparticles. Standard characterization techniques such as TEM, FE-SEM, EDX, were then performed on the synthesized Co nanoparticles.

## 2. MATERIALS AND METHOD

Materials used in this research work were cobalt chloride electroplating grade; sodium dodecyl sulphate (SDS, LOBA Chemie, India, 92%); polyvinylpyrrolidone (PVP Winlab, UK); hydrazine hydrate solution (LOBA Chemie, India, 80%); Sodium Carbonate (Guandgonjg Guanghua, China, 99%); de-ionized distilled water was used in the preparation of all the solutions. A thermostatically controlled hot plate with magnetic stirrer (Yellow Line) was used in this research work. The nano-sized cobalt particles were synthesized by dissolving 10 g of $CoCl_2$ in a glass beaker containing 100 mL of de-ionized water which was maintained at 40°C. When the temperature rose at 70°C the reaction occur and the black particles formed. 20 g/l of SDS and 20 g/l of PVP were added to the solution. In order to study the effect of PVP and SDS on the formation of nano-Co particles a cobalt solution was made without adding any SDS and PVP. The pH of the cobalt solution was then increased to 10.2 by adding concentrated sodium carbonate solution. 50 mL of hydrazine was added to the solution slowly while stirring was on all the time. Temperature of the Co solution was increased to 60°C before adding the hydrazine to the Co solution. Reaction was also carried out at higher temperatures such as 60 and 100°C under reflux conditions. At 60°C as the reaction continues appearance of gray/black precipitates in the beaker meant that cobalt particles have started to form. However, under reflux condition at 100°C the conversion was very quick (less than 20 min), froth formation was minimized. While the cobalt particles are formed at 60°C there is a huge volume expansion of the reacting solution because we use SDS as surfactant and according to equation 2 nitrogen gas is formed and hence care had to be taken not to spill the solution over the reaction vessel e.g. much bigger beakers were use that could handle the volume expansion of the reacting chemicals. As the reaction proceeded the top of the beaker became covered with thick froth; simultaneously Co particles were deposited at the bottom of the reaction vessel. Under reflux condition, however, this volume expansion was very little. The gray/black particles so formed were the aggregated nanosized nickel particles. The products were collected, centrifuged (4000 rpm), washed with distilled water and ethanol for three times and finally desiccated at room temperature before characterization. The froth also contained a fair amount of fine Co particles hence these particles were recovered by washing with acetone and water before drying. It has been observed that hydrazine used from a freshly opened bottle gives much faster reaction. The cobalt particles were characterized using, Scanning Electron Microscope (SEM) FEI–NOVA 200Nanolab with EDAX, Transmission Electron Microscope (TEM) JEOL - JEM 2100F and X-ray diffraction (XRD) JEOL JDX – 8030 X-ray Diffractometer System.

## 3. RESULTS AND DISCUSSION

Hydrazine is a normal reducer; its reductive ability varies according to the pH value of the solution. In acid medium, $\varphi^{o}_{N2H4}$ is 0.23V and $N_2H_4$ is easily oxidized to $NH_3$. In a basic medium, $\varphi^{o}_{N2H4}$ is -1.16V and it can be easily oxidized to $N_2$. At 25°C, $\varphi^{o}_{/Co2+/Co}$ is -0.28V, so it is possible to reduce cobalt ions in basic medium. The reaction equation between cobalt chloride and sodium carbonate in aqueous medium can be written as follows:

$CoCl_2(aq) + Na_2CO_3\ (aq) = Co(OH)_2\ (s) + 2NaCl(aq) + CO_2\ (g)$ ………….. (1)

Hydrazine is added to the solution containing cobalt carbonate at 60°C to enhance the reaction rate. The reaction equation between cobalt and hydrazine is:

$2Co^{2+} + N_2H_4 + 4OH^{-} = 2Co + N_2\uparrow + 4H_2O$ …………… (2)

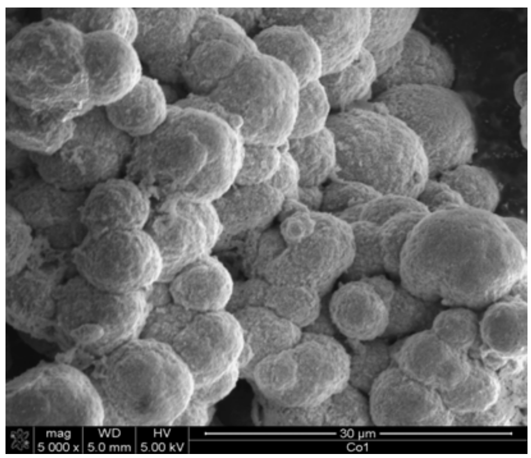


Fig 3. SEM image of cobalt nanoparticles synthesized without SDS and PVP

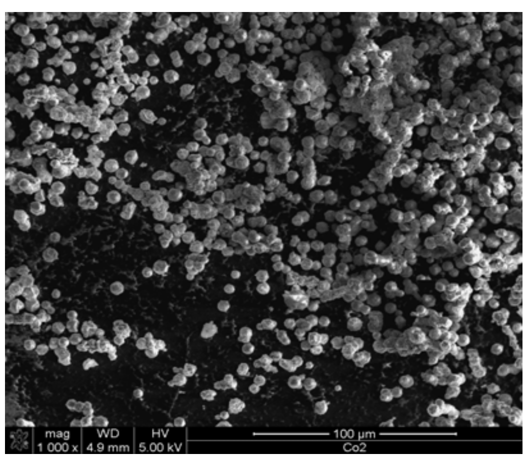


Fig 4: SEM image of cobalt nanoparticles synthesized with SDS and PVP

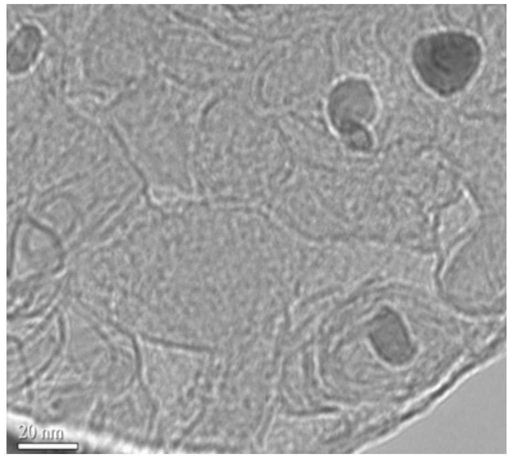


Fig 5: TEM image of cobalt nanoparticles synthesized without SDS and PVP (35nm)

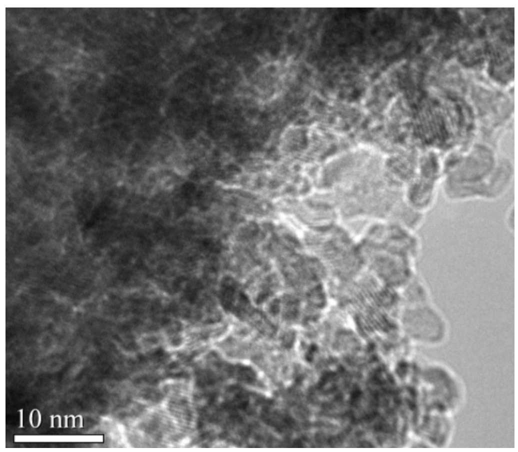


Fig 6: TEM image of cobalt nanoparticles synthesized suing SDS and PVP

Figure 3 and 4 shows the SEM images of synthesized cobalt nano particles with and without SDS and PVP. SEM images show the morphology of the Co powders, very small spherical shaped objects clearly observed. According to the SEM images the monodispersed spherical particles are produced in the technique with surfactant and protecting agent. The protecting agent prevents agglomeration during nucleation.

Figure 5 and 6 shows the TEM images of synthesized cobalt nanoparticles with and without SDS and PVP respectably. These indicate the presence of many small and spherical particles. The cobalt nano particles which synthesized in presence of SDS/PVP are smaller in diameter than those which are synthesized without presence of SDS/PVP. Due to the presence of surfactant and polymer the particles become finer and smaller in diameter (about 6nm).Figures 7 and 8 are SEM/EDAX plots of the Co powders synthesized at 60 to 80°C respectively. Both Figures show two clear peaks of Co. The oxygen and carbon peaks are negligible in Figure 7; however, the oxygen level observed in Figure 8 shows some prominence. The peak intensity of the Co sample synthesized by using a surfactant (SDS) and a polymer (PVP) is larger than the peak intensity of Co particles synthesized without using SDS and PVP. Clearly the effect of using SDS and PVP has resulted in the refinement of the cobalt particles. Figure 5(TEM images) shows the presence of cobalt particles which are 20 nm in diameter where Figure 6 shows the cobalt nano particles as finer as 6 nm in diameter. The smaller paticles in diameter because of using SDS and PVP.

Cobalt crystals are magnentic at the same time nanosized particles are known to have very large surface areas, hence these synthesized nano-particles will also have very high surface energy. Consequently these fine cobalt crystals will be attracted towards each other and very quickly form aggregated cobalt particles in order to reduce their surface energies which is shown in Fig 2. We conclude that linear PVP molecule has template effect which means the newborn cobalt crystals will be attracted by these PVP templates, with time the newborn cobalt crystals will grow along the PVP chains, it may be the reason why these linear cobalt crystals formed are monodispersed spherical as observed in figures 4 and 6. The concept of surfactant micelle formation could help to deduce the most likely reaction mechanisms for the formation of nano-sized Co particles would be that these surfactant molecules (SDS) will also have this template effect on the formation of cobalt particles. These surfactants reduce the interfacial tension between the newborn particles by adsorbing SDS at the liquid-metal interface so formed. However, PVP has a definite template effect on the formation and retention of the nanosized Co particles; spherical/monodispersed cobalt nano particles are formed due to template effects of PVP and SDS. As the reaction temperature is increased even finer particles are produced with an increase in the rate of particle formation.

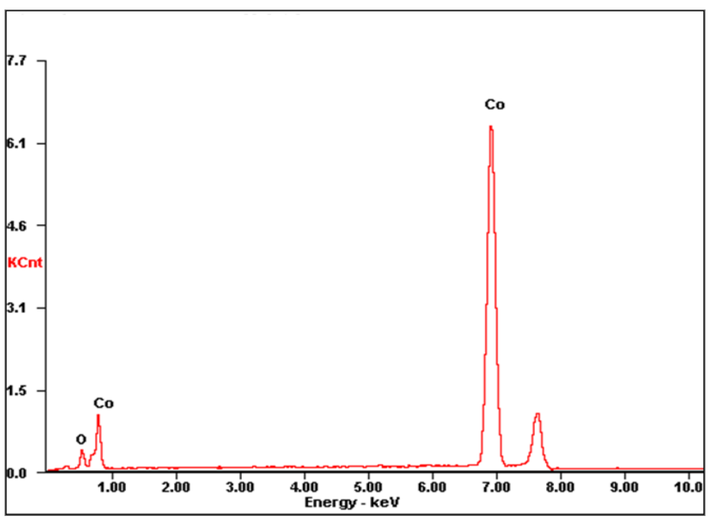


Fig 7: SEM-EDAX image of cobalt nanoparticles synthesized without SDS and PVP

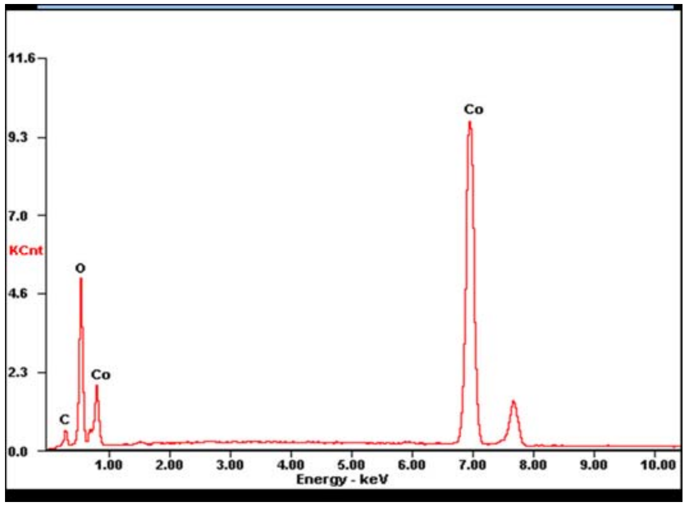


Fig 8: SEM-EDAX image of cobalt nanoparticles synthesized without SDS and PVP

## 4. CONCLUTION

Nano-sized cobalt particles have been prepared by a simple polymer-surfactant interaction of a cationic polymer polyvinylpyrrolidone (PVP) with an anionic surfactant, sodium-dodecyl-sulphate SDS in a strong basic medium. Our research shows that the rate of reduction increases as the temperature is increased from 60 to 100°C under reflux conditions; under these conditions the particles sizes formed are also much smaller during using of SDS and PVP. The combination of SDS/PVP reaction produced nano-sized cobalt particles which were much finer than the reactions where SDS and PVP were not used. PVP has shown some dispersion power, it has been found to be capable of preventing cobalt particles from gradual agglomeration.

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# A STUDY OF THE LIMITATIONS OF EXISTING EARTHQUAKE DISASTER MANAGEMENT SYSTEMS IN BANGLADESH AND A NOVEL SEMI-CENTRALIZED TIER-BASED EARTHQUAKE DISASTER MANAGEMENT SYSTEM PROPOSITION

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## ABSTRACT

Being located at the junction of three major plates namely the Indo-Australian plate, the Eurasian Plate and the Indo-Chinese plate, Bangladesh is always regarded as an earthquake prone country. Within the last 100 years, four great earthquakes of magnitude exceeding 8 in Richter scale have been occurred with 10 others exceeding magnitude belt. With the rapid economic growth and the construction of multitudinous unplanned urban infrastructures, the big cities that lie in the seismic zone of Bangladesh are more vulnerable to earthquake. The colossal and irrevocable losses of lives as well as properties and the quasi-periodic nature of earthquake beckon the quintessence of an effective earthquake disaster management system for this small developing country.

In Bangladesh, complete earthquake monitoring and disaster management facilities are still not available. The major difficulties in earthquake disaster management are inefficient communication, intricate interaction and lack of coordination as well as timely service delivery. In this paper, with the understanding through substantial literature review, the present earthquake status of Bangladesh has been analyzed in terms of tectonic position, most quake prone zones etc., then the existing earthquake management system has been investigated with their flaws and eventually a novel, innovative, semi-centralized, hierarchical and cost effective earthquake catastrophe management system has been proposed in holistic approach, which is compatible with the socio-economic condition and geographic topology of Bangladesh.

The nature and level of destruction have made earthquake different from other types of prevalent natural disasters; so as the pre- and post- disaster management systems. No centrally controlled disaster management system is effective for earthquake, because if the central system itself becomes damaged by the earthquake aftermath, the whole network will be out of action. Therefore, the proposed management system divides the entire topography of Bangladesh into several cells considering the level of risk, i.e. high risk, moderate risk and low risk; and stratifies the management regulatory units into several tiers based on the preponderance of activities. Each tier has been allocated with a defined level of activities according to the hierarchy of importance. Depending on the intensity of emergency, each cell has been equipped with the required disaster management tools. The proposed system is

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consequently more reliable. Conclusively, some services integrated with the system have been suggested that are readily implementable and acceptable by the general people.

**Key Words:** Cell; Disaster management; Earthquake; Seismic zone; Tectonic plate; Tier; Topography

## 1. INTRODUCTION

On December 26, 2004, a catastrophic earthquake of Richtar scale 9.0 ransacked the Sumatra-Andaman Islands which killed at least 80,000 people in Indonesia, 41,000 people in Sri Lanka and 10,000 in India [1]. A total of over 150,000 people died because of the outrageous earthquake and its aftermath-the tsunami. From this evidence, the vehemence and destructiveness of earthquake can easily be perceived. Earthquake can be defined as a sudden, transient trembling in the earth's crust, resulting from the propagation of seismic waves caused by faulting of the rocks either at shallow and/or deeper depths [2]. Bangladesh, from geographic point of view, is a disaster prone country. Cyclone, drought, flood and landslides are considered as the most prevalent natural disasters in Bangladesh due to their frequency of occurrence. But being situated in the active tremor zone, this country is at extreme earthquake risk as well. Nevertheless, earthquake has still not been treated with proper concern from the top level administration of Bangladesh and consequently, there is no defined earthquake risk management system in the country. But the recent tremors and the quasi periodic nature of earthquake admonish to build up a complete earthquake disaster management and risk mitigation system as early as possible, or the country may face unimaginable aftermath of this macabre natural disaster in near future.

A considerable number of researches have been conducted on earthquake prediction, preparedness and risk mitigation. Some articles suggested GIS (Geographic Information System) based earthquake damage assessment system and some delineated innovative software based earthquake management system [3-8]. In this paper, we have proposed an innovative Earthquake Disaster Management System (EDMS) for Bangladesh. The system is well-suited with the geographical topography of Bangladesh. It uses the existing technology and infrastructures and focuses on the community based disaster management approach.

The paper is organized as follows: the next two subsequent parts delineates the tectonic position and earthquake status of Bangladesh and then the existing earthquake disaster management activities in Bangladesh are mentioned with their flaws. The proposed EDMS is then presented. Some services are proposed for the system in the subsequent section.

## 2. TECTONIC POSITION OF BANGLADESH

Fig 1 depicts the tectonic plates and faults in Asia-Pacific region. From Fig 1, we see that Bangladesh is located at the junction of three major plates namely the Indo-Australian plate, Eurasian Plate and the Indo-Chinese plate. About 50 to 55 million years ago, the Indian plate was fused with the adjacent Australian plate and is called together the Indo-Australian plate [9]. The Eurasian Plate includes most of the continent of Eurasia, with the notable exceptions of the Indian subcontinent, the Arabian subcontinent, and the area east of the Chersky Range in East Siberia [10]. Later a part of it containing Singapore, Thailand, Cambodia, Vietnam, a part of China etc has separated from it taking the name Indo-Chinese Plate.

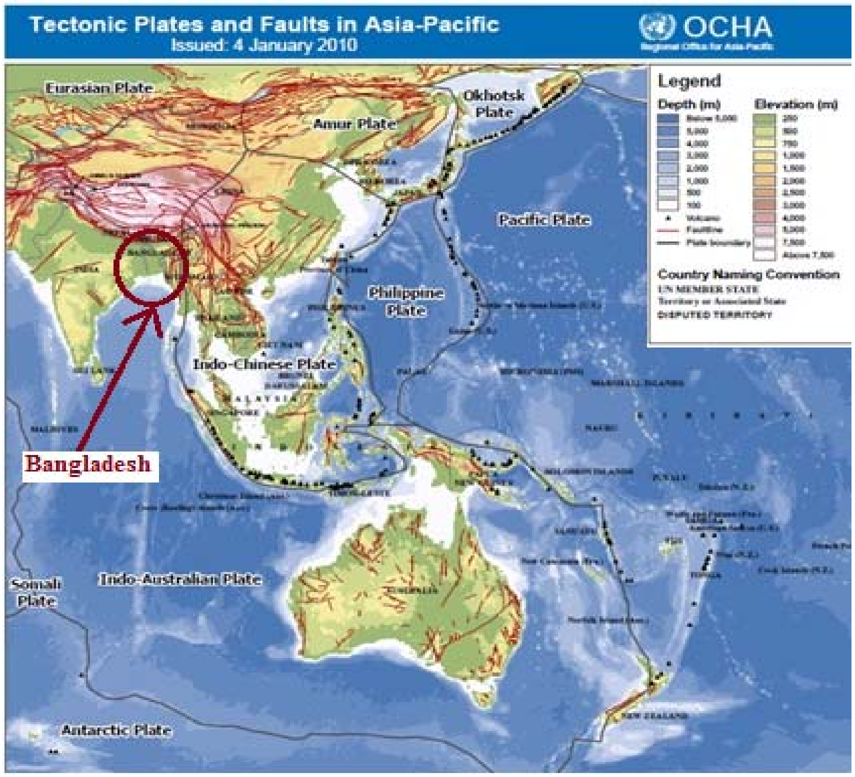


Fig 1: Tectonic plates and faults in Asia-Pacific (Source: http://ochaonline.un.org/roap)

Tectonicity and geology of Bangladesh and adjoining areas have been studied in details by Guha (1978), Matin et al. (1983), Sesoren (1984), Bolt (1985) and Khan (1991). It is revealed in the above literatures that the surface geology of Bangladesh is related to its tectonic evolution which started during late Cretaceous period when the northward moving Indian plate collided with Eurasian plate. The collision caused the northern extremity of Bay of Bengal to separate into gulfs of Assam and Burma. During second collision at the end of Eocene time, the gulfs were narrowed. Due to the third collision, occurred in the middle Miocene, folding occurred in the sediments of Chittagong, Sylhet and Assam. The fourth and fifth collisions caused mainly vertical movements. The Shillong plateau and Mikir hills formed a horst during the fourth collision. The fifth collision uplifted the red clay tablelands.

## 3. PRESENT EARTHQUAKE RISK OF BANGLADESH

Bangladesh is surrounded by the Himalayan Arc and Shillong Massif in the north, the Tripura Uplift [11] and the Arakan Yoma Suture in the east and complex Naga-Disang-Jaflong thrust zones in the northeast [12] (Fig 2a). It is also at the site of the Dauki fault system along that consist myriad subsurface active faults and a flexure zone called Hinge

Zone [12]. To the northwest part of Bangladesh, a northeast-southwest treading fault, located to the west of the Jamuna river and south of Bogra town and called the Bogra fault, has recently been discovered [11]. These faulty regions provide the necessary zones for movements within the basin area [12]. According to [13], at present Bangladesh has eight active fault zones, namely- Bogra, Tanore (Rajshahi), Tripura, Sitakunda-Tekna,

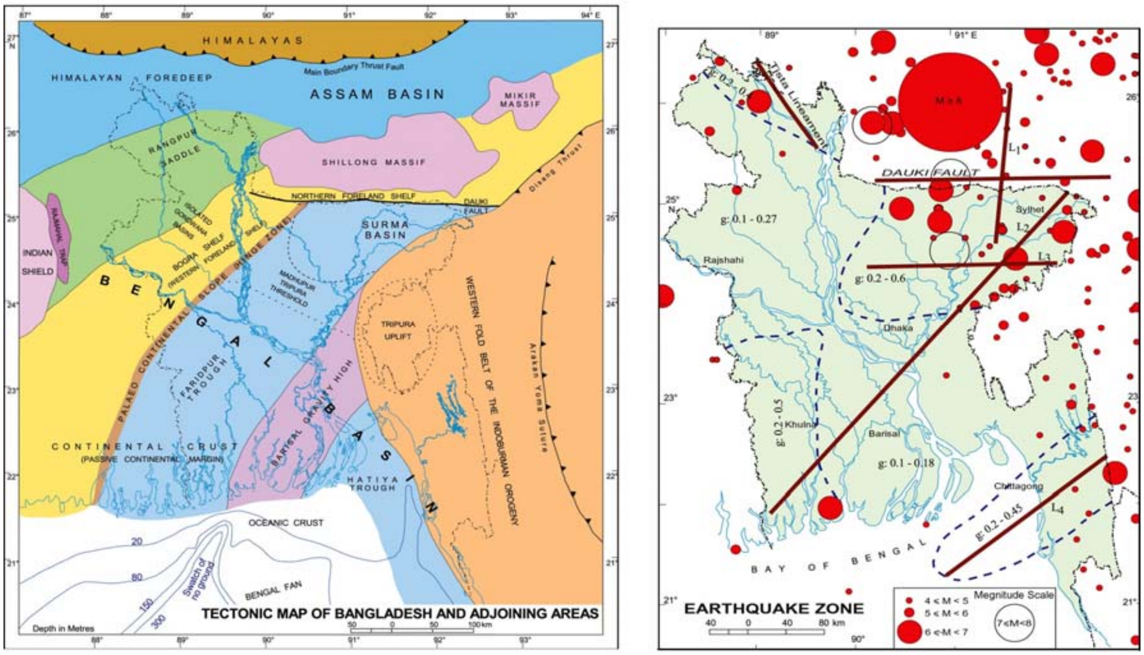


Fig 2: (a) Tectonic map for Bangladesh (Source: Guha, 1978); (b) Seismic Activity of Bangladesh

Dauki (Haluaghat Fault), Dhubri, Chittagong, Shahjibazar (sub-Dauki fault) and Rangamati (Borcal) fault zone.

In the tectonic map of Bangladesh (Fig 2b), the distribution of epicenters is found to be linear along the Dauki fault system and random in other regions of Bangladesh. The investigation of the map demonstrates that the epicenters are lying in the weak zones comprising surface or subsurface faults. Most of the tremors are of moderate rank (magnitude 4-6) and lie at a shallow depth. In the northeastern region (Surma Basin), major events are controlled by the Dauki fault system. The events located in and around the Madhupur tract also indicate shallow displacement in the faults separating the block from the alluvium [12].

The tectonic plate movement affects the tremor situation. The Indo-Australian plate is moving in NNE (north-northeast) direction at the rate of 3-5 cm per year, while the Eurasian plate is moving north by 2 cm/yr (0.8 in/yr) [9]. The Indo-Chinese plate is also moving in NNE direction [14]. This unequal movement is causing the Eurasian plate to deform and the Indian plate to compress at a rate of 4 mm/yr (0.15 in/yr) [9]. The movement of Indian and Eurasian plates has been locked at the foot of the Himalayas for many years, storing strain energy within the earth-crust (very thin layer of the earth, about 30km thick), which can be released in the near future to cause a massive tremor in Bangladesh, northeast part of India and Myanmar [14]. Bangladesh is also shortening at a rate of 6 mm per year that yields the accumulation of strain energy that may be exceed the strength of the rock to cause major earthquake [15]. Therefore, Bangladesh is in the real threat of earthquake. A joint research venture of Lamont-Doherty Earth Observatory, Columbia University, USA and the department of Geology, Dhaka University infers that Dhaka, the capital of Bangladesh, is moving 30.6 mm/year in the direction northeast [16] and the rate of strain accumulation in and around Dhaka is high enough to cause an earthquake of magnitude 6.8 [16]. Furthermore, the four active sources of earthquake in the Bay of Bengal, called F1, F2, F3 and F4, have a capability of generating earthquakes of over 7 magnitude creating tsunami.

## 4. EXISTING EARTHQUAKE DISASTER MANAGEMENT SYSTEM

The Government of Bangladesh (GoB) has no specific earthquake risk management system so far. The Ministry of Food and Disaster Management (MoFDM) of GoB, which is responsible for the disaster risk reduction, has three agencies, namely– Disaster Management Bureau (DMB), Department of Relief and Rehabilitation (DRR) and Directorate of Food (DoF); the first two are responsible for the disaster management throughout the country. DMB has undertaken few initiatives in regards of earthquake mitigation. On 29 January, 2001, DMB was assigned to prepare inventory of available rescue equipment and machineries in the urban and rural areas to mitigate the earthquake disaster and to promote earthquake awareness program as part of public motivation. DMB has shown some other activities, such as two national level workshops, preparation of a comprehensive training module and a handbook on earthquake for public awareness with UNICEF assistance [17]. But most of the activities of DMB are non-structural and therefore, not sufficient and effective up to ground level.

There are few other organizations for the tremor risk mitigation. Bangladesh Earthquake Society (BES) was formed in 2002 as a multi-disciplinary national professional society dedicated to the cause of preparing the nation to face the threat of earthquakes. BES has its members drawn from various professionals including engineers, geologists, architects, planners and personnel involved in disaster management [18]. Unfortunately this organization also shows fewer structural activities than required. There are almost 20,000 Non-governmental organizations (NGOs) in Bangladesh [19]. Most of them work in the poverty alleviation, health, environment, pollution, women right and other domain, but none of them work dedicatedly for earthquake risk mitigation.

The preponderant factors of the absence of a concrete management system for earthquake risk mitigation in Bangladesh are infrequent occurrence of earthquake, lack of consciousness and advertising, insufficient research and training, underdeveloped technology and equipment, lack of experts and professionals, poor economic condition, tardiness in policy making, and political as well as economic instability. Therefore we should concentrate on community based disaster management framework incorporating the local people along with the professionals and utilizing the existing infrastructures and assets.

## 5. OUR PROPOSED EARTHQUAKE DISASTER MANAGEMENT NETWORK

It is undoubted that the immediate establishment of a distinct, well organized Earthquake Disaster Management System (EDMS) is quintessential for the present circumstance of Bangladesh. In this section, we have proposed a novel semi-centralized EDMS architecture that is compatible with the socio-economic condition and geographic topology of Bangladesh. The network is *'cell-based'* in terms of topography, *'tier-based'* in terms of

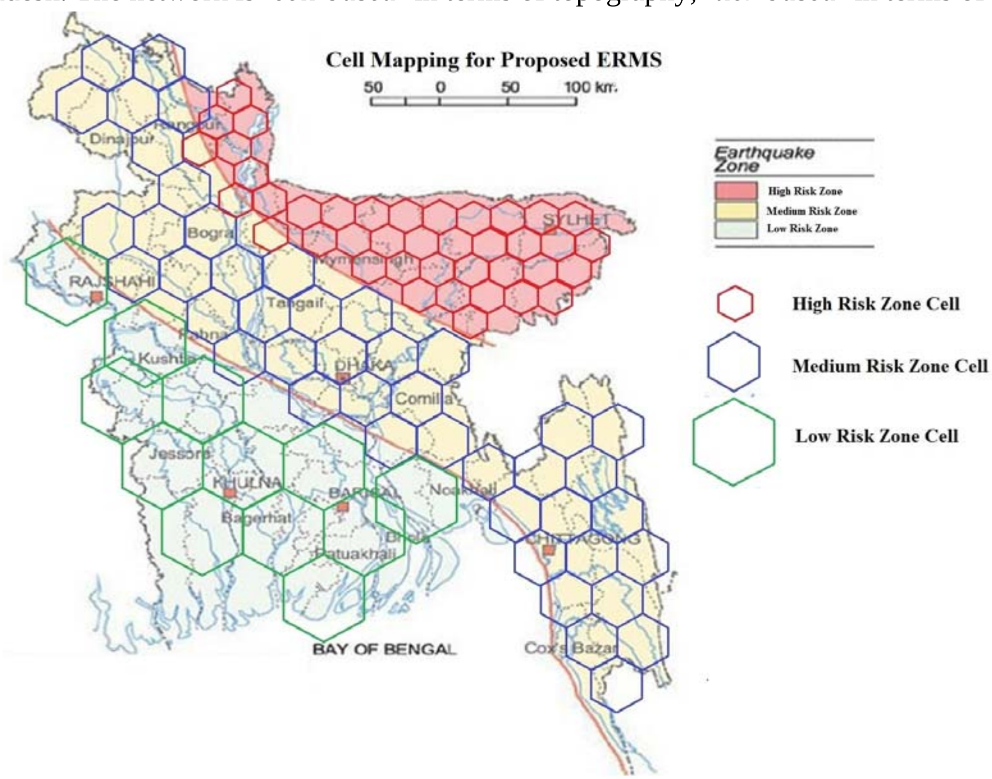


Fig 3: Cell mapping for the proposed system (background map source: GSB)

management and *'semi-centralized'* in consideration of administrative activities. The system model is described in the following subsection.

### 5.1 System Description: Cell and Tier Concept

In this model, the entire region of Bangladesh is divided into several cells. A cell is a defined geographic region where the management system will be operated by some defined management group. The area of a cell will depend on the earthquake risk and damage level as well as the density of population and resources. The lower risk regions will occupy fewer cells and vice versa. According to a seismic zoning map of Bangladesh National Building Code (BNBC-1993), the entire area of Bangladesh is divided into three distinct zones: zone-1 (high risk), zone-2 (moderate risk) and zone-3 (low risk). About 26% area of the country are in zone-1, 38% in zone-2 and 36% in zone-3 [20]. Panchagarh, Rangpur, Gaibandha, Kurigram, Jamalpur, Sherpur, Mymensingh, Netrakona, Sunamganj, Kishoreganj, Moulvibazar, Sylhet, Habiganj and Brahmanbaria, parts of Thakurgaon, Sirajganj, Tangail, Rangamati, Khagrachhari and Cox's Bazar are placed in the highest risk zone, zone-1. Zone-2 includes Rajshahi, Natore, Magura, Meherpur, Comilla, Brahmanbaria, Feni and Dhaka while

Zone-3 is made up of all the islands, Barisal and Patuakhali. The cell mapping is shown in Fig 3.

The management units all over the country will be divided into two tiers. Two-tier hierarchy is considered for the decentralization of administration, uniformity of services to be provided and for simplicity as well as flexibility. The tier hierarchy is visualized in Fig 4. The tier-1 management units are some well organized modern earthquake risk management centers that

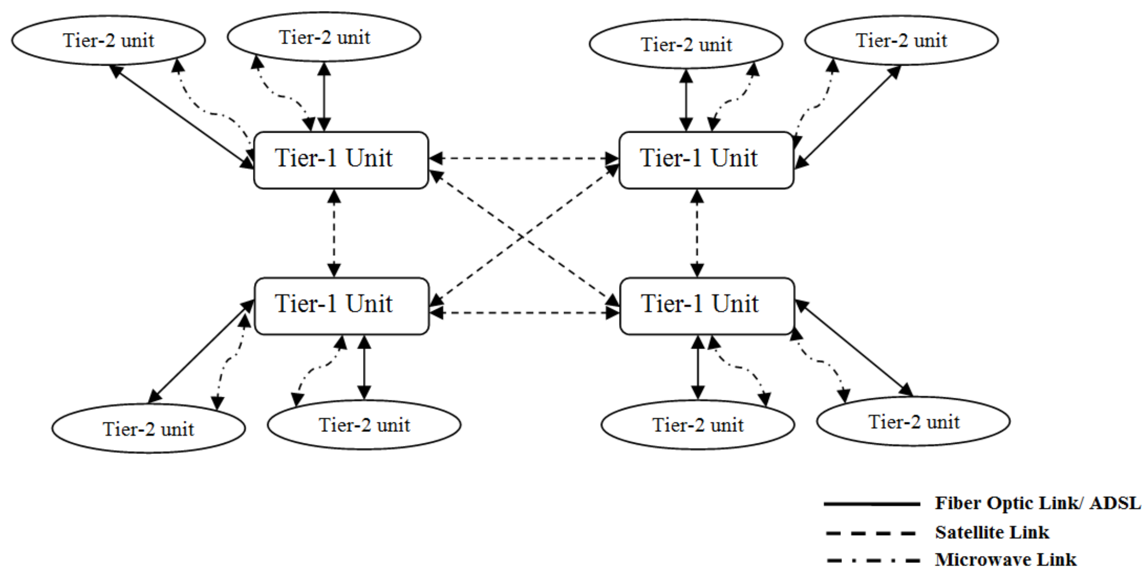


Fig 4: Tier hierarchy with communication link of the proposed system

will control the whole EDMS operations with services by *grid* concept, that is, the entire earthquake management resources, technologies and information will be allocated commensurately among these units, and the units will share the resources and services with one another according to the necessity. The tier-1 units will be regulated and patronized entirely or with some level of privatization by the GoB. One tier-1 unit will monitor the operations of the underlying tier-2 units. The tier-2 units are the local community based earthquake rehabilitation centers located at each cell of the country. The local hospitals, upazila health complexes, schools and other community based institutions can be chosen as tier-2 units with some requisite arrangements and extensions.

The communication between tier-1 units will be satellite communication using VSAT (Very Small Aperture Terminal) technology. At present, there are about 21 VSAT service providers in Bangladesh [21], whose network can be used. The existing fiber optic backbone network and the vast wireless mobile network in Bangladesh may be good and more cost effective choices but their functions are limited by the user congestion and the chance of network rupture during the time of earthquake. Therefore, VSAT technology is the best option to set the communication between the tier-1 units. The tier-1 units will be connected by fully connected VSAT mesh network topology [22] to increase system reliability and effectiveness. The communication between tier-1 units and tier-2 units may be accomplished by wireless mobile network, fiber optic network or simple microwave radio links. This communication should have some redundancies (more than one type of communication link) if possible in order to ensure the Quality of Service (QoS).

The nature and extensiveness of destruction of earthquake differentiate it from other natural disasters. Unlike tornado or whirlpool, the earthquake forecasting system is still not developed and the aftermath of the earthquake cannot be precisely predicted. Consequently, the EDMS should also be different from the hackneyed disaster management systems. The proposed network thus decentralizes the core level administrative systems with the concept of tier. All of the tier-1 units will have equivalent administrative power and so for all of the tier-

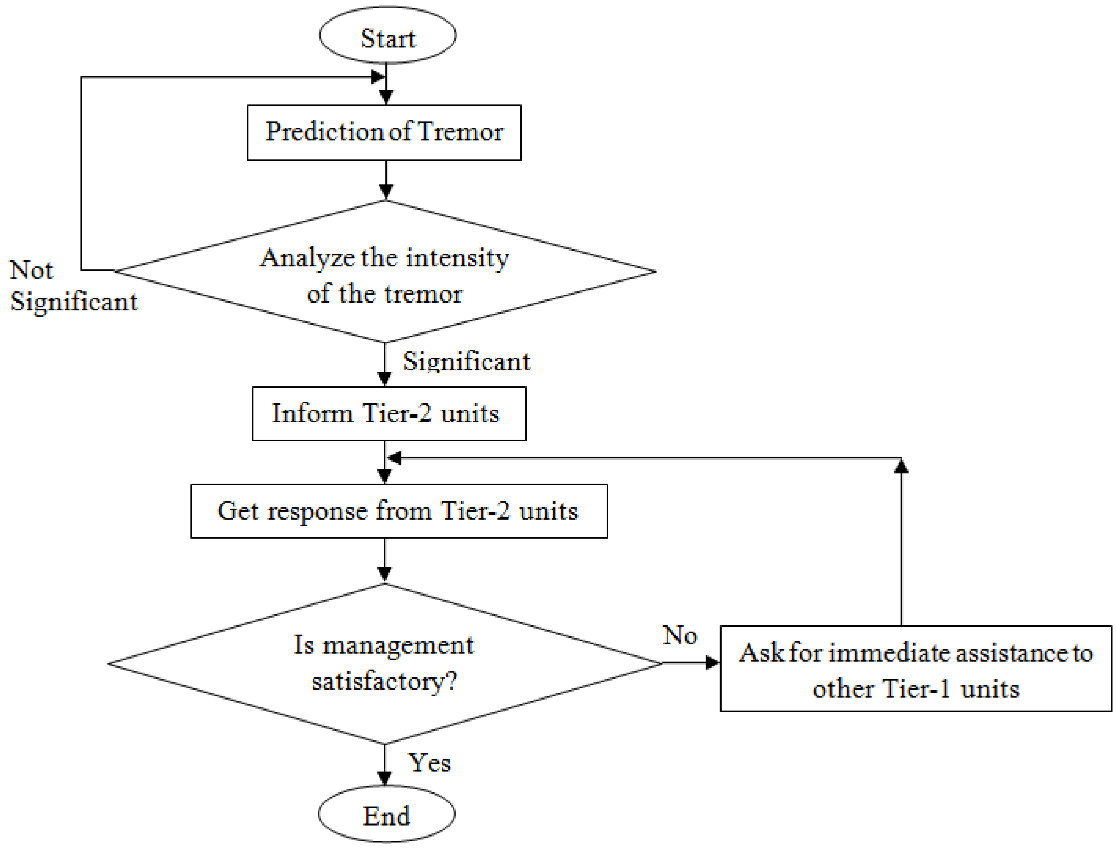


Fig 5: Work flow diagram for Tier-1 unit

2 units. The tier-1 units will be responsible for predicting earthquake, planning risk mitigation, integrating and regulating the tier-2 units and sharing the services in case of necessity. The tier-2 units will be the operational units; they will respond immediately after the tremor to save life and mitigate the risk according to the directions provided by the tier-1 units.

**5.2 Network Operation**

The tier-1 risk management units will have developed earthquake prediction and risk management equipments and trained professionals from home and abroad. The units will continuously check the seismic wave pattern, tectonic plate movement and other GIS parameters to predict the possible tremor. In case of any abnormality or critical condition, the corresponding tier-1 unit will immediately inform the subsequent tier-2 units with alert signals to take the preventive measures. The tier-2 units will be equipped with risk management subunits, such as emergency rescue team, emergency medical team, fire-fighters, locally trained volunteers, operators from utility companies, i.e. electricity, gas etc.

After receiving the alert signal, different subunits will start to perform respective duties and inform the respective tier-1 unit. In case of critical condition, the tier-1 units will ask immediate assistance from the nearby tier-2 units that are controlled by the other tier-1 unit. The management planning will be regulated in tier-1 level. The work flow diagram of a tier-1 unit is depicted in Fig 5.

## 6. PROPOSED SERVICES OF THE NETWORK

Like other disaster management system, the services of our proposed system can be divided into two broad phases: (1) Pre-disaster risk mitigation, and (2) Post-disaster damage management.

### 6.1 Pre-disaster risk mitigation

This is the preventive and most important phase of earthquake damage management. The foremost pre-disaster service should be the successful prediction of earthquake occurrence and pre-assessing the corresponding damage level. Currently, there are four earthquake observatories in Bangladesh which are not sufficient. Systematic prediction of earthquake can be accomplished by considering hazard mapping, crustal deformational studies, lithological characterization and structural setting of the region, frequency of fore shock, land level survey, water tube tiltmeters, geomagnetic observations, geothermal gradient, gravity survey etc. In the context of Bangladesh, destruction of unplanned engineered and non-engineered infrastructures, highway damage, power failure, myriad deaths, avalanche landslide and coastal tsunami are the momentous risks of earthquake. Challenges of earthquake risk mitigation include densely populated area, unplanned urbanization, non-engineered and self-engineered building construction, violation of building codes, narrow roads, lack of modern disaster management equipments and trained personnel, lack of consciousness, technological and economic limitation etc. The obstacles can be overcome by community approach. The tier-2 units can build up communities in their respective areas to solve the local obstacles.

General people should be aware of the level of destruction of earthquake. Consciousness can be developed among general people by arranging aftershock safety and risk management training and drill on a regular basis. Government, local communities and leading private organizations can play significant role in this regard. In each cell, for every three months, there may be a locally organized ‘*Earthquake risk mitigation day,*’ when the scientific and effective methods of safety and risk management will be exhibited and the local people will be trained and drilled. National and local broadcasting media and newspapers can also contribute in raising the consciousness of the mass people by providing up-to-date information and tips about risk management.

Some other pre-disaster proposed services are: advanced training programs for the professionals and operators, reserving earthquake emergency kits in each building, formation of emergency rescue and medical team, encouraging the owner of the risky buildings to reconstruct their houses according to BNBC by providing loans and adoption of earthquake insurance.

### 6.2 Post-disaster damage management

After the earthquake, the immediate requirement will be the emergency rescue team. Most of the urban roads of Bangladesh are narrow and overloaded by the traffic, and after the tremor the roads are supposed to be physically damaged. Therefore helicopter based emergency rescue team will be a good option. Waterway is another important medium of transportation in Bangladesh. So the tier-1 units may have sufficient arrangement of airway and waterway transportation while the local tier-2 units should have locally available emergency transportation stuffs. Emergency supply of water and food, emergency medical treatment, rehabilitation of the victims, prompt request for international aid, preparation for the aftershock (mild tremor after the major earthquake) etc. are some other post disaster damage mitigation services.

## 7. CONCLUSIONS

In this paper, we have proposed a contemporary and pragmatic EDMS architecture with some services that are innovative for Bangladesh. The model utilizes the existing resources and technologies to build up a modern community based earthquake resistant framework. It also emphasizes on both structural and non-structural services and incorporates the government as well as non government institutions. Consequently the system is cost effective and reliable. Furthermore, the authentic involvement of general people makes the makes system more realistic. The model will therefore build up a complete and concrete framework for the successful management of earthquake disaster in Bangladesh.

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# IMPROVEMENT IN HYDRODYNAMIC MODELING OF AN ESTUARY IN A MIXED TIDAL REGIME BY GRID ALIGNMENT AND REFINEMENT

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## ABSTRACT

Water levels and flows in the Singapore coastal waters are driven by the complex interactions of the Indian and Pacific Ocean tides, seasonal monsoon driven contributions and also forced by local winds. Tides in the South China Sea (east of Singapore) are mainly diurnal while those in the Andaman Sea (west of Singapore) are predominantly semi-diurnal. Mixing of different tidal components is occurring in the Strait of Singapore makes the coastal water around Singapore much more complex. The Singapore Regional Model was developed to simulate hydrodynamics in the Strait of Singapore which produces overall balanced tidal representation in this region. However, resolution and alignment of the grid system of the model with respect to the depth contours in some of its sub-regions i.e., the Johor estuary area required further improvement. For this the grid system of the model was modified and compared the simulated results with field measurements. The computed flow velocities agreed better with field observations when the grid resolution was increased. However, improving the alignment of the grid with the channel boundary (with a much lower increase in grid resolution) provided a substantially larger improvement of the model performance.

**Key Words:** hydrodynamic modeling; water levels; tidal currents; grid refinement and alignment; Singapore coastal water; Johor estuary.

## 1. INTRODUCTION

The Strait of Singapore connects the Indian Ocean with the South China Sea and is one of the busiest shipping routes in the world. The strategic location of Singapore stimulates rapid development including ports and harbour activities, land reclamation and shore protection works, thereby heavily impacting the environment. This requires a thorough understanding of the hydrodynamics of the area, and assesses impact of development on water quality and morphology. However, the hydrodynamics in the Strait of Singapore are complex for a number of reasons. First, Singapore is located in an exceptionally sharp transition zone where dominantly diurnal tides (in-between Sumatra and Borneo) change into semi-diurnal tides (in-between Sumatra and Malaysia, just North of Singapore) within a distance of several 100’s of km [13]. The transition from diurnal to semi-diurnal is the result of an increase of the M2 amplitude (especially in the Singapore Strait) and a decrease in diurnal amplitudes. As a result, the water levels are mainly semi-diurnal while currents are predominantly

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diurnal. Secondly, numerous islands exist in the Strait, both rock outcrops (the Indonesian Riau Archipelago) and coral reef islands. And thirdly, a pronounced monsoon-driven residual flow exists, of which peak velocities may exceed tidal currents around neap tide.

Development of numerical hydrodynamic models for the Strait of Singapore has started since the nineties using two-dimensional models [10], followed by i.e., [2, 5, 9, 14] etc. In recent years, several progresses were made on three-dimensional hydrodynamic model for the region. All of the studies applied local models with rectangular grids covering water bodies only around Singapore. All model studies overestimate the semi-diurnal currents and underestimate the diurnal currents. This is probably the result of the complex tides around Singapore, with dominance of diurnal currents and semi-diurnal water levels, in combination with local boundary conditions. Reproducing the complex tidal dynamics needs a model with open boundaries located far away from the area of interest. Simultaneously, the grid resolution has to be sufficiently fine to reproduce local hydrodynamic phenomena.

Recently [15] developed a boundary fitted depth-integrated hydrodynamic model (Singapore Regional Model, SRM) which stretches from the Andaman Sea to the Borneo coast to simulate the flow dynamics accurately for this region. [11] used the SRM and a nested local model within SRM to quantify the effect of grid resolution on tidal propagation around Singapore, but concluded that improvements were marginal. [8] also verified the effect of grid resolution on hydrodynamic modelling mainly for tidal water level prediction. They used the SRM for their study and increased the resolution of central part of the domain (hereafter called as Refined Singapore Regional Model or SRMR), which improves the tidal predictions within the refined region but reduces the tidal predictions elsewhere. The aim of this study is to improve modelling of tidal propagation through better alignment of the computational grids with local bathymetry.

Even though it is well known that orthogonal grids should be optimally aligned with local depth contours, documentation on the effect of this alignment in scientific literature is scarce. More attention has been made to the effect of grid resolution; i.e., [3,7] etc. The improvement of modelled hydrodynamics with increasing grid resolution has led rapid development in unstructured grid modelling systems. A disadvantage of unstructured grids, however, is that the lower order advection schemes commonly used in these models require a higher grid resolution to obtain the same level of accuracy as structured grid models [12]. This can lead to increased computational time, depending on the grid architecture; see for example the review by [4]. A properly designed structured grid may therefore still be preferred over unstructured grids, depending on the required model accuracy, processes, and timescales.

The aim of this paper is to analyse the effect of grid alignment and resolution on the hydrodynamics in general, but flow velocities in particular, in the mouth of the Johor River. For this purpose three different model results were compared: the original model, a strongly refined model, and a less refined but more aligned model. Model results were compared with field measurements to assess improvement of the model performance, and subsequently analysed the effect on physical transport mechanisms.

## 2. SETUP OF THE MODEL

### 2.1. Model description

The tidal flow is modeled using Delft3D-flow, simulating two- or three-dimensional unsteady flow and transport phenomena resulting from tidal or meteorological forcing, including the effect of density differences due to a non-uniform temperature and salinity distribution. The program is based on three-dimensional shallow water equations, the continuity equations and the transport equations for conservative constituents. The set of partial differential equations in combination with appropriate initial and boundary conditions are solved with an Alternating Direction Implicit (ADI) finite difference scheme on an Arakawa 'C' grid system [1]. Because of the solution is implicit, the numerical stability is not restricted by the time step or by grid size. However, the accuracy of the flow decreases with increasing time step. In order to optimize the time step with which the model still produces accurate results, the Courant number was evaluated and a time step of 4 minute was set based on the critical Courant number $4\sqrt{2}$ to ensure accuracy. For this study, the model was applied in two-dimensional, horizontal mode, i.e. the modeled current velocities are depth-averaged and density driven flow in the vertical is neglected. Meteorological boundary conditions, i.e. wind forcing, are also neglected.

**2.2. Model applications**

The three models used in this study are the Singapore Regional Model (SRM), the Refined Singapore Regional Model (SRMR), and the Refined and Aligned Singapore Regional Model (SRMRA). All of the models cover part of the two large water bodies surrounding Singapore, the South China Sea in the east and the Andaman Sea in the west. A small portion of the Java Sea is included in the southern domain of the model. The model features a boundary fitted curvilinear orthogonal grid system to simulate water levels and flow patterns. Fig. 1 shows the model domain with its depth variations. The figure also shows the observation locations (T1, T2, C1, J1, J2 and OL) and fresh water discharge locations (01~15). The bathymetry of the model mostly based on the Admiralty charts with maximum depth of about 2 km in the Andaman Sea and about 160 m in the Strait of Singapore. The bathymetry in the Strait was updated with most recent bathymetric surveys. Fig. 2 displays the grid system of the model with a close-up view around Singapore. The grid system follows the general orientation of the deep channel in the Singapore Strait. The grid cell size increases from 200 m to 300 m around Singapore up to 15 km at the open boundaries.

The model is forced at its offshore open boundaries by eight main tidal constituents (Q1, O1, P1, K1, N2, M2, S2 and K2) and residual flows. A salinity of 31 ppt was considered at the

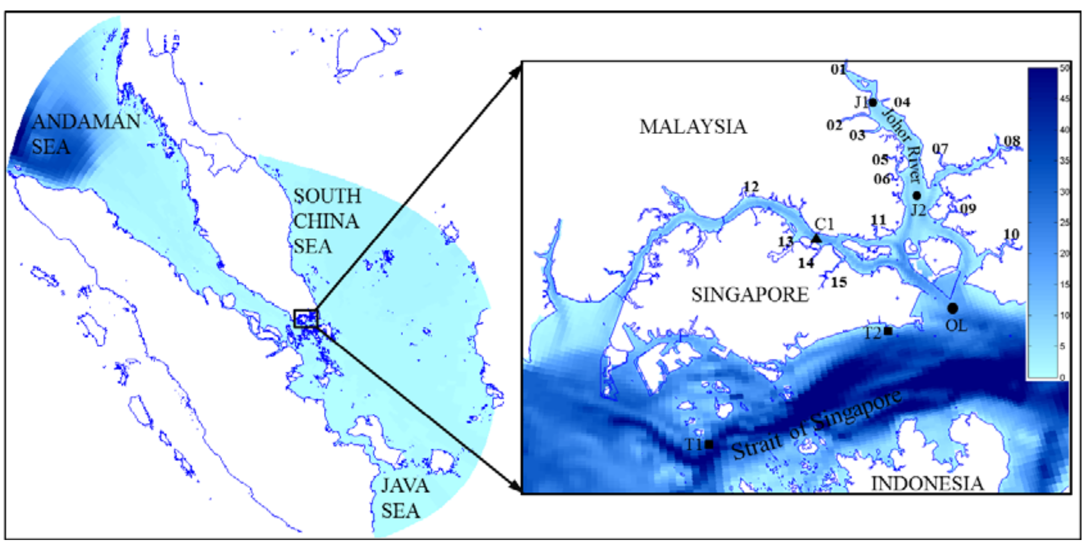


Fig 1: Model domain of the Singapore Regional Model with depth variation (left panel) and close-up view around Singapore with discharge locations (01~15) and observation locations. Constant freshwater inflow with zero salinity was prescribed in all the discharge locations.

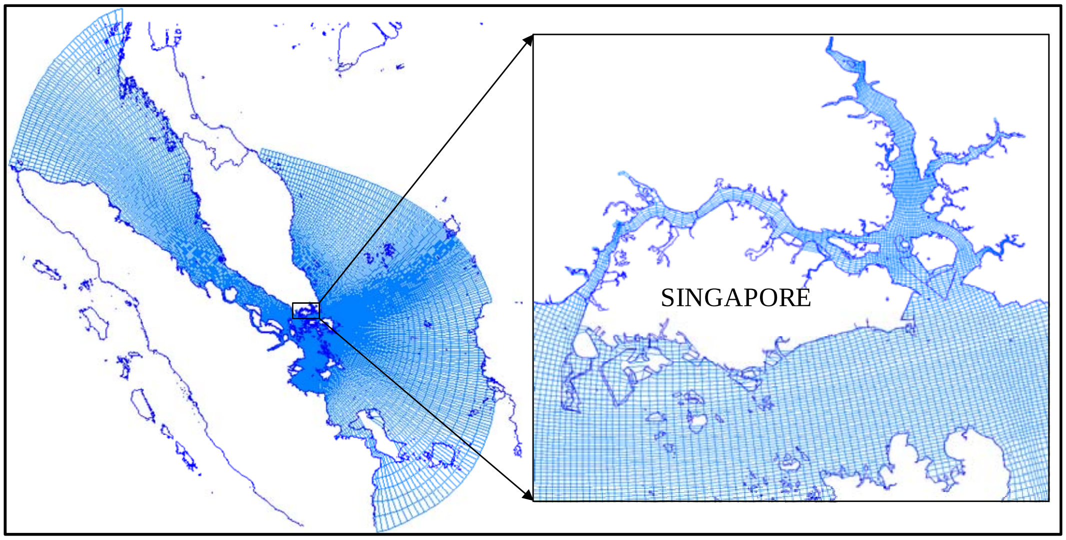


**Fig 2**: Grid distribution of the Singapore Regional Model with a close-up view around Singapore. Curvilinear orthogonal grid system was designed using Delft3D for resolving the complex coastlines.

offshore open boundaries. A constant freshwater inflow with zero salinity was also prescribed in all the discharge locations as shown in Fig. 1 for the main stream of the Johor River and its different tributaries. The river flow was estimated using monthly accumulated rainfall data in the surrounding catchment area, which is the only available format, using the volumetric rational method as explained by [6].

The SRM was refined three times in *n* and *m* directions around Singapore, as described by [8] to obtain the SRMR. Discharge, boundary conditions, roughness and all other model settings are kept similar to the SRM. Due to refinement, the Courant number increases and simultaneously the accuracy of the model will be reduced if we keep the same time step of the SRM. Hence, to get an optimized model setup with higher model accuracy, the time step was reduced to 2 min for the SRMR.

The SRMRA is based on the SRM which was refined locally up to a factor 2. Part of the existing grid from the SRM was subsequently removed and replaced with a rotated grid following the depth contours (see Fig. 3). In the narrow channels located both sides of the Tekong Island has 3~5 grids in a cross-section which are oriented at an angle as can be seen from the SRM grid system. However, the modified grid system is now more refined compared to the SRM grids with 6~10 grids in those narrow channels and oriented almost along the channels boundaries. Total number of grids increases due to this modification, but much less than the SRMR grids. As for the SRMRA, boundary conditions and model settings are similar as the SRM.

## 3. MODEL RESULTS

### 3.1. Model validation

The SRM was run for Jan to Dec 2004 and results were validated with measured water levels and flow velocities collected by the MPA (Maritime and Port Authority of Singapore). A spring-neap tidal cycle of measured and computed water levels at T1 and T2 (within the

Strait of Singapore; locations denoted with solid rectangles in Fig. 1) are compared in Fig. 4. This reveals that the water surface fluctuations obtained from the SRM model are in good agreement with the field data though some minor discrepancies exist: the observed low waters are slightly lower than the predicted low waters, and also there is a minor phase shift. The tidal range is approximately 1.5 m during neap tide and increases up to 2.5 m during spring tide. Since the agreement with the SRM is already sufficiently good, water levels computed with SRMR and SRMRA are not further compared with observations; instead we focus on the flow velocity.

Current speeds and directions are difficult to reproduce accurately since they are strongly affected by the local bathymetry. Fig. 5 shows a comparison between measured and computed depth averaged tidal current magnitude and directions at C1 using the SRM (same time period as for the water level comparison). The flow velocity has been measured with a bottom-mounted ADCP using a 1 m vertical resolution. The depth-averaged current was

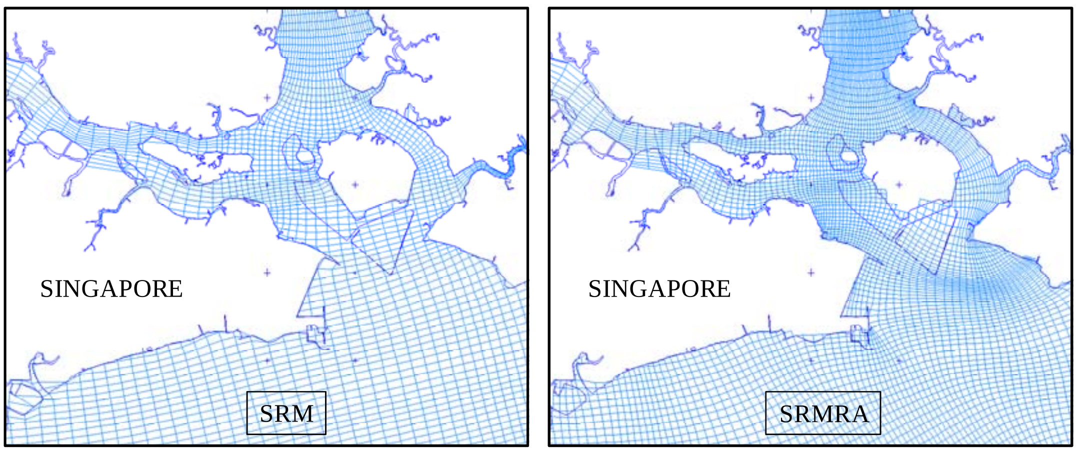


Fig 3: Grid distribution of the Singapore Regional Model (SRM) and Singapore Regional Model Refined Aligned (SRMRA). The SRMR is the SRM model locally (through domain decomposition) refined with a factor 3 and therefore not shown. The boundary locations of SRMR and SRMRA are identical to the SRM, shown in Fig. 2.

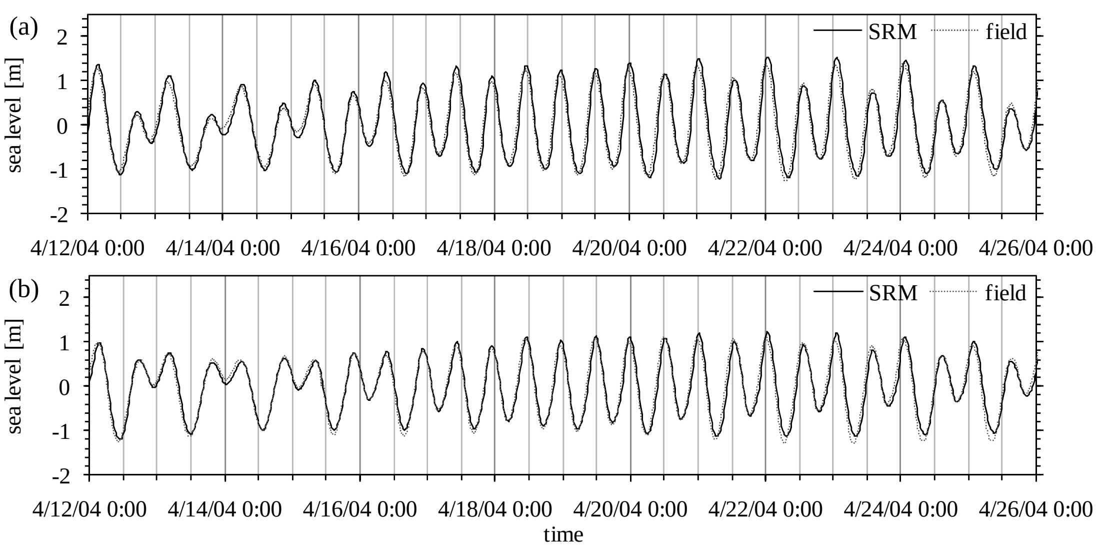


Fig 4: Time history of simulated sea level fluctuations and its comparison with field measurements at (a) T1 and (b) T2 locations covering a neap-spring period.

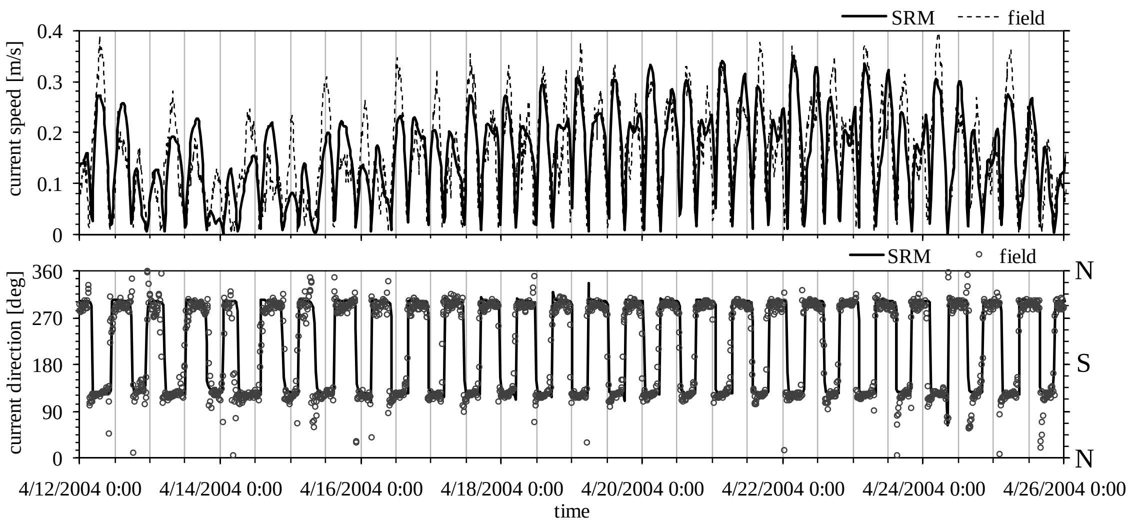


Fig 5: Time series of depth averaged tidal current and direction and its comparison with field measurement at C1.

computed from the multi-layer data and used for the comparison. The model predicts current speed and direction with good agreement though the ebbing current is slightly under predicted (differs approx. 10 cm/s). Based on the tidal elevation and flow velocity results, we can see that the SRM could capture the tidal hydrodynamics satisfactorily at some regions within the Singapore coastal waters.

The model results were checked at different locations around Singapore and found the water level variations are predominantly semi-diurnal with wide range of flow velocities. The flow velocities are sometimes strongly decoupled from the water level variations. Diurnal variation of flow pattern is observed in the Singapore Strait, which is predominantly semi-diurnal within the Johor River and mixed diurnal – semi-diurnal near the mouth of the Johor Estuary. Fig. 6 compares the tidal velocities and its directions with field measurements at OL (location shows in Fig. 1). Predominantly diurnal pattern of flow velocities are observed during neap tides, which is semidiurnal during spring tide. The SRM fails to reproduce the shorter phases during the neap tide. The SRM also under-predicts the flow velocities during some ebbing periods. Hence, further improvement of the original SRM is needed particularly for the regions where the tidal variations are mixed and has multi-directional effect on velocities.

The SRMR was run for the same period as the SRM and compared with field data. Fig. 7 shows the time series of simulated current speed and direction at OL. Major improvement is observed in the flow velocities during flood tide, whereas ebb flow velocities are still under-predicted. Little improvement is observed in flow direction during spring tide. Hence, the SRMR performs better than the SRM due to refinement, but computationally becomes expansive as the grid number increases.

Also the SRMRA was run for Jan to Dec 2004 with a 4 min time step. Fig. 8 compares the simulation results of sea level variations between the SRM, SRMR and SRMRA at the observation location OL. This reveals that the SRMRA predicts lower low waters than the SRM. It was observed that the SRM tends to underestimate low waters (see Fig. 4); the re-alignment results in improved water level predictions. However, computed flow velocities and directions have improved significantly as can be seen from Fig. 9. The modeled flow velocities and directions are in good agreement with observations. The ebb velocity peaks were underestimated by both the SRM and SRMR (especially during spring tide) is now accurately reproduced.

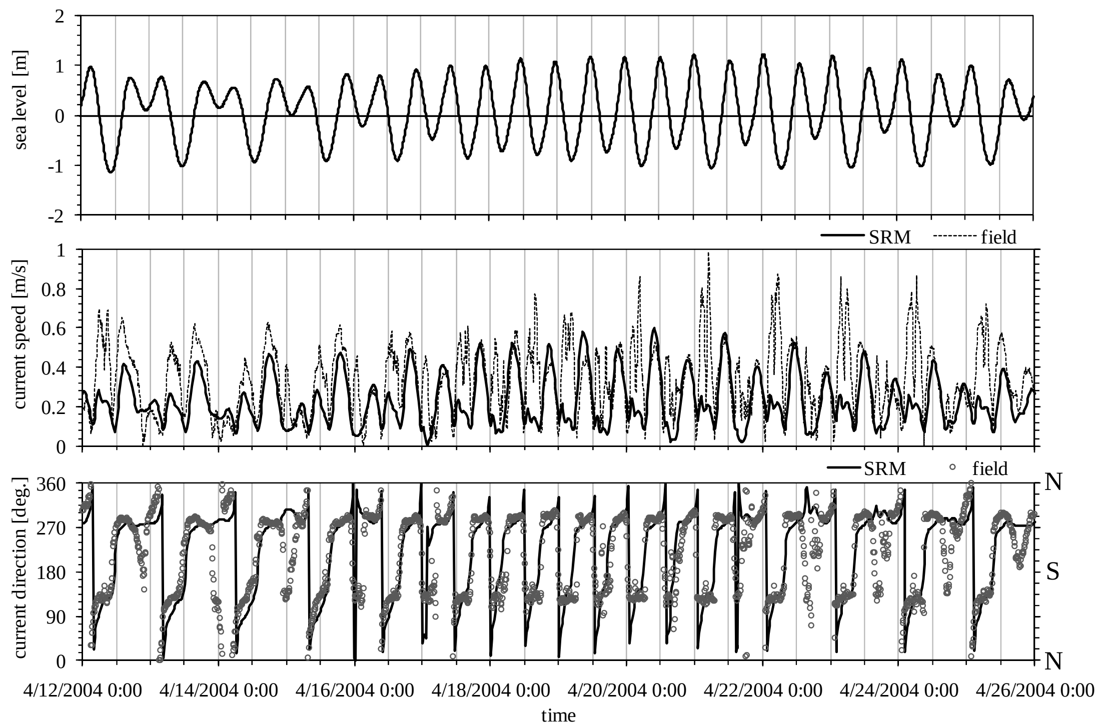


Fig 6: Time series of computed sea level variation with depth averaged tidal current and direction and its comparison with field measurement at OL.

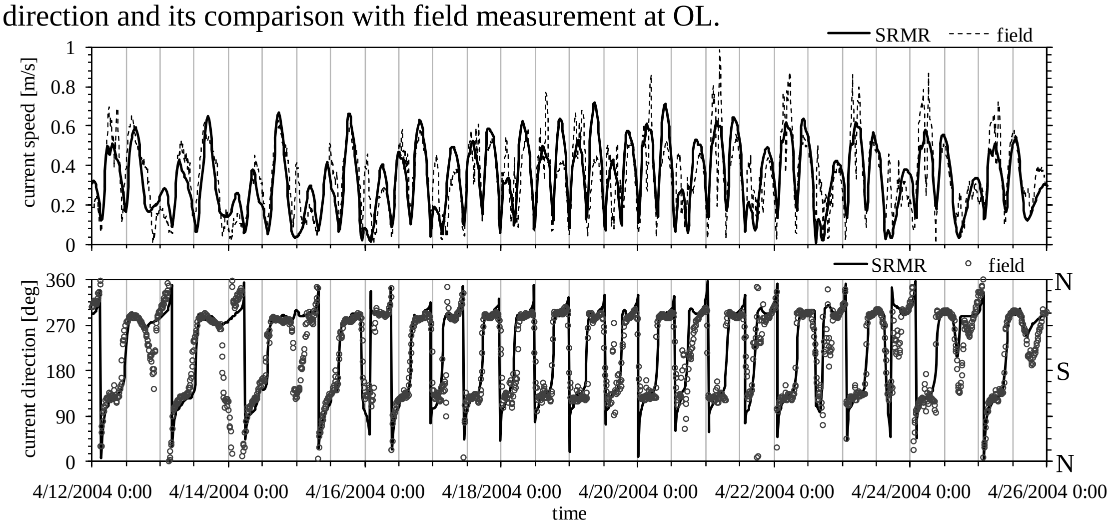


Fig 7: Time series of simulated depth averaged tidal current and its direction using the refined grid model (SRMR) and its comparison with field measurement at OL.

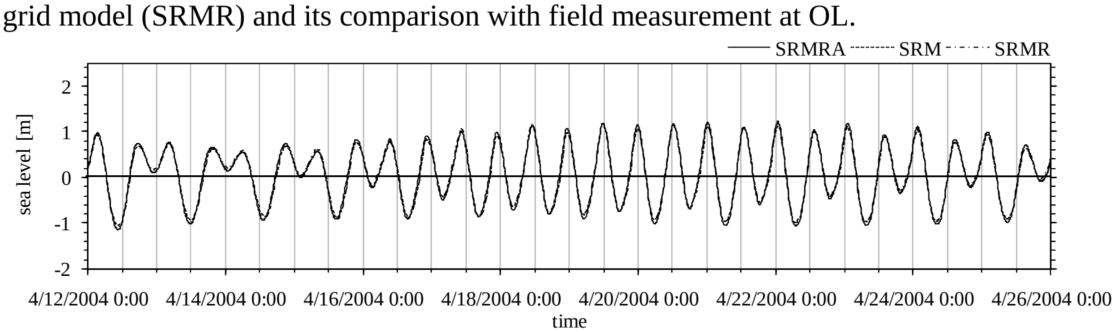


Fig 8: Time history of simulated with SRM (a) and SRMRA (b) sea level fluctuations at the OL.

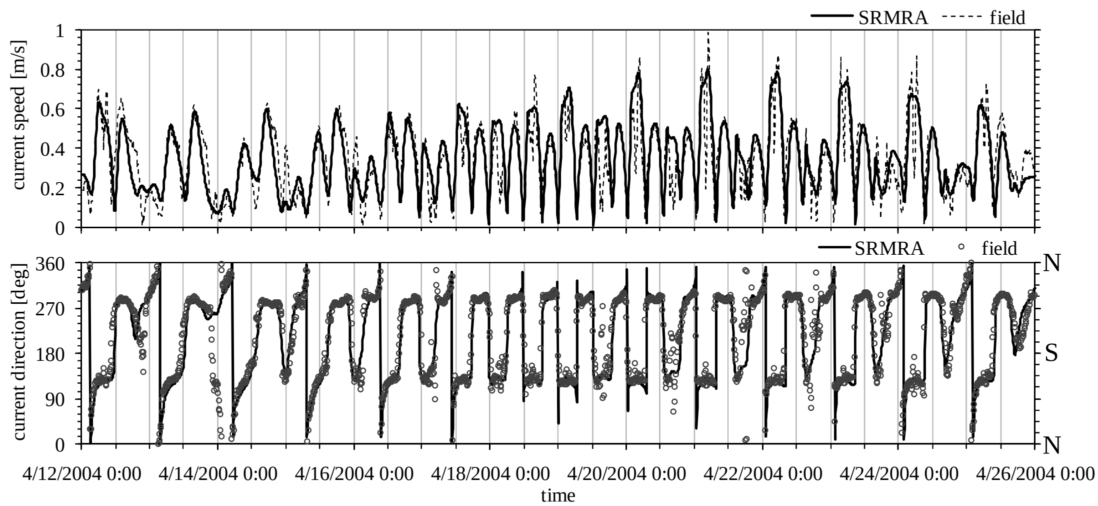


Fig 9: Time series of simulated depth averaged tidal current and direction using the modified grid model (SRMRA) and its comparison with field measurement at the OL.

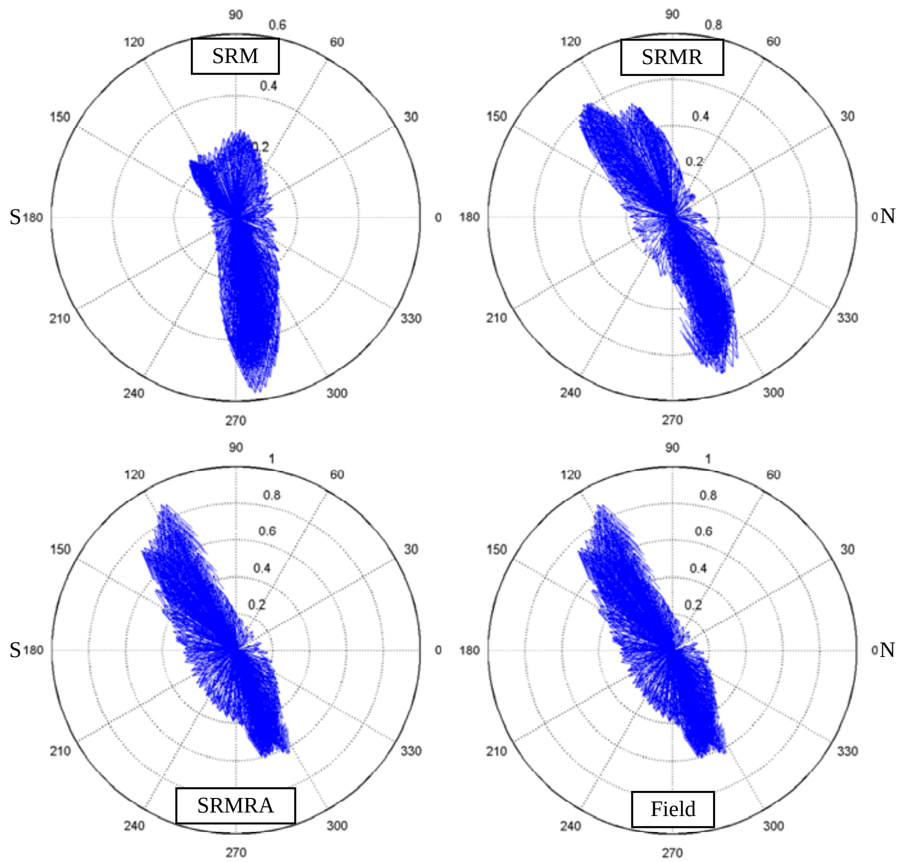


Fig 10: Velocity rose during the spring-neap cycle (20100412 0:00 hr – 20100426 0:00 hr) at the OL from the results of different models and field measurements.

Velocity roses for depth-averaged tidal currents at the observation location (OL) computed by all three models (SRM, SRMR and SRMRA) and its comparison with field measurements are shown in Fig. 10 to further illustrate model performance. Results are shown for a spring-neap period (4/12/2004 0:00 hr to 4/26/2004 0:00 hr). The major difference is observed in the velocity rose of the SRM from field measurements. The refined model (SRMR) improves the quality, but still strongly diverges from the field data. However, significant improvement is observed from the refined and aligned model (SRMRA) which is completely in agreement with the field data. Both the SRM and the SRMR simulate flood-dominant flow velocities whereas ebb-dominance is predicted by SRMRA (in agreement with field observations). The simulated tides and tidal currents by SRMRA, except for very negligible differences in magnitude and phase between the field data and the computed results, are well predicted. The change in grid system without changing other parameters improves the model performance substantially.

## 4. DISCUSSION

On an Arakawa 'C'grid, the u (m)-component of the velocity is centered on the east and west faces, and the v (n)-component of the velocity is centered on the north and south faces. The ADI method splits one integration time step into two stages. Each stage consists of half a time step. In both stages, all the terms of the model equations are solved in a consistent way with at least second order accuracy in space. The horizontal advection terms are discretized using a higher-order dissipative approximation. The advantage of the ADI-method is that the implicitly integrated water levels and velocities are coupled along grid lines, leading to systems of equations with a small bandwidth. The drawback is that the grid alignment influences the computational results in bathymetrically complex fluvial or coastal areas.

The computation results show that the largest difference between the original, the refined, and the refined and aligned grid in the tidal channels are east and west of Tekong Island (Fig. 1). At their narrowest location, the width is 1 and 1.5 km (resp.). These channels are covered with 2 / 3 (resp.) grid cells in the m-direction in the SRM, but 6 / 9 (resp.) cells in the SRMR. In the n-direction, about 5 computational cells exist in the m direction (both east and west channel; hence 15 in the SRMR model. In the SRM, the low amount of computational cells can be expected to conflict with the ADI solver, since this computes first the flow in m-direction, followed by the flow in n-direction. However, it is surprising that improvement due to grid refinement alone (the SRMR) is relatively small. This shows that (staggered) grid design should not only focus on refinement aspects, but especially on proper alignment with depth contours. The relevance of the work presented here is that even though more and more refined models are being set-up, properly designing structured grids may provide better results than high resolution unstructured grids.

## 5. CONCLUSION

Being between the two large water bodies i.e., Andaman Sea and South China Sea with different tidal types, hydrodynamics of the Singapore coastal waters are relatively complex. The Singapore Regional Model (SRM) was developed using Delft3D modeling system to simulate the tidal flows for the whole water bodies between Andaman Sea, South China Sea and part of Java Sea. In order to obtain accurate hydrodynamic information around Singapore the inner grid of the model particularly near the mouth of the Johor Estuary were modified. The modified model (Singapore Regional Model Refined and Aligned, SRMRA) produces better results due to its finer resolution and more specifically better alignment with narrow channels.

The flow velocity is predominantly diurnal in the Singapore Strait, semi-diurnal in the Johor Estuary, and mixed diurnal - semi-diurnal near the mouth of the estuary. The original SRM poorly reproduce this mixed variation. At the observation location presented here (OL), neap tide is characterized by diurnal currents while semidiurnal currents dominate during spring tide. Both the SRM and SRMR predict flood dominated flow velocities, whereas the SRMRA predicts ebb dominance, in good agreement with observations. Hence, the SRMRA improved the essential characteristics of the flow significantly better due to its higher resolution, but especially due to the better alignment of the grids in some narrow channels. The importance of grid alignment relative to grid resolution shows that increasing the grid resolution only is not sufficient to substantially improve hydrodynamic models.

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# IMPACTS OF CLIMATE CHANGE ON WATER AND SANITATION SYSTEM IN BANGLADESH

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## ABSTRACT

All climatic parameters have probable significant impacts on water and sanitation systems. Climate change will have significant impacts on water resources, as there is very close connection between the climate and hydrological cycle. Rising in temperatures will increase evaporation and lead to increases precipitations, frequent and extreme floods and droughts in different regions and different times. Variable precipitations pattern and snow melt will influence water availability, water supply, sanitation, water contamination and drainage congestion. Climate changes are likely to lengthen the transmission season of vector-borne diseases and alter their geographic range; floods, droughts, cyclonic storms will disrupt water supply, sanitation. Both the water quality and quantity may be affected due to the impacts of climate change such as sluggish flow of groundwater due to reduce hydraulic gradient, intrusion of saline water in the coastal groundwater, lowering of water table due to lower recharge. Sluggish groundwater flow due to climate change and sea level rise is likely to increase arsenic contamination. In Bangladesh, 30 million of people drink with arsenic more the Bangladesh standard (0.05mg/L) and 50 million more than WHO standard (0.01 mg/L). More than 38,000 Arsenocosis patients have been identified by national screening. 85% and 60% people have access safe drinking water in rural and urban areas, respectively. On the other hand, floods in the monsoon will increase dilution factor and aeration of water causing a decrease chemical and organic pollution but submergence of sanitation and sewerage facilities during high floods and cyclones may cause increased microbial contamination of water. The two diseases- diarrhea and dysentery are the main cause of death during floods due to drink-polluted water. Microbial activities become double for each 10°C increase of temperature. The increase of 1.4 to 5.8 °C temperature will result in 14% t0 58% increase in microbial activities and dissolved oxygen content of water will be reduced at higher temperature. This study suggested that consider of more technological options for both urban and rural areas considering both water and non-water options, e. g. eco-sanitation and raising mass awareness about climate change for improved water and sanitation systems.

**Key Words**: Climate change, water quality, sanitation, contamination, groundwater**.**

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## 1. INTRODUCTION

Climate is simply the weather that is dominant or normal in a particular region; the term climate includes temperature, rainfall and wind patterns. Geography, global air and sea currents, tree cover, global temperatures and other factors influence the climate of an area, which causes the local weather. Climate change is among this century's gravest challenges, particularly for developing countries, which are both vulnerable to a range of adverse impacts and lack the adaptive capacity to deal with them. The earth's climate has always varied naturally, in the past cooler cycles due to variations in the earths orbit round the sun, sunspot activity or volcanic eruptions, have altered the climate. However, large changes have been very gradual over huge time periods; nevertheless they are still blamed for the extinction of the dinosaurs. What is new is that humans are now, due to pollution from industrial processes and wasteful lifestyles directly influencing the climate of the earth. Human influence is now believed to be changing the climate much faster than occurring in the past under natural processes. The world's climate has always been changing between hotter and cooler periods due to various factors. However, for the first time in the earth's history it has now been firmly established that its human inhabitants are altering the climate through global warming as a result of greenhouse gas emissions. Although the basic science is now clear, the full range of effects due to human influenced climate change is still not fully understood.

The results of climate change some hazardous event observed in our beautiful world like drought or no rainfall, flood, tornado, cyclone, ice melting etc and the effect of hazardous event like the agricultural production (including fish cultivation, livestock etc) has decreased as near about 15% for salinity, the drought, heavy rainfall, tornado or the cyclone etc. In aspect of climate change some specific area of the world or some least development country has treated as mostly vulnerable country of the world like as Bangladesh. Bangladesh has a specific image in international climate change negotiations and campaigns: of the country that stands to suffer the most from climate change, while having done the least to deserve it. In contrast, while Bangladesh is the most populated mega delta in Asia, it has less economic clout than the Chinese mega cities that are threatened by similar circumstances. Bangladesh stands to suffer a high risk of damage from climate change for several reasons. Bangladesh is a small country with a large population of about 130 million located just east of India between 20° and 26° north latitude and 88° to 92° east longitude. Geologically and geographically, Bangladesh is a low-lying active delta interlaced by rivers and waterways, the outlet of three gigantic Himalayan rivers into the Bay of Bengal. It lies on a geological fault-line and has a high risk of earthquakes. It is prone to tropical cyclones. In Bangladesh out of six seasons, three are prominent. Monsoon generally starts in the month of may and continues till October. During this season more than 905 of the rainfall take place. Winter is very dry and during the Pre-monsoon air gets hot and its moisture and the relative humidity is low. During dry season, both groundwater and surface water becomes scarcity. In flooded area pure drinking water is a major problem in Bangladesh. Bangladesh's rivers altering the hydrological cycle; more powerful tornados and cyclones; and sea level rise displacing communities, turning freshwater saline and facilitating more powerful storm surges. Among them water sanitation sector will in turn be the most affected by the adverse effects of climate change. The impact will be intensified by the fact that Bangladesh is both one of the most populated and one of the poorest nations on earth. Among then water sanitation sector will in turn be the most affected by the adverse effects of climate change. The objective of this study is to understand the impact of climate change and climate on water and sanitation.

## 2. METHODOLOGY

The whole study was conducted by collection of secondary information on various aspects related to water and sanitation was done through literature review, Bangladesh Bureau of Statistics, journals, books, published documents and the Internet.

## 3. RESULTS AND DISCUSSION

It is predicted that climate change could have devastating impact on water and sanitation sectors. The impacts of climate of climate change could affect water and sanitation in Bangladesh in many ways: the sea-level rise will threaten for fresh water. Hazards like floods, droughts, cyclone and others, which are aggravated by climate change and its variability, are being experienced more frequently in Bangladesh than ever before (Table 1).

Table 1: Natural Disasters in Bangladesh from 1904 to 2007

| Disaster Events | No. of events | Person Killed | Total affected |
|---|---|---|---|
| Drought | 6 | 1900018 | 25002000 |
| Ave. per event | | 316670 | 4167000 |
| Earthquake | 6 | 34 | 19125 |
| Ave. per event | | 6 | 3188 |
| Epidemic | 32 | 403588 | 3063665 |
| Ave. per event | | 12612 | 95740 |
| Extreme Temperature | 19 | 2291 | 187200 |
| Ave. per eve | | 121 | 9853 |
| Flood | 79 | 52773 | 323657363 |
| Ave. per event | | 668 | 4096929 |
| Wave/ Surge | 2 | 3 | 12010 |
| Ave. per event | | 2 | 6005 |
| Wind Storm | 157 | 624352 | 75275556 |
| Ave. per event | | 3977 | 479462 |

[Source: 1].

Water is an essential resource for all life and a requirement for good health and sanitation. It is a critical input for industry and essential for sustainable growth and poverty reduction. Climate change will alter patterns of water availability by intensifying the water cycle. Droughts and floods will become more severe in many areas. There will be more rain at high latitudes, and less rain in the dry subtropics. Hotter land surface temperatures cause more powerful evaporation and hence more intense rainfall, with increased risk of flash flooding. Increased evaporation creates water availability reduction, salinization of water resources and lower groundwater levels. Floods affect water quality and water infrastructure and increase fluvial erosion, which introduces different kinds of pollutants to water system. Also drought affects water availability and water quality. Differences in water availability between regions will become increasingly pronounced and areas that are already relatively dry are likely to become drier [2]**.** Reduced water supplies would place additional stress on people, agriculture, and the environment. Already, some 1.7 billion people, a third of the world population live in water stressed countries, a figure expected to rise to 5 billion by 2025. Climate change will exacerbate the stresses on water supply caused by pollution and by growing populations and economies. The most vulnerable regions are arid and semi-arid areas, some low-lying coasts, deltas, and small islands [3]. Table 2. shows the changes of climate over time within this century.

Table 2: Climate Change Scenarios for Bangladesh NAPA.

| Year | Annual | Temperature Change (°C), Mean | | Annual | Precipitation Change (%), Mean | | Sea Level Rise |
|---|---|---|---|---|---|---|---|
| | | Dec-Jan-Feb | Jun-Jul-Aug | | Dec-Jan-Feb | | |
| 2030 | 1 | 1.1 | 0.8 | 5 | -2 | 2030 | 1 |
| 2050 | 1.4 | 1.6 | 1.1 | 6 | -5 | 2050 | 1.4 |
| 2100 | 2.4 | 2.7 | 1.9 | 10 | -10 | 2100 | 2.4 |

[Source: 4].

Salinity intrusion and arsenic contamination as two key threats to the water sector in Bangladesh, and recommended that the government pay urgent attention to this particular sector. Sea level rise could potentially force around 33 million of their land by 2050 and up to 43 million of their land by 2080 [5] and this is only taking into account the direct effect of sea level flooding. If salinity, river gradient reduction, drainage congestion, erosion and other indirect effects of sea level rise are taken into account the almost the entire 51-97 million expected to be living in the coastal zone by 2080, may have to eventually leave their homes [6]. So, these refugees will be suffering much problems lack of pure drinking water and sanitation. While Dhaka already struggles to maintain basic services like electricity and sanitation as its population swells by up to 400,000 new arrivals each year [7]. At present, salinity in river water has exacerbated the inundation problems from Cyclone Aila. The tidal surge during the cyclone rushed over or broke rivers’ embankments and covered farmland in saline water. Sea water does not only harm that which it covers. It also seeps into the groundwater table and surface water near the coast. Shallow and deep tube wells bring up brackish water. Many of these lush and moist places suffer a lack of potable drinking water. Sluggish groundwater flow due to climate change and sea level rise is likely to increase arsenic contamination. World Health Organization [8] reports that there are about 2.5 million tubewells in Bangladesh and more than 95% of the Bangladesh population of 120 million drinks well water. The present crisis may have affected more than 50 million of people in Bangladesh provisional guideline value (0.01mg/L) [8]. More than 38,000 Arsenocosis patients have been identified by national screening.  85% and 60% people have access safe drinking water in rural and urban areas, respectively. Reduction of river flow in the dry season will reduce dilution factor and oxygenation of water due to stagnation resulting in an increase in the pollution of the rivers. On the other hand, floods in the monsoon will increase dilution factor and aeration of water causing a decrease chemical and organic pollution but submergence of sanitation and sewerage facilities during high floods and cyclones may cause increased microbial contamination of water. Microbial activities become double for each

10°C increase of temperature. The increase of 1.4 to 5.8 °C temperature will result in 14% to 58% increase in microbial activities and dissolved oxygen content of water will be reduced at higher temperature. So, both the water quality and quantity may be affected due to the impacts of climate change such as sluggish flow of groundwater due to reduce hydraulic gradient, intrusion of saline water in the coastal groundwater, lowering of water table due to lower recharge.

Bangladesh sets its national target to achieve 100% sanitation by 2013. Almost 15 of every 100 people lack adequate, safe sanitation. Due to inundation of low lying lands the low cost pit latrines, septic tank soak wells are submerged, resulting pollution of water bodies and spreading waterborne diseases. More flooding in monsoon submergence of sewer network and treatment plant, damage of septic tanks soak wells, pit latrines and other sanitation infrastructure, water quality affected from increased pathogen loads, organic and nutrients. Floods damages sanitation infrastructure. The two diseases- diarrhea and dysentery are the main cause of death during floods due to drink-polluted water. Drought creates availability of water in winter months especially in drought-prone northwest region, no water for sanitation. More flooding in monsoon submergence of sewer network and treatment plant, damage of septic tanks soak wells, pit latrines and other sanitation infrastructure, water quality affected from increased pathogen loads, organic and nutrients. Cyclones and storm surges extensive damage to sanitation infrastructure and polluting all the drinking water sources in the coastal areas of Bangladesh, most PSFs become unusable. The impact of climate related disasters on health is also much worse due to lack of uncontaminated drinking water and lack of proper sanitation facilities. Women and adolescent girls suffer as sanitation systems are destroyed: many women who are refrain from using the toilet during the day and consequently suffer from urinary tract infections. Bangladesh is already vulnerable to outbreaks of cholera and other waterborne diseases but the effects of climate change will make these more common. Adaptation measures to this threat can include ‘climate proofing’ sanitation facilities and domestic water supplies. Health will be further affected by changes in the water cycle. Floods create new breeding sites for disease vectors such as mosquitoes, and trigger outbreaks of water-borne diseases like cholera [2]. For instance climate change is projected to increase the amount of diarrhoeal diseases in poor regions by approximately 2-5% by 2020 [9]. In Bangladesh it has been found that rainy conditions favour malaria and pneumonia, hot dry conditions favour diarrhea, non-pneumonia respiratory infections and dysentery, while floods led to outbreaks of rabies, and trypanosomiasis in some areas. Vector-borne which are diseases spread by a ‘vector’ such as insects like mosquitoes, sandflies are particularly sensitive to climate factors so diseases like malaria, fliarisasis, dengue fever, leishmaniasis etc. are all expected to become an increasing threat to the health of many.

## 4. CONCLUSIONS

Bangladesh is prone to salinity intrusion, waterlogging, sea level rise, tidal surge, and cyclone. One aspect of climate change is that through unstoppable, it is still likely to slow in its manifestations. Improvement in the weather and flood forecasting systems, early warning system, improving drainage, increase awareness etc., are some of the options for waterlogged areas, where pure drinking water and lack of sanitation facilities are the common scenario.

The impact of climate change on water and sanitation sector is undeniable and will most certainly worsen if governments fail to take suitable steps right now. Climate change is affecting the quality and quantity of water. Sanitation facility depends on water. Adaptation to climate change can reduce vulnerability and delay the process. Depending on the local environment as well as the magnitude of the changes alleviation strategies have to be developed. With the available technologies it would be possible to increase sanitation facilities, which would depend on the dissemination of these technologies to the end-user and also on the availably and affordability of extra input required for this purpose. To tackle pure drinking water scarcity problem, effort should be made to develop economically affordable rainwater harvesting system

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# SOLID WASTE MANAGEMENT AND ENVIRONMENTAL HAZARDS IN RAJSHAHI CITY, BANGLADESH

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## ABSTRACT

The Rajshahi City generates approximately 350 tones of solid waste every day while the amount increases to 400 tones during summer. Of the total, only 210 tones are collected and dumped into the open dumping ground at Nawdapara. The remaining 140 tones of waste are dumped straight into drains, water bodies and open spaces. The RCC is also not responsible for collecting waste from households and in many mahallas the communities have organized themselves to collect the waste and dispose of it to the local collection points. Over 40% solid wastes of Rajshahi city are dumped into drains, open spaces and water bodies, causing environmental pollution and health hazards. The present solid waste management practice being followed is based on the end-of-pipe approach, i.e. collect-transport-dispose. This approach is neither sustainable nor cost-effective. Waste management in Rajshahi city that the RCC's open dumping ground at Nawdapara is unscientific and contributing to pollution. Low-lying areas, drains and canals are clogged with waste, unsanitary crude dumping practice due to rampant dumping of solid wastes over years. The study showed that rats, flies, and other diseases vectors breed in open dumps, as well as in poorly constructed or poorly maintained housing, in food storage facilities, and in many other places where food and harborage are available for rats and the insects associate with them. Ecological impacts, such as water and air pollution, also have been attributed to improper management of solid waste. Liquid from dumps and poorly engineered landfills has contaminated surface waters and groundwater contains toxic elements, such impact to as Cu, As or many contaminated water supplies with unwanted salts of Ca and Mg. This study reflects the present scenario of solid waste management and adverse impacts of pollution through inappropriate dumping of solid waste in Rajshahi city. An environmentally sound waste collection, transportation, resource recovery and disposal, energy and resources recovery system and Public-Private-Community Partnerships are required to improving existing practice of solid waste management to minimize environmental hazards in Rajshahi City, Bangladesh.

**Key Words**: Solid waste, RCC, management system, pollution, environmental hazards

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## 1. INTRODUCTION

Waste is merely raw material in the wrong place. Solid waste is the unwanted or useless solid or semi solid material generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). A huge quantity of solid waste generate in all the developed and developing countries per day. Solid-waste management may be defined as the discipline associated with controlling the generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a manner that is in accordance with the best principles of health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes. Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effectively managing waste for a municipality. One of the most obvious impacts of rapidly increasing urbanization and economic development can be witnessed in the form of heaps of municipal solid waste. Solid-waste management is a major challenge in urban areas throughout the world. Without an effective and efficient solid-waste management program, the waste generated from various human activities, both industrial and domestic, can result in health hazards and have a negative impact on the environment. Despite the huge expenditures, urban areas in Bangladesh are still grappling with the challenge of preventing environmental degradation due to inadequate solid-waste management. The sites are situated in and around the city areas of low-lying open spaces, unclaimed land, riverbanks and roadsides [1]. Apart from the contamination of water resources and air pollution due to the open dumping of solid waste, the health hazard is another key issue to be addressed. So, solid-waste management has become an important issue in Rajshahi City, Bangladesh and it needs to be resolved through an integrated community, private-sector, and policy-based approach. In order to evaluate the present practices of solid waste in Rajshahi city was conducted.

## 2. METHODOLOGY

### 2.1. Study area

The study area is Rajshahi City, which is the divisional headquarters of Rajshahi Division as well as the administrative district in shown in figure 1. It lies between 24° 21‘ and 24° 25‘ north latitudes and between 88° 32‘ and 88° 40‘ east longitudes. Rajshahi is located in the north-west of the country and has an estimated population of around 7,72,000 people [2]. It consists of 30 wards with a total area of 96.69 $km^2$ and is situated on the northern banks of the river Padma (the downstream of the Ganges river in India). The climate of the city is generally marked with monsoons, high temperature, considerable humidity and moderate rainfall. The minimum temperature varies from year to year from between 10°C to 27°C in winter and the maximum temperature varies between 24°C to 36°C in summer. During April and May the city experiences the highest temperature. It has a mean annual rainfall of below 1524 mm compared to a national average of 2540 mm [3].

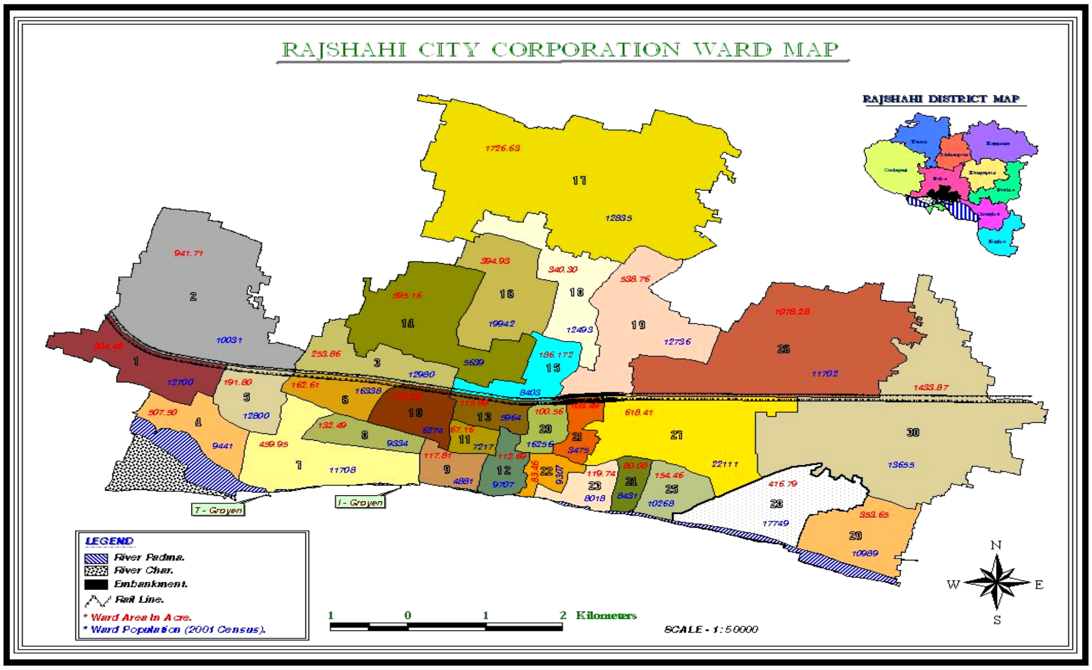


Fig 1: Map of the study area

### 2.1. Data collection

Both primary and secondary data have been collected to conduct this study. Primary data collected through field survey. The authors are from Rajshahi and their personal observation, living, and discussion with the professionals are other sources of primary data. Secondary data have been collected from different sources like journals, books, published documents and the Internet.

## 3. RESULTS AND DISCUSSION

### 3.1. Waste Management Authority

Rajshahi City Corporation (RCC) is the key government institution in waste managements in the city of Rajshahi. Provision of water supply and disposal of solid wastes; the construction and reconstruction of roads and culverts; restoration of drains and management of storm water; eradication of mosquitoes; and the provision of health services to city residents are the main activities of RCC. The present solid waste management practice being followed in the study area is based on the end-of-pipe approach, i.e. collect-transport-dispose. This approach is neither sustainable nor cost-effective. The sustainable way for solid waste management is based on 4 R's principle i.e. reduce, reuse, recycle and recovery of the waste. Rajshahi is not a major industrial area, but it is famous for the silk industry. The city lacks a adequate solid waste system the domestic, hospitals & clinics and workshops are collected and go directly into the open dumping in Nawdapara without any treatment. This may have a significant effect on water, soil and air quality. Various types of waste are causing adverse effect on living organisms and environment. As a result, human and animal diseases occur, the air and soil environment are spoiled and the entire natural ecosystem balance is disturbed. Solid waste management in RCC is operating under the conservancy wings by conservancy staffs under the direct supervision of Mayor of this city. Among them there is a suitable number of engineer, administrative officers, officers , street sweepers, driverss, screws and labours (regular or master role). Table 1. shows a list of the exsisting staffs of the conservancy wings of the those who are engaged water supply system.

Table 1: Manpower and resource of conservancy of Rajshahi City Corporation.

| Items | Rajshaahi City corporation |
|---|---|
| Manpower | 1073 |
| Tractors | 8 |
| Lorries | 16 |
| Hydraulic trucks | 2 |
| Rickshaw-van | 182 |

### 3.2. Waste generation

The Rajshah city generates approximately 350 tonnes of solid waste every day while the amount increases to 400 tones during summer. Of the total, only 210 tones are collected and dumped into the open dumping ground at Nawdapara. The remaining 140 tones of waste are dumped straight into drains, water bodies and open spaces or littered around.

### 3.3. Waste handling and transport

Waste collection methods vary widely among different countries and regions. Domestic waste collection services are often provided by local government authorities, or by private companies in the industry. Collection of solid wastes of urban areas is difficult and complex because the generation of residential commercial-industrial solid wastes is a diffuse process that takes place in every home, every apartment building and every commercial and industrial facilities as well as the streets, parks etc. the common types of residential services are curb, alley, setout-setback, setout and backward carry. In the study area alley and backward carry service are using for solid waste collection. The characteristics these services are compared in Table 2. In the study area, community collection system is used. In this system, the city householders carry their waste bins or similar facilities situated at a specific locations or open roadside open space and deposit waste their. Solid waste collection truck visits these locations at regular intervals and hauls the accumulated wastes to treatment or disposal sites. The authority argued that it reduces considerably the number of collection points. But some bins are found broken as a result the wastes are spread here and there and create odor and fly nuisance, open space for waste gathering ingress rain water that leads to leachte pollution. Recently collecting household waste by Riksha-Van at night in word No. 12, 22 and 29 within 7pm-11pm. Collection and available facilities of the city area is shown in Table 3.

Table 2: Comparison of residential collection services

| Considerations | Curb | Alley | Setout-setback | Setout | Backward |
|---|---|---|---|---|---|
| Requires homeowner cooperation: | | | | | |
| To carry full containers | Yes | Operational | No | No | No |
| To empty full containers | Yes | Operational | No | Yes | No |
| Required schedule service for homeowner cooperation | Yes | No | No | Yes | No |
| Poor aesthetically: | | | | | |
| Spillage and litter problem | High | High | Low | High | Low |
| Container visible | Yes | No | No | Yes | No |
| Attractive to scavengers | Yes | Highest | No | No | No |
| Prone to upset | Yes | Yes | No | Yes | No |
| Average no. of persons in crew required for efficiency | 1-3 persons | 1-3persons | 3-7 persons | 1-5 persons | 3-5 persons |
| Crew time | Low | Low | Great | Medium | Medium |

Table 3: Collection facilities of Rajshahi City Corporation

| Items | Rajshaahi City corporation |
|---|---|
| Number of dustbins | 800 |
| Solid waste collection | Manual |
| Frequency of solid waste collection | Daily, twice and once a week based on generation |
| Amount of collected solid waste | 210 tones |

### 3.4. Waste recycling and disposal

Recycling and reclamation are now strongly promoted for conservation of resources and prevention of environmental degradation. Bangladeshi cities often collect only 40% to 50% of waste generated, with open dumping the only disposal method available [4]. In Bangladesh, wastes having some market value are being reclamation or salvaged in three stages. In the first stage, housewives separate refuse of higher market value such as papers, bottles, fresh containers, old cloths, shoes etc. and sale them to street hawkers. Mostly children of slum dwellers known as “Tokai” carry out the second stage salvaging. They collect different items of low market value from waste collection bins. The items include broken glass, cans, cardboard, waste papers, rags, plastics, metals and miscellaneous commercial wastes discarded by households. Scavengers at final disposal sites do the third stage of salvaging when municipal trucks unload fresh refuse. The reclaimed materials reach the waste and materials shop through street hawkers who purchase old materials directly from households and through solid waste collectors who reclaim the materials from bins and final disposal sites. These reclaimed materials require intermediate processing like washing, drying and sorting. The refuse dealers separate the materials in proper form and sell them to consumers as well as supply them to appropriate processing for reuse as raw materials. The most common consumer products recycled in RCC area include aluminum beverage cans, steel food and aerosol cans, HDPE and PET bottles, glass bottles and jars, paperboard cartons, newspapers, magazines, and corrugated fiberboard boxes. PVC, LDPE, PP and PS are also recyclable, although these are not commonly collected. These items are usually composed of a single type of material, making them relatively easy to recycle into new products. The recycling of complex products (such as computers and electronic equipment) is not collected for recycling due to more difficult for reusing. In RCC area huge quantity of phencidil glass bottle are found in the solid waste. These glass bottles are collected by scavenger and it gathered in Nomovadra (in front of Bangladesh Sericulture Board) where sorting for sell. Carton papers and steel food cans are also sorting and transporting here industry for new material produce. Despite source reduction, reuse, recycling and composting divert significant portions of MSW, large amount of wastes still need to be placed in landfills. There is only one landfill in RCC. Finally the collected waste dumped into the open dumping ground at Nawdapara dumping site area of 15.95 acres which shown in figure 2.

Satellite emage of dumping site

Dumping site

Fig 2: Solid Waste Dumping Site of Rajshahi City Corporation.

**3.5. Environmental hazards due to inadequate solid waste management**

In urban areas, the most adverse impact of solid waste is incidence and prevalence of various diseases. In Rajshahi City, malaria, respiratory problems, eye and skin diseases are the worst impacts. In the City, adverse impacts of inadequate solid waste management are as follows:

- Liquid from dumps and landfills has contaminated surface waters and groundwater.

- Solid waste blocks the drainage system and creates sewage stagnant in drainage and produce breeding place for mosquitoes and create bad odor, and inconvenience.
- Impact to watersheds and ecosystems, energy consumption and cost efficient waste offsets management, greenhouse gas emissions.
- Waste pickers that are directly involved waste collection, sorting and recycling are exposed to health hazards e.g respiratory problems and skin diseases are common. Scavengers suffer from serious occupational health risks. Because of manual handling and lack of protective clothing and equipment, they are undoubtedly exposed to various health risks [4].
- Waste pickers are normally injured during collection of saleable materials from the dustbin. In the case of waste from hospitals and clinics, it was found that among total professional injuries 42% was needle injury caused during pushing injection or blood drawing from patients at the laboratory, 24% was sharp injury during cleaning and rest 34% was injury during ampule breaking [5].
- In Rajshahi city, around 60% of the cattle of the market slaughterhouses are slaughter on the roadsides. Cattle wastes such as blood, bones, cow-dung etc., are dumped into nearby drains or roadsides. After dumping cattle waste dog, cat, crow and animals are eat this and spread here and there which create nuisance and cause transmission of diseases.
- Various harmful microorganism and undegradable substances e.g polythene degraded the soil fertility of the dumping area.
- Liquid leached from this waste dumps may contain toxic elements, such impact to as Cu, As or many contaminated water supplies with unwanted salts of Ca and Mg. While the capacity of nature to dilute, disperse, degrade, absorb, or otherwise dispose of its unwanted residues in the atmosphere, in the waterways, and on the land is well known, humans cannot stress those natural capacities with their unwanted residues too much or an ecological imbalance will be imposed on the biosphere.

## 4. CONCLUSIONS

The study showed that the present situation of solid waste management in Rajshahi City. The City authority cannot collect and dispose more than 60% of the waste generated. The collection and transportation of garbage is seriously hampered by poor operation and maintenance. There is also a perceptible risk to the health of the population because of the absence of regulated disposal facilities, which leads to open collection and dumping. Furthermore factors such as uncontrolled leachate, mixing municipal and biomedical waste, and the presence of carcinogens in the waste contribute to increasing the health disparities in exposed population groups. Some of the recommendations based on this study are as to ensure an environmentally sound waste collection, transportation, resource recovery and disposal system; and Promotion of Public-Private-Community Partnerships in solid waste management which improve the present solid waste management and reduce environmental hazards and increase city dwellers; colour coded recycling bins for waste separation at the source of production.

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# EFFICIENCY OF COCONUT SHELL TO REMOVE POLUTANTS FROM WATER

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## ABSTRACT

This study was conducted with batch and continuous column type laboratory experiments to remove heavy metals and organic matter by using activated carbon of coconut shell (ACCS). Synthetic wastewater was used to evaluate the heavy metal removal capability at a starting pH of 6.5. The sorbent dosages in the predetermined synthetic solutions were 10, 16.7 and $20gL^{-1}$. In the batch tests, 1g of ACCS removed about 50, 211, 458 and 59µg of cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn), respectively. The column was continuously operated for 14 days at 100 to $125Lh^{-1}$ until equilibrium concentration was achieved. Moreover, the laboratory column showed removal efficiency (RE) of 100% without any desorption. The data fit the Freundlich isotherm model. The batches with low heavy metal concentrations of Cd, Cu and Zn exhibited an RE of approximately 99%, whereas 87 to 100% of Pb was removed from most of the batches, indicating the superior effectiveness of the procedure. In addition, the full-scale column filter with a 10L ACCS filter was capable of reducing about 30% of the total organic carbon (TOC) and 50% of hydrogen peroxide ($H_2O_2$) from semiconductor wastewater at a continuous flow rate of approximately $125L\ h^{-1}$.

**Key Words:** Activated carbon; Coconut shell; Isotherm; Heavy metal; Sorbent

## 1. INTRODUCTION

Adsorption using commercial activated carbon is an effective but expensive purification and separation technique used in industry, especially in water and wastewater treatments to remove heavy metals [1, 2]. The heavy metals discharged into the aqua-environment present a special concern as they are bounded to bioaccumulation and excessive concentrations are associated with various diseases in humans and animals. Here, activated carbon of coconut shell (ACCS) and a full-scale column filter packed with ACCS were used in a laboratory, batch and column study. Walnut, hazelnut, almond, and pistachio shell-based activated carbon was used to remove Cd, Cu, Pb and Zn from aqueous solution [2]. Activated carbon from palm shell also has Pb adsorption ability [3]. The main objective of this study was to evaluate the efficiency of ACCS as a sorbent in laboratory tests under well-controlled experimental conditions [4]. After promising results obtained from batch tests, a set of columns were developed to investigate the possibility of using ACCS under continuous flow conditions.

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## 2. MATERIALS AND METHODS

### 2.1 Sorbents

Sorbent materials with a similar particle size were used as particle size may have an effect on the removal [4]. ACCS was sieved to the desired particle size (0.6 ~ 1mm) and dried at 40ºC for 3h without additional treatment before being used in the batch experiments [4].

### 2.2 Heavy metal concentrations

In this study, we attempted to use realistic concentration ranges where the lowest values were below or about US Environmental Protection Agency (USEPA) fresh water acute limits [6] and the highest values were significantly higher, as shown in Table 1. The purpose was to evaluate and compare the sorbents at both highly and slightly polluted conditions, since some sorbents are effective at rather high concentrations but are less efficient at low concentration [4].

Table 1: USEPA limit values and initial concentrations ($C_o$) of heavy metals

| | **Concentrations (µg $L^{-1}$)**; [$^a$ used for 20g $L^{-1}$ sorbent dosage] | | | |
|---|---|---|---|---|
| | **Cd** | **Cu** | **Pb** | **Zn** |
| **USEPA** | 2 | 13 | 65 | 120 |
| **Batch 1** | 7671; 1767$^a$ | 8992; 1807$^a$ | 8775 | 9394; 1979$^a$ |
| **Batch 2** | 3834; 882$^a$ | 4299; 902$^a$ | 4402 | 4905; 900$^a$ |
| **Batch 3** | 1567; 214$^a$ | 1703; 246$^a$ | 2608 | 2786; 476$^a$ |
| **Batch 4** | 763; 120$^a$ | 893; 116$^a$ | 1762 | 1959; 339$^a$ |
| **Batch 5** | 409; 22$^a$ | 463; 30$^a$ | 894 | 958; 256$^a$ |
| **Batch 6** | 94; 9$^a$ | 128; 14$^a$ | 474 | 506; 142$^a$ |
| **Batch 7** | 43; 3$^a$ | 51; 6$^a$ | 105 | 102; 72$^a$ |
| **Batch 8** | 11 | 23 | 61 | 75 |

### 2.3 Batch experiments

Sorption experiments were carried out using synthetic solutions in 50 ml beakers at room temperature (28.1ºC). The required concentrations of Cd, Cu, Pb and Zn were obtained by step-by-step diluting their stock commercial solutions to the desired concentrations. The ionic strength of the water samples was controlled using 0.01M NaCl, and the pH changes during the experiments were minimized using 0.003M $NaHCO_3$ [4]. Before starting the batch experiments, the pH of all solutions was adjusted to 6.5 using strong acid or base solutions. Afterwards, sorbent dosages were set at 10, 16.7 and 20g $L^{-1}$ [4] in the predetermined synthetic solutions. The solutions and sorbents were then mixed by gently shaking the batches in a mechanical shaker at 100 rpm for 24h. The pH values were checked after the completion of the shaking to identify any possible pH variations from the starting values. Later, the batches were taken from the shaker and filtered through 0.45µm filter paper, after which the filtrates were acidified to pH 1.5 ~ 2 and stored at 4ºC until the heavy metal measurements. One set was also run as a control batch with sorbent but without any heavy metal addition. All the chemicals used were reagent grade and were used without any further purification.

### 2.4 Column experiment

The fixed bed columns were packed with ACCS with a particle size range of 0.6 ~ 1mm and used as up-flow reactors. Influent water was pumped through the ACCS-packed column with peristaltic pump. The column had an inner diameter of 55mm with a 25mm high layer of glass beads and a 95mm high layer of ACCS. Fig. 1 shows a schematic diagram of the column [7]. The columns were operated using upward flow at room temperature and air free distilled water (without heavy metals) was run through the columns for 24h prior to starting the experiments in order to wet the columns and establish equilibrium between the adsorbent and water. Uniform solution distribution, minimized pressure gradients and reduced channeling and fouling of the adsorbent were achieved by using this design and operation procedure [7]. During the 14-day experiment, flow rates were set at 100 to 125mL $h^{-1}$ and inflow heavy metal concentrations of 1.6, 1.7, 2.6 and 2.8mg $L^{-1}$ of Cd, Cu, Pb and Zn were used, respectively.

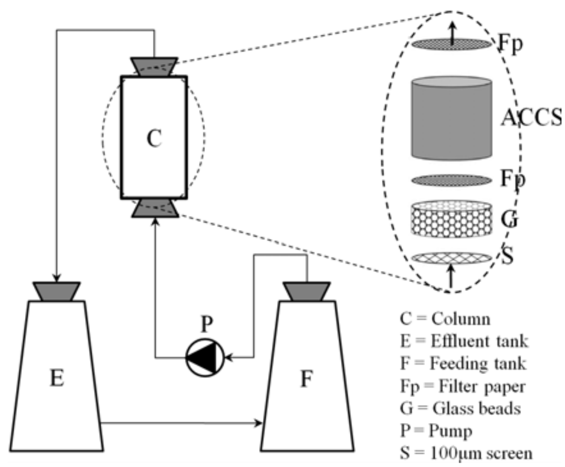


Fig 1: Schematic diagram of the adsorption column and the column detail

### 2.5 Full-scale column study

An ACCS-packed column filter with an effective volume of 10L was studied. A continuous downward flow of contaminated water at 125L $h^{-1}$ was provided throughout the 45-day study with a starting pH of $3 \pm 0.08$. Semiconductor industrial wastewater with a significant concentration of total organic carbon (TOC) and hydrogen peroxide ($H_2O_2$) was used directly. In the influent (Inf.), Iron (Fe) (<0.05mg $L^{-1}$), aluminium (Al) (<0.1mg $L^{-1}$) and Cu (<0.05mg $L^{-1}$) showed very low concentrations. Samples were collected fortnightly and stored until measurement.

### 2.6 Analyzing sorption data

For ACCS, the solid phase heavy metal concentration, $q_e$ (μg $g^{-1}$), was determined by analyzing the corresponding heavy metal concentration before and after the treatment using Eq. 1:

$$q_e = (C_o - C_e) / X \qquad (1)$$

where, $C_e$ is the equilibrium heavy metal concentration in the solution (μg $L^{-1}$), and $X$ the sorbent dosage (g $L^{-1}$). The metal removal efficiency percentage [2] of the adsorbent was defined by Eq. 2, while Eq. 3 was used as the linear form of the Freundlich isotherm to fit the sorption data:

$$\text{RE}\ (\%) = [(C_o - C_e) / C_o] \times 100 \quad \ldots\ldots(2)$$

$$\log q_e = \log K + n^{-1} \log C_e \quad \ldots\ldots(3)$$

where, $K$ is correlated with the quantity of sorbate associated with the sorbent, and $n$ is the Freundlich isotherm constant related to the sorption strength.

## 3. RESULTS AND DISCUSSION

### 3.1 Physical properties

The removal of heavy metals from wastewater by agricultural wastes is a green chemistry method for improving environment cleanliness [2]. Fig. 2 shows an image, taken by environmental scanning electron microscope (E-SEM), showing the satisfactory surface of an ACCS particle with voids to adsorb heavy metals. The Fourier transform infrared (FTIR) spectra revealed indicated the different surface structures of the carbon such as aliphatic, aromatic, and cyclic as observed by the bands at 1460 $cm^{-1}$ and over the 1320-1100 $cm^{-1}$ range. All the analyzed spectra possessed bands at 3300-3500 $cm^{-1}$, revealing the presence of alcoholic, phenolic or acidic OH with hydrogen bonding. The peaks at 2000-2100 $cm^{-1}$ were attributed to the C≡C group and those at 2200-2300 $cm^{-1}$ to the C≡N group. The bands at 2000-2300 $cm^{-1}$ were considered to correspond to C=N=S or C=N=C. These results indicated that carbon possesses a similar structure to that of standard activated charcoal, but has greater capacity to remove heavy metals [2].

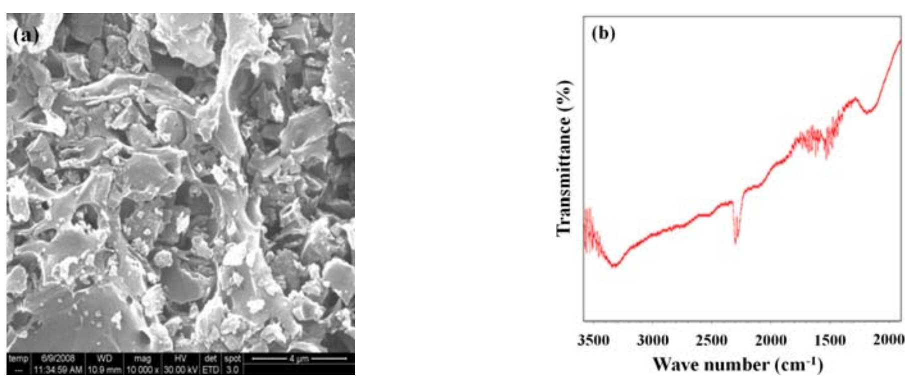


Fig 2: (a) E-SEM image of ACCS before being used as a sorbent and (b) FTIR spectra of ACCS

### 3.2 Equilibrium concentrations for batch tests

The results of the simultaneous removal of Cd, Cu, Pb and Zn using different sorbent dosages are presented in Fig. 3 on a double logarithmic scale for batch tests. As expected, the amount of heavy metal removed increased with increasing initial heavy metal concentration in all of the batches. For the Zn adsorption, a satisfactory removal was observed at the sorbent dosage of 20g $L^{-1}$ for all batches. Three and two batches at a sorbent dosage of 16.7 and 10g $L^{-1}$, respectively, showed removal below USEPA limits. In other cases, the batches with relatively low heavy metal concentrations showed better results for all sorbent dosages.

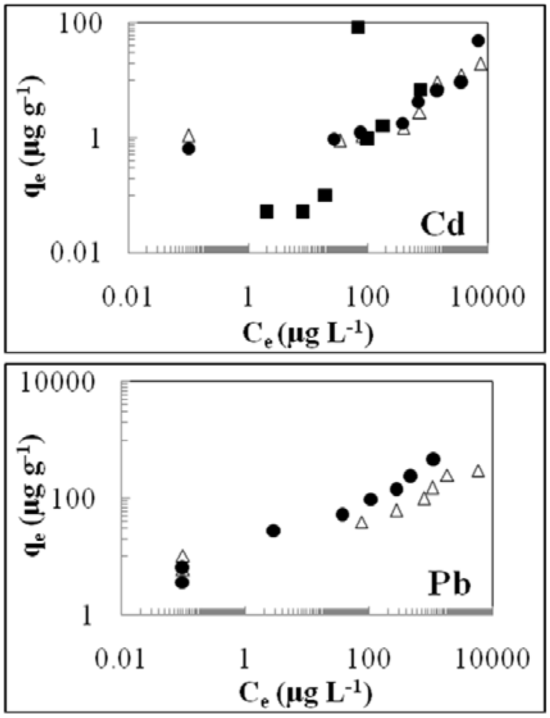


Fig 3: Cd, Cu, Pb and Zn removal using different sorbent dosages
(■ 20g $L^{-1}$, ● 16.7g $L^{-1}$, Δ 10g $L^{-1}$)

### 3.3 RE in column test

The removal efficiencies of the heavy metals in the column test are shown in Fig. 4. For the $C_e$ measurement, samples were collected at 1, 6, 18, 36, 72, 96, 168 and 317h after the starting time. Pb showed an RE of 94% after 1h, and all the heavy metals showed an RE of nearly 100% after 6h. To check the desorption criteria, the column was run continuously for 14 days. No desorption was observed as the column showed satisfactory results while maintaining a constant $C_e$ for 14 days.

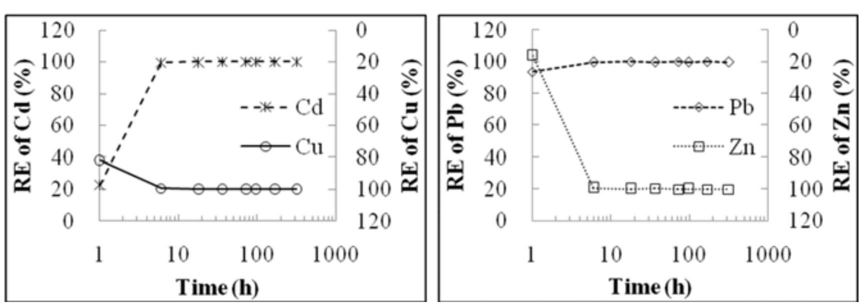


Fig 4: Removal efficiency (RE) according to time for Cd, Cu, Pb and Zn

### 3.4 Full-scale column filter

Table 2 shows the influent and effluent concentration of semiconductor wastewater during the study. The heavy metal concentration was nearly the same in the effluent as in the influent, indicating the absence of any leaching inside the column. Moreover, TOC and $H_2O_2$ were reduced by approximately 30% and 50%, respectively, with respect to the influent levels. The continuous flow exhibited better long-term performance in heavy metal removal and other experimented parameters, thereby demonstrating the longevity of the column. The $H_2O_2$ efficiency was reduced by nearly 33% on the third day of study. Subsequently, RE of $H_2O_2$ was maintained nearly constant at around 50%.

Table 2: Influent and effluent properties of full-scale column

| Properties | 2008-04-15 | | 2008-04-29 | | 2008-05-13 | | 2008-05-27 | |
|---|---|---|---|---|---|---|---|---|
| (mg $L^{-1}$) | Inf. | Eff. | Inf. | Eff. | Inf. | Eff. | Inf. | Eff. |
| TOC | 1.243 | 0.837 | 1.103 | 0.759 | 1.004 | 0.709 | 0.977 | 0.63 |
| $H_2O_2$ | 10 | 5 | 10 | 5 | 15 | 10 | 10 | 5 |
| Fe | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Al | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cu | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |

### 3.5 Influence of dosage

The RE was corrected for the mass of adsorbent in the batches and is given as the amount of metal ion removed per unit sorbent dosage (g $L^{-1}$). Fig. 5 shows the RE per dosage of adsorbent versus the amount of sorbent dosage, while the other parameters are maintained constant. The figure shows that the RE per dosage of the adsorbent generally improved with decreasing dose for Cd, Cu and Pb, while for Zn it very slightly increased with increasing sorbent dosage.

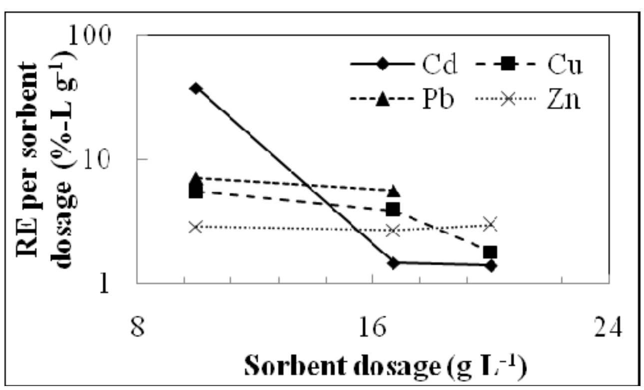


Fig 5: Influence of sorbent dosage on heavy metal RE

### 3.6 Removal efficiency (RE) of heavy metals

The heavy metal RE from contaminated water at various sorbent dosages is shown in Fig. 6. To investigate the relation, mean values for all batches at different sorbent dosages were divided by the respective dosage. The RE of Pb was above 87% for all the batches at a sorbent dosage of 16.7g $L^{-1}$ while at a sorbent dosage of 20g $L^{-1}$, RE was increased by 57% or more in all batches except batch 1, which showed an RE of 35%. The RE of Cu was mostly above 55% at a sorbent dosage of 16.7g $L^{-1}$. At higher sorbent dosages, the adsorption of low concentrated heavy metals was around 99%. The RE of Cd and Zn was relatively low for most of the batches at all conditions. Zn showed better RE at a sorbent dosage of 16.7g $L^{-1}$ in batch 6 while a very low RE was achieved at a sorbent dosage of 20g $L^{-1}$, indicating the effect of sorbent dosage.

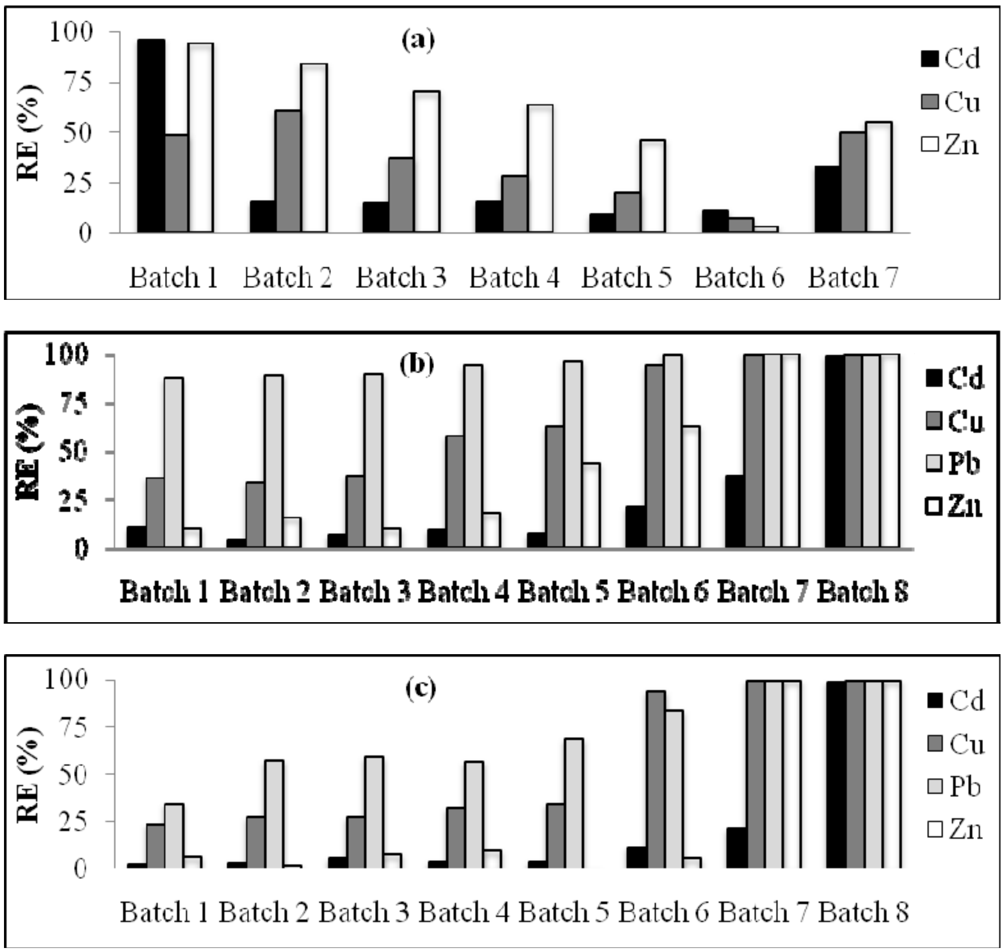


Fig 6: Effect of sorbent dosages [(a) 20g $L^{-1}$, (b) 16.7g $L^{-1}$ and (c) 10g $L^{-1}$] on removal efficiency (RE) of Cd, Cu, Pb and Zn.

### 3.7 Sorption isotherm

Table 3 shows Freundlich isotherm constants with the $r^2$ values for all sorbent dosages investigated in this study. For Zn, at the sorbent dosages of 10 and 20g $L^{-1}$, the $r^2$ values were very low, indicating a poor correlation. For others, the $r^2$ values of $\geq 0.5$ signify statistically significant correlation. Although $r^2 \geq 0.5$ shows a fair correlation, using the estimated Freundlich isotherm for prediction is considered highly uncertain unless $r^2$ is close to 1 [4]. Accordingly, Pb showed the most correlated result to fit the isotherm. Cu showed a better correlation than Cd as $0.87 \leq r^2 \leq 0.94$. Furthermore, the isotherm maintained the correlation with $r^2 \geq 0.5$ for Cd.

Table 3: Freundlich isotherm constants for different sorbent dosages

| Heavy metals | Sorbent dosage (g $L^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20 | | | 16.7 | | | 10 | | |
| | ***K*** | **1/*n*** | **$r^2$** | ***K*** | **1/*n*** | **$r^2$** | ***K*** | **1/*n*** | **$r^2$** |
| Cd | 0.02 | 1.01 | 0.53 | 0.59 | 0.33 | 0.68 | 0.79 | 0.26 | 0.57 |
| Cu | 0.01 | 1.22 | 0.88 | 4.04 | 0.37 | 0.94 | 6.03 | 0.32 | 0.87 |
| Pb | - | - | - | 13.50 | 0.45 | 0.98 | 14.81 | 0.32 | 0.95 |
| Zn | 0.20 | 0.78 | 0.05 | 7.59 | 0.18 | 0.86 | 6.18 | 0.02 | 0.00 |

## 4. CONCLUSION

The present study results have demonstrated the potential effectiveness of ACCS in heavy metal removal. Satisfactory results were achieved for heavy metal RE in both for the batch and continuous studies. The heavy metal RE was dependent on the sorbent dosages with lower sorbent dosages exhibiting better RE than higher dosages. ACCS was found to be suitable for batch treatment with low heavy metal concentrations. No sorbent leaching occurred during the batch tests and full-scale studies, indicating an acceptable adsorbent quality. The porous surface and FTIR spectra revealed properties similar to those of standard activated carbon.

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