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WATER QUALITY AND HEAVY METAL POLLUTION ASSESSMENT OF TURAG RIVER, BANGLADESH

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ABSTRACT*:*

The aim of the study is to investigate the extent of pollution of the Turag River. Effects of industrial wastes, municipality sewage and agricultural runoff on the river water were investigated. The study was conducted within the Tongi Bridge to Ejtema Field,since this portion of river is highly polluted. The study involves assessment of five heavy metal (Pb, Cd, Cu, Cr and Zn) concentration on the river water. It also determine the physical, biological and chemical parameters of surface water at different points.To assess contamination, Bangladesh Environment Consrvation Rules 1997, World Health Organization(WHO) and US environmental Protection Agency's (USEPA)Guidelines were applied. The mean values of pH, color, turbidity, total dissolved solids(TDS), total suspended solids(TSS), NO_3, NH_3, dissolve oxygen(DO), chemical oxygen demand(COD), bio-chemical oxygen demand(BOD_5) were 7.25, 156, 62 NTU, 0.048gm/l, 0.053gm/l, 0.53mg/l, 8.1mg/l, 0.52mg/l, 48mg/l and 12.3mg/l respectively. The metal contents were ranging over following intervals: Pb: 0.073-0.1 mg/l; Cd: 0.002-0.003 mg/l; Cr: 0.039-0.061mg/l; Cu: 0.047-0.05 mg/l; Zn: 0.019-0.065 mg/l.The heavy metals were analyzed statistically by using principal component analysis (PCA) and hierarchical cluster analysis (HCA) methods. Strong positive correlation's between the contaminants of Cu and Pb(r=0.655), Cd and Zn(r=0.896); Cu and Cr(r=0.5), indicating the existence of common origin and negative correlations among Cd-Pb(r:-0.655), Zn-Pb(r: -0.922), Cu-Zn(r:-0.896) and Cd-Cr(r:-0.5) indicating that this metals have complicating geochemical behaviors.The study shows that the river is facing pollution and the water, sediment and fish are not completely safe for health.

Keywords: Heavy metal, DO, COD, BOD_5 , Principal component analysis, Cluster analysis.

INTRODUCTION

Due to rapid and unplanned urbanization and industrialization the Turag river is facing a serious pollution problem. The river receives partially treated and untreated sewage effluent, sewage polluted surface run-off and untreated industrial effluent from nearby residence and industrial areas. The rivers are further polluted by indiscriminate throwing of household, clinical, pathological & commercial wastes and discharge of spent fuel and human excreta. Heavy metals contamination in aquatic environment is of critical concern, due to toxicity of metals and their accumulation in aquatic habitats. Trace metals in contrast to most pollutants, not biodegradable, and they undergo a global ecological cycle in which natural water are the main pathways. Of the chemical pollutants heavy metal being non-biodegradable, they can be concentrated along food chain, producing their toxic effect at points after far removed from the source of pollution (Tilzer and Khondoker, 1993). Exposure to heavy metals has linked to several human diseases such as development retardation and malformation, kidney damage, cancer, abortion, effect on intelligence and behavior, and even death in some cases of exposure to very high concentrations. The study monitored the surface water quality to predict the present condition of Turag River, considering spatial variation in heavy metal content.

METHODS AND MATERIALS

Sample Collection:

In order to achieve the research objective, samples were collected from three different locations of the Turag River . (Latitude and Longitude for each site are illustrated in Table 1). Criterias for selection of sampling stations were based on the locations of industrial units and land use pattern to quantify heavy metal concentration. Polyethylene plastic bottles (2 liter capacity) were used as sample containers to avoid undesirable changes in characteristics of samples. New bottles were cleaned with strong metal free acid. The containers were rinsed with sample water prior to collection.

Table 1: Global positioning system (GPS) data of sample collection in Turag river

Designation	Location	Latitude	Longitude
T-1	Kamarpara	23^0 52' 54.58"N	90^0 24' 03.20"E
T-2	Ejtema Maidan	23^0 53' 15.54"N	90^0 23' 32.80"E
T-3	Tongi Bridge	23^0 53' 29"N	90^0 23' 24.30"E

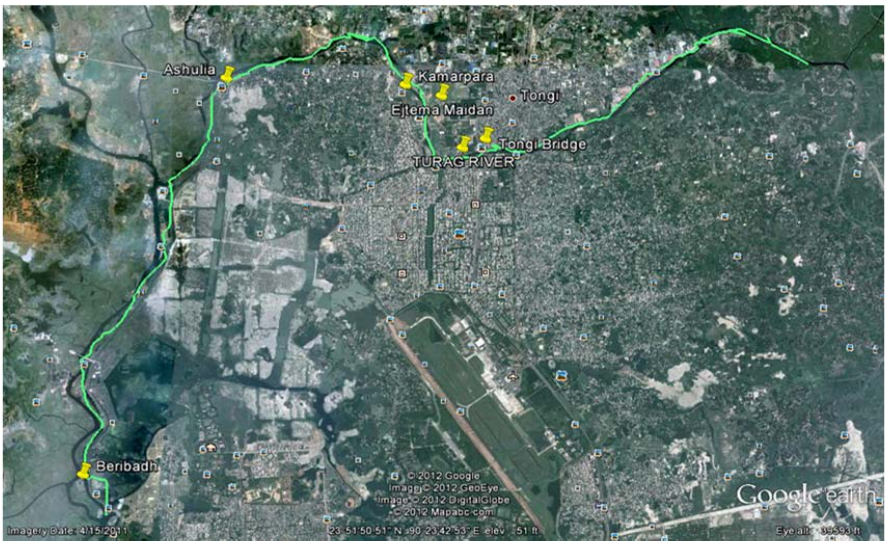

Fig 1: Map showing the sampling Locations

Sample Analysis:

Samples collected from these station points were tested for ten pollution parameters to study the pollution aspects of the effluents from the associated industries and municipality's wastes and hospital wastes. The BOD_5 test was based upon determination of dissolved oxygen. Do was measured by modified idometric method. Two or more BOD bottles were filled with sample, at least one was analyzed for dissolved oxygen immediately, and the others were incubated for 5days at 20^0C. After 5 days the amount of dissolved oxygen remaining in the incubated sample was determined and the 5 day BOD was calculated by subtraction of the 5 day results from those obtained from initial day. And other parameters were measured by using the standard test procedures. To determine five heavy metals (Pb, Cd, Cr, Cu and Zn) concentration atomic absorption spectrophotometer is used. After collection, sediment samples were dried in a vacuum oven at 105^0C until constant weight, lightly ground in an agate mortar for homogenization and prepared 500 ml solution. Finally, five heavy metals (Pb, Cd, Cr, Cu and Zn) concentration were determined in the environmental engineering laboratory, BUET by using atomic absorption spectrophotometer.

RESULTS AND DISCUSSIONS

A. Water Quality Parameters

Water samples were collected from the Turag River and tested for physical qualities, chemical contents, and microbiological counts. The important water quality parameter such as pH, Color, Turbidity, TDS, TSS, NO_3, NH_3, DO, COD, BOD_5 were analysed. The test results are shown in Table 2.

Table 2: Concentration of Various Parameters in Turag River

Sample ID	**pH**	**Color**	**Turbidity (NTU)**	**TDS (gm/l)**	**TSS (gm/l)**	**NO_3 (mg/l)**	**NH_3 (mg/l)**	**DO (mg/l)**	**COD (mg/l)**	**BOD_5 (mg/l)**
T-1	7.61	105	82.5	0.058	0.066	0.3	5.6	0.43	41	9.7
T-2	7.21	120	43	0.046	0.049	0.7	5.5	0.67	33	5.8
T-3	6.93	242	60.3	0.041	0.044	0.6	13.1	0.47	70	21.3
Mean	7.25	155.7	61.9	0.048	0.053	0.53	8.10	0.52	48	12.3
Max	7.61	242	82.5	0.041	0.066	0.7	13.1	0.67	70	21.3
Min	7.21	120	43	0.058	0.049	0.3	5.6	0.43	33	9.7

BOD and COD are the important parameters of water quality assessment. According to Bangladesh standards the permissible limit of BOD_5 of inland surface water is 2 mg/l, 3mg/l and 6 mg/l for drinking, recreational and fishing purposes respectively. So the water of the Turag river is satisfactory for fishing purposes, but at some location not suitable for drinking and recreational purposes. It was found that COD values were greater than the BOD_5 values of the river water for the same station point. During the determination of COD, organic matter was converted to carbon dioxide and water regardless of biological assimilability of the substances. In the case of Dissolved Oxygen (DO), standard for sustaining aquatic life is 4mg/l whereas for drinking purposes it is 6mg/l and wastewater discharge from industrial units and projects according to inland surface water (Bangladesh ECR 1997). DO values for Turag river are far below the standard value.

A standard for inland water surface and irrigated land are 5mg/l and 15 mg/l repectively for NH_3 (Bangladesh ECR 1997). The test result shows NH_3 values vary from 5.5 to 13.1 mg/l, which indicates that river water is not suitable for irrigation. From our test result measured values for NO_3 are 0.3 to 0.7 mg/l.

The other water quality parameter such as pH, Color, Turbidity, TDs and TSS are shown table 3 below and which provides a comparison with WHO standard and Bangladesh standards (ECR 1997) for drinking purposes. pH values are satisfied the limit but other parameters indicate that river water is not suitable for dinking purposes.

Table 3: Comparison of water quality parameters of Turag River with the WHO standard and Bangladesh standard (ECR, 1997)

Water Quality Parameter	Test results of Turag river	WHO standard	Bangladesh standard
pH	6.93 to 7.61	6.5-8.5	6.5-8.5
Color	105 to 242	15	15
Turbidity (NTU)	43 to 82.5	10	5
TDS (gm/l)	0.041 to 0.058	0.1	0.1
TSS (gm/l)	0.044 to 0.066	-	0.01

B. Heavy Metal Concentration

Metal contents were ranging over following intervals: Pb: 0.073-0.1 mg/l; Cd: 0.002-0.003 mg/l; Cr: 0.039-0.061mg/l; Cu: 0.047-0.05 mg/l; Zn: 0.019-0.065 mg/l. Mean concentration of the metals were: Pb:0.083 mg/l;Cd:0.002 mg/l;Cr:0.048mg/l;Cu:0.049 mg/l; Zn: 0.04 mg/l, which indicate metals from higher to lower order as: Pb>Cu>Cr>Zn>Cd.

Table 4: The test result (mg/l) for the water sample of the Turag River

Location	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
T-1	0.076	0.002	0.061	0.05	0.037
T-2	0.1	0.002	0.043	0.05	0.019
T-3	0.073	0.003	0.039	0.047	0.065
Mean	0.083	0.002	0.048	0.049	0.04
Max	0.1	0.003	0.061	0.05	0.065
Min	0.073	0.002	0.039	0.047	0.019

Before evolving a judgement on the observed distribution of metal levels regarding their probable origin, the metal data was first examined on the basis of basis of linear correlation between metal pairs in terms of significant positive correlation coefficient. Strong positive correlation's between the contaminants of Cu and Pb(r=0.655), Cd and Zn(r=0.896); Cu and Cr(r=0.5), indicating the existence of common origin and negative correlations among Cd-Pb(r:-0.655), Zn-Pb(r: -0.922), Cu-Zn(r:-0.896) and Cd-Cr(r:-0.5) indicating that this metals have complicating geochemical behaviors.

Table 5: Correlation Matrix between different metal pairs

	Pb	Cd	Cr	Cu	Zn
Pb	1.000				
Cd	-.655	1.000			
Cr	-.327	-.500	1.000		
Cu	.655	-1.000	.500	1.000	
Zn	-.922	.896	-.064	-.896	1.000

Further confirmation of this hypothesis was secured through multivariate method so f statistical analysis(Hair et al. 1988). To this effect to multivariate techniques were applied: Principal Component Analysis(PCA) and Cluster analysis(CA).

PCA usingVarimax normalized rotation was conducted for common source identification. The variables are correlated with two principle components in which 100% of the total variance in the data is found. The rotated Principal Component Loadings are given Table 6.

Table 6: Rotated Principal Matrix

Rotated Component Matrix[a]

	Component	
	1	2
Pb	-.932	-.362
Cd	**.884**	-.468
Cr	-.037	**.999**
Cu	-.884	**.468**
Zn	**1.000**	-.027

The first component with 68.64% of variance comprises Zn and Cd (bold figures) with high loadings. This association strongly suggests that these variables have a similar source. The second component contributes Cr and Cu at 31.36% variance.

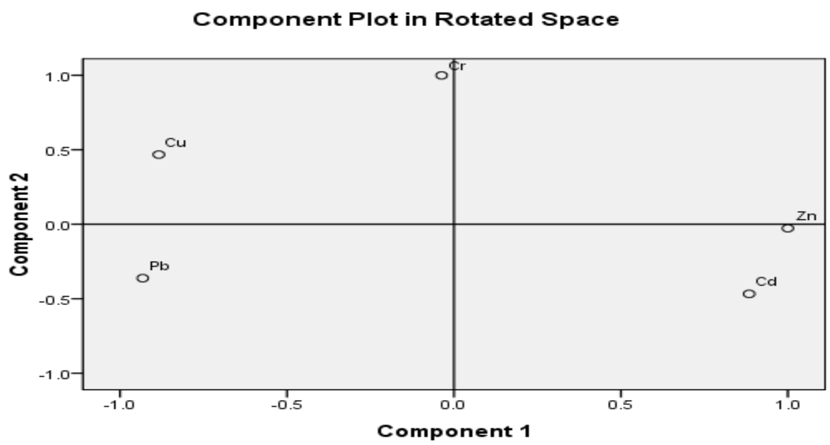

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Fig-2: Principal component plot in a rotated space

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* * * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * * *

Dendrogram using Average Linkage (Between Groups)

                        Rescaled Distance Cluster Combine

  C A S E       0         5        10        15        20        25
 Label     Num  +---------+---------+---------+---------+---------+
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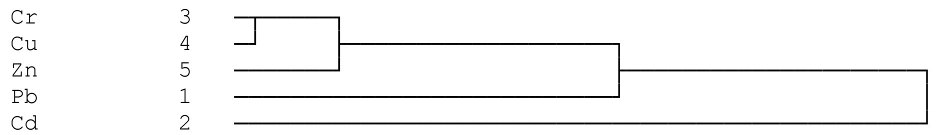

Fig 3: Dendogram of Cluster Analysis

The corresponding cluster analysis Dendogram (shown in Fig 3) showed good agreement with PC2 (relation between Cu-Cr) but not showed good agreement between Zn-Cd.

CONCLUSION

From the study it is revealed that, untreated sewage and industrial effluents are the main source of pollution. The river water containing variable amounts of heavy metals increaseing in concentration and causes several human diseases, people who using river water. The various heavy metals follow the order of Pb>Cu>Cr>Zn>Cd. Strong positive correlation's between the contaminants of Cu and Pb(r=0.655), Cd and Zn(r=0.896); Cu and Cr(r=0.5), indicating the existence of common origin and negative correlations among Cd-Pb(r:-0.655), Zn-Pb(r: -0.922), Cu-Zn(r:-0.896) and Cd-Cr(r:-0.5) indicating that this metals have complicating geochemical behaviors.

Comparing the water parameter result with WHO standard and Bangladesh standard (ECR 1997), it indicates that Turag river water is not suitable for drinking purposes but it can be used as fishing or other purposes. On the basis of BOD_5 and COD value, river water can be used for fishing purposes but not drinking purposes. It is alarming that the pollution concentration is rapidly increasing day by day as different types of land uses are developing along the banks of the Turag river which lead to more pollution generation and more encroachment on riverbanks. But, it is a matter of fortune that the pollution level of the Turag has not yet gone beyond treatability and the river has not experienced the massive grasp of encroachment.

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HEAVY METAL CONTAMINATION IN SOIL AND CROP OF FARMLANDS ADJACENT TO MATUAIL LANDFILL SITE

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ABSTRACT

Dhaka, the capital city of Bangladesh, produces tonnes of solid wastes everyday. Due to crude, unsanitary dumping procedure, these wastes in a disposal site have significant impacts on the adjacent areas. In this study an attempt has been undertaken to find out the heavy metal contamination in soil and crops of farmlands adjacent to Matuail landfill site. Two types of samples were collected from adjacent farmlands to Matuail landfill site. These are (i) soil sample and (ii) crop sample. The samples were analyzed to determine the concentration of heavy metal parameters such as Fe, Cu, Mn, Cd, Pb and Cr. The test results showed that the concentration of Cu, Cr and Pb in the soil of root zone depth of all the tested plants were higher than the typical concentration range in the soil. This finding showed that the soil of adjacent farmland was contaminated with toxic metals. The distribution of heavy metal in the different parts of crop samples was found in the order of: leaf>stem>root except Cd. The regression coefficient, R is determined to show the correlation of contamination of heavy metal between soil and crops. The accumulation of heavy metals in different parts of the plants were expressed by Metal Transfer Factor “f” and was found that the f value of Cd in all the plants was higher than that of other metals.

Keywords: Solid Waste, Heavy Metal, Soil Contamination, Crop Sample, Metal Transfer factor

INTRODUCTION

Dhaka, the capital of Bangladesh, is one of the most densely populated cities in the world with about 23,029 persons /km^2 (Wikipedia, 2008). This huge population generates thousands of tonnes of solid wastes everyday. Dhaka City Corporation (DCC) is the designated authority for collection, transportation and disposal of the solid wastes. For a long time it is a common practice to dispose of solid wastes in open low lying areas in an unplanned and unscientific manner (Huda 2002), until recently DCC converted one of its largest dumping site Matuail into a Sanitary landfill (Khaled & Amin, 2008). Before that, DCC used to dispose of unsegregated (including toxic, non-toxic and hazardous wastes) solid wastes indiscriminately onto this site over a long period. The wastes dumped in this site have significant negative impacts on the soil, groundwater, surface water and the vegetation around the site. The soil becomes contaminated by the leaching of toxic heavy metals from the wastes over the years. The inhabitants in the adjacent areas use farmlands for growing seasonal vegetables and crops. They often use the leachates for irrigation purpose also. But they are not concerned about the soil pollution and consequent contamination in edible plants by heavy metals. This paper investigates the heavy metal contamination such as Fe, Cu, Mn, Cd, Pb and Cr in the soil and plants growing in the surrounding area of Matuail landfill site. It also attempts to find out a correlation of contamination between the soil and the grown products.

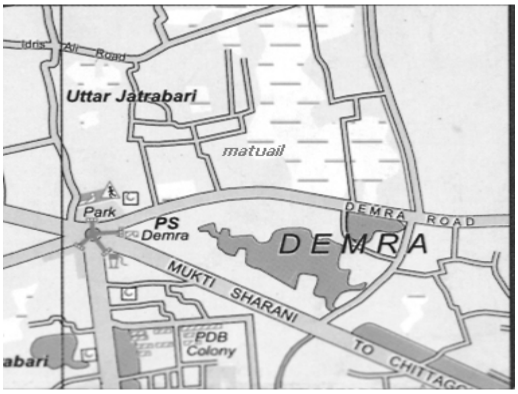

Figure 1: The study area

Figure 2: Crop field adjacent to disposal site

Figure 3: Leachate flowing along the periphery of the crop fields

Figure 4: Leachate water is being used for irrigation

THE STUDY AREA

Matuail landfill site is approximately 5 km to the south-east direction from zero point of Dhaka City. This landfill covers about 52 acres of land out of which 13 acres had been developed for parking and rest 39 acres for land filling. Almost every day approximately 2000 tons of wastes is disposed of here (Khaled and Amin, 2008). Adjacent to the waste disposal site, there are low lying agricultural lands. Local people use this land for cropping and vegetation. It is enclosed by earthen dike to isolate the waste disposal site.

SAMPLING AND ANALYSIS METHODS

Matuail has been used as a solid waste disposal site for more than twelve years. In this site solid wastes that were dumped long ago have been converted to soil and local people use the adjacent areas for agriculture. In this study two types of samples were collected to assess the heavy metal contamination. These are (i) Soil samples from the farmlands adjacent to the landfill site and (ii) Crop and vegetable samples growing in those farmlands. In each case soil sample was extracted from the root zone depth of different crops.

There are several methods available for detection of heavy metal concentration. In this study heavy metals in soil and crop samples were determined using Flame Atomic Absorption Spectrophotometer (FAAS). This method requires the transformation of a solid sample into solution from which metal concentrations are determined. For this acid digestion methods are used to convert the Heavy metals in soil and crop samples to a soluble form.

Sample preparation

For this analysis, the collected soil samples and crop samples were prepared by digestion method following the standard procedure. The most important methods used for sample digestion consist of open vessel digestion by digester block and closed vessel digestion by microwave oven. Required temperature was maintained during transportation of the samples to the laboratory and during analysis. To analyse the concentration of heavy metals (Fe, Mn, Cr, Cd, Cu, and Pb) in soil as well as crop sample, samples were digested in order to convert all the metallic forms into ionic states following the standard procedure. The soil and crop samples were digested by following two different procedures (Khaled & Amin, 2008).

Analysis of soil and crop sample

The prepared samples were analyzed to determine the concentration of heavy metal (Fe, Cu, Mn, Cd, Pb and Cr) by Flame Atomic Absorption Spectrometer (FAAS) following the standard method (APHA, AWWA and WEF, 1998).

The metal content of crop sample in mg/kg of dry weight was then calculated according to the following relationship:

$$Mcs = Ccs * (Lcs/Wcs) * 1000 \quad \text{------------------------} \quad (1)$$

Where

Mcs= Metal concentration in mg/kg in crop sample.
Ccs= Metal concentration in ppm (or mg/l) found using AAS.
Lcs= Volume of sample in liter (0.1 liter in this case).
Wcs= Oven dried mass of crop sample in gm (2.0 gm in this case).

The same method is used to calculate the metal content in the soil samples.

RESULTS AND DISCUSSIONS

Seasonal vegetables grown in the adjacent land of disposal site are subjected to pollution from leachate and contaminated soil. This section presents this contamination in following formats.

Table 1 shows the concentration of heavy metals in the soil of the farmlands. Secondly the distribution of heavy metal concentration in different parts of crop samples is shown through pie charts (Figure 5 to Figure 8). Thirdly Figures 9 and 10 present the correlation of contamination of heavy metals between crop and soil. The potential of metal transfer from soil to crop is shown in the bar chart (Figure 11).

Contamination of Soil sample

Table 1 indicates that the concentration of heavy metals in soil samples found in the present study exceeds the typical content (mean value) of heavy metal in almost each case. Particularly Cu, Pb and Cr concentration in the soils is much higher than the concentration found in natural soil. From this finding it can be said that, indiscriminate disposal of mixed solid waste over the years without any segregation and any sanitary land filling practice, contaminates the soil around the disposal site and consequently contaminates the crops growing in that contaminated soil.

Table 1: Heavy metal concentration in the soil samples

Sample Identification				Concentration present (mg/kg)					
				Fe	Cu	Mn	Cd	Pb	Cr
Sl no	Sample description	Scientific name	Part						
1	Paddy	Oryza sativa	Root zone depth soil	21845	74.6	111.1	0.44	52.63	21.54
2	Tomato	Lycopersicon esculentum	Root zone depth soil	20401	52.4	87.5	0.06	53.34	19.57
3	Radish	Raphanus sativus	Root zone depth soil	18816	91.1	80.2	0.6	54.05	26.06
4	Red amaranth	Amaranthus gangeticus	Root zone depth soil	21793	76.4	101.9	<M.D.L	46.23	27.2
Comparison Value									
Typical range (mg/kg) (Huq and Alam, 2005)				18-2280	1-20	17-334	0.013-0.21	0.1-10	0.014-3.4

Distribution of Heavy metal concentration in different parts of crop samples

The main sources of contamination of heavy metals in vegetables and crops are through their growth media (soil, air, nutrient solutions) from which these are taken up by the roots or foliage. The accumulation of toxic metals occurs through the roots and then transport them to the stems or leaves.

Table 2 presents the heavy metal concentrations in different parts of crop and vegetables. Although the presence of heavy metals in different parts are in considerable concentration, no comment can be made on the safety level regarding the metal concentration since no standard for allowable limit of heavy metal in these plants was found.

Table 2**:** Heavy metal concentration present in the different parts of crop samples

Serial no	Sample description	Part	Concentration present (mg/kg)					
			Fe	Cu	Mn	Cd	Pb	Cr
1	Paddy	Root+ Stem+ Leaf	2065	34.3	147.15	1.31	<M.D.L	7.5
2	Tomato	Root	219	14.15	19.65	0.3	<M.D.L	2.05
		Stem	259.5	26.15	57.25	1.37	<M.D.L	3.48
		Leaf	1089	45.65	93	1.14	12.8	8.95
		Fruit	151	26.15	17.7	1.05	<M.D.L	8.25
3	Radish	Root	335.5	10.7	14.9	0.24	3.56	10.21
		Stem	179	15.4	32.9	1.31	<M.D.L	14.22
		Leaf	941.5	29.75	139.95	0.66	<M.D.L	7.83
4	Red amaranth	Root+ Stem+ Leaf	1086.5	30	195.1	1.6	42.65	4.95

The distribution of heavy metal concentration in different parts (root, stem, leaf) of vegetables is shown through the pie charts. From Figures 5 to 8, it is observed that in most cases the distribution pattern of metals is in the order of: leaf > stem > root except for Cd.

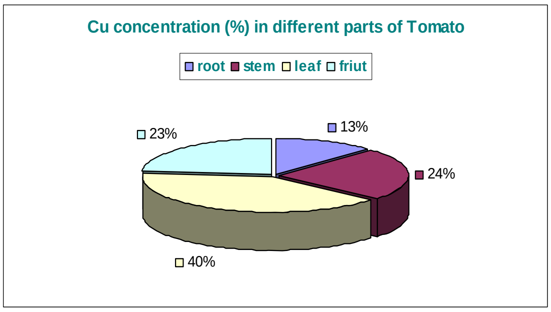

Figure 5: Distribution of Cu in different parts of Tomato

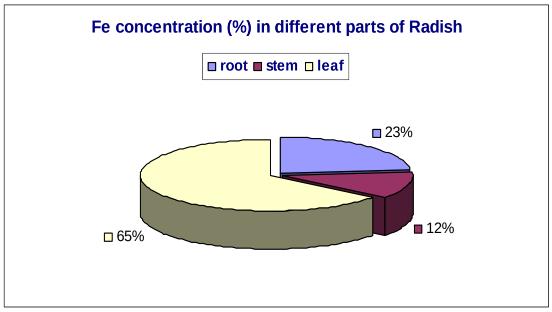

Figure 6: Distribution of Fe in different parts Radish

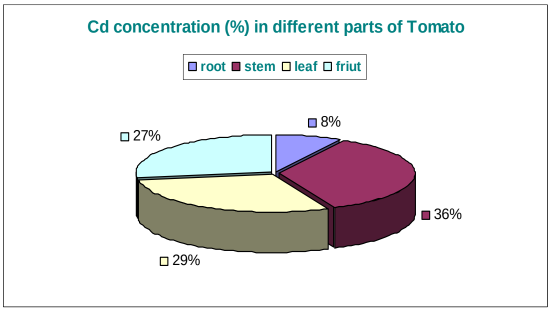

Figure 7: Distribution of Cd in different parts of Tomato

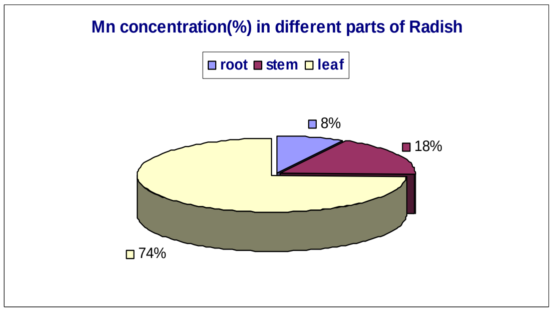

Figure 8: Distribution of Mn in different parts of Radish

Correlation between soil and crop sample

An attempt was made to determine whether any correlation exists between concentrations of heavy metals in soil and crops.

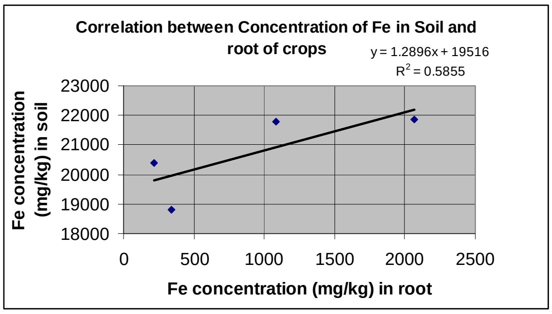

Figure 9: Correlation (Fe) between in soil and crops.

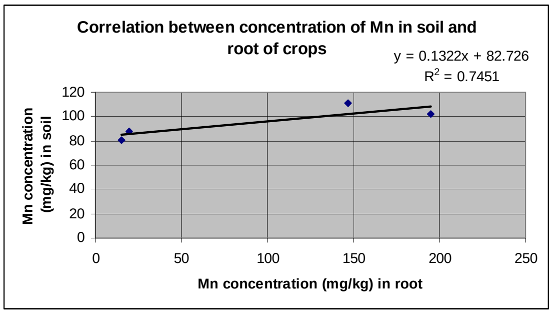

Figure 10: Correlation (Mn) between in soil and crops.

From Figures 9 and 10, it can be seen that there is a significant positive correlation between concentration of Fe [Figure 9, R^2 =0.5855] and Mn [Figure 10, R^2 =0.7451] in plant roots and soil. This indicates high bioavailability of Fe and Mn in these soils.

Metal transfer factor from soil to crop

The accumulation of metal in different parts of plants through the soil was determined and expressed by the metal transfer factor 'f',which is also known as the transfer coefficient (Smith, 1996). The metal transfer factor f is determined using the following formula,

$$f = [M]p / [M]s \quad \text{-------------------------------} \quad (2)$$

Where:

[M] = metal concentration

p, s subscripts refer to plant and soil respectively.

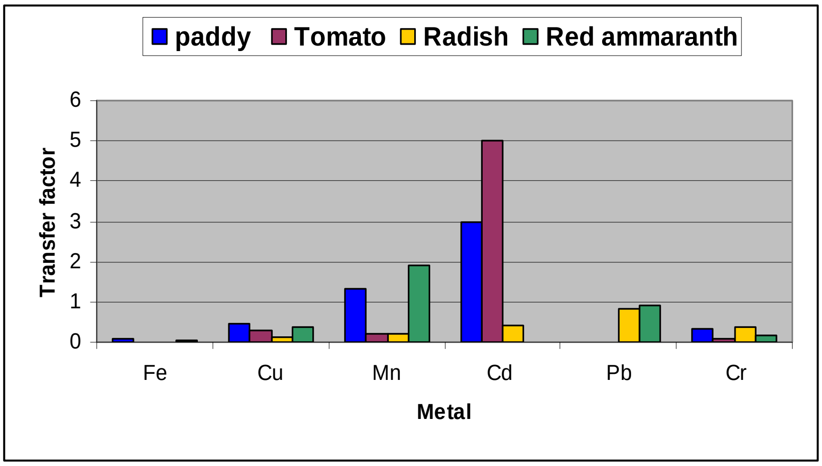

Figure 11: Metal transfer factor for each metal from soil to crop

Figure 11shows the transfer factor (f) of different heavy metals from soil to crop. Highest f value was found for Cd in case of Tomato. TF values are below 1, except for those of Mn in Paddy and Red amaranth.

CONCLUSION

Although Matuail waste disposal site has recently converted to a sanitary landfill, its long use as a dumping site has a significant impact on the surrounding environment. The present study result shows that the soil of the adjacent farmlands is contaminated by the toxic heavy metals. The crops and seasonal vegetables grown in this soil also contain a considerable amount of heavy metals. The distribution pattern of heavy metals in different parts of crops is in order of: leaf>stem>root except for Cd. The regression analysis indicated the high bioavailability of Fe and Mn in soils. Therefore, there exists a cause of concern regarding the contamination and its impact on public health. Vegetable farming in that area is mainly conducted by farmers with low socio-economic status cultivating small or marginal landholdings. These people often have little choice but to farm in polluted areas adjacent to the disposal site, and have limited access to advice and support. This is potentially posing a serious threat to public health as heavy metals find their way to the food chain through the plants grown in the surrounding areas.

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CHARACTERIZATION OF SEPTIC TANK SLUDGE FOR USING AS POTENTIAL SUBSTRATE FOR BIO-PRODUCTS

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ABSTRACT

The potentiality of septic tank sludge as new substrate for bio-product through liquid state bioconversion was examined through the physical and chemical characterization and fungal culture experiment. The characterization experimental results show the septic tank sludge contains high organic content of 0.925±0.07 gm/l which is source of carbon, and nitrogen of 36.62±2.37 mg/l, phosphorus of 4.21±0.33 mg/l, potassium of 2.68±0.13 mg/l, chloride of 41.45±1.37 mg/l and iron of 3.74±0.27 mg/l that can serve as micro and macro nutrient. The culture experiment proved that the fungal strains were able to grow in septic tank sludge and capable to produce cellulase enzymes. Therefore, it can be claimed that the septic tank sludge might be used as renewable substrate for microbial product through liquid state bioconversion.

Keywords: Septic tank sludge, characteristics, substrate, liquid state bioconversion, bio-products

INTRODUCTION

The global challenge of present century is to protect the environment of our world from adverse impact of human activities for extreme civilization. At the present situation, septic tank sludge (STS) in urban and also rural areas of developing country like Bangladesh is becoming threat for conservation of environmental quality. Mainly, urban areas of Bangladesh is experiencing serious problem to dispose of the septic tank sludge (STS). The situation is becoming more critical gradually due to the unplanned development of urban areas. Usually, individual septic tanks are used for the disposal of human excreta due to the absence of common sewerage system which creates proper treatment and disposal problem of STS.

Several techniques have been developed in order to treat the highly biodegradable septic tank sludge. Ponding, anaerobic and aeration systems are the most adopted treatment processes. The drawbacks of these systems are the requirement of a large land area and the system suffers from control and maintenance problems, biogas generation caused in air pollution etc. However, the usual practice of STS disposal in Bangladesh is by burial in deep pit under the ground. The usual disposal of this septic tank sludge always contributes an environmental problem such as the generation of methane during its anaerobic digestion and the production of high COD while percolating the leachate to the groundwater. This is not in favor with the recent growing interest in the global environmental issue, specifically relating to reducing emission of greenhouse gases worldwide in order to control global warming.

In fact, there is no suitable and sustainable developed technology yet focused on process development and improvement to utilize such organic residue for value added applications. In addition, the world attention on this issue implicating that climate resilience system must be proposed as an approach to convert this cheap organic renewable substrate to other bio-product. However, several studies have been carried out to produce the cellulase enzymes from sewage treatment plant sludge through liquid state bioconversion (Alam et al. 2003). The source of septic tank sludge and sewage treatment plant sludge is same except the treatment process. Considering this assumption, septic tank sludge might be potential substrate for the production of cellulase enzymes. Therefore, the study was carried out to find out the suitability of the STS as new substrate for the production cellulase enzymes by liquid state bioconversion using potential local microorganisms which could grow by utilizing organic waste as it contains sufficient amount of carbon, nitrogen, macro-and micro-nutrients.

MATERIALS AND METHODS

Septic tank sludge was used as sample. The physical characteristics and chemical constituents of septic tank sludge were determined through the laboratory experiment. Laboratory stock fungal strains were used for evaluating the microbial growth in septic tank sludge and production of cellulase enzymes.

Sample collection

Representative septic tank sludge was collected in plastic container from the septic tank of Ziaur Rahaman Hall in Rajshahi University of Engineering and Technology. The collected sludge samples were stored in the environmental engineering laboratory at temperature of 4^{o}C in chiller to avoid the further microbial decomposition after collection from the septic tank. The samples were taken out from the chiller whenever necessary for performing the experiments.

Characterization

The laboratory experiments are carried out to determine physical parameters such as the concentration of total solid (TS), total dissolved solid (TDS), total suspended solid (TSS), BOD_5 and COD according to laboratory experimental procedure available in the Environmental Engineering laboratory, RUET. Volatile organic carbon content was determined by loss on heat method. Ash content was determined by burning at 550^{o}C in muffle furnace. Electric conductivity and pH were measured by a Hach Sension^{Tm} 156 Multiparameter apparatus. The chemical constituents were ascertained by conducting experiment following the HACH experimental manual for the determination of the concentration of iron, chloride, total nitrogen, potassium and phosphorus.

Fungal strain

Four strains of *Aspergillus niger*, IBO-102MNB (IMI396648), IBO-103MNB (IMI396649), IBO-109MNB (IMI396650), and IBO-114MNB (IMI396651) were collected from Bioenvironmental Engineering Research Unit (BERU), Department of Biotechnology Engineering, International Islamic University Malaysia. These strains were collected from orange pieces placed in open space and confirmed the species level of identification by the microbial indentification service, CABI Europe-UK (Alam et al., 2010). These strain were selected for this study because of their cellulase enzyme production ability by using oil palm empty fruit bunch (EFB) through solid state bioconversion (Bari et al., 2009, 2011)

Preparation of inoculum

The cultures of *A. niger* were grown on PDA plates at 32^{o}C for 4 days and washed with 25 ml sterilized distilled water to prepare the inoculums. Spore suspension was collected in a 100 ml Erlenmeyer flask by filtering with Whatman No. 1 filter paper. The spores were counted with the haemocytometer to maintain the density of 1×10^8 spores/ml.

Experimental procedure for liquid state bioconversion

Fifty milliliter of septic tank sludge was taken in 100 ml Erlenmeyer flask and sterilized by autoclaving at 121°C for 15 min. Spore suspension inoculums of 1% (v/v) was added to the substrate and incubated in rotary shaker with 100 rpm for 2, 3, 4, 5 and 6 days at room temperature (30±2°C). The initial pH of the substrate recorded varied from 7.5 to 7.8 but not adjusted during the bioconversion process. All experiments were carried out in triplicate. The samples after bioconversion were collected by filtering with Whatman No. 1 filter paper and analyzed for observing the formation of cellulase enzymes.

Determination of protein content

The biomass was collected by filtering the substrate after bioconversion with Whatman No. 1 filter paper. The biomass retain on filter paper was dried in oven at 60°C for 24 hours. The dried biomass was removed from filter paper and ground in powder. Lowry procedure (Folin-Phenol-Reagent) was adopted to analyze soluble protein using Bovine Serum Albumin (BSA) as standard (Lowry *et al.*, 1951). The protein content increase indicated the level of biomass and was estimated by the difference between treated and non-treated sample after bioconversion (Prado et al., 2005).

Determination of cellulase enzyme activities

Reducing sugar was analyzed to determine the activity of cellulases enzyme production with Aspergillus niger by dinitrosalicylic acid method (DNS) (Miller, 1959). The activity of exo-1, 4-β-D-glucanases (exo-cellulase) was determined using Filter Paper (Ghose 1987). The soluble derivative of cellulose, carboxymethyl cellulose (CMC), is widely used for the assay of endo-cellulase activity. Activity on CM-cellulose can be determined by measuring the increase in redusing power of the solution or the fall in viscosity (Ghose, 1987).

RESULTS AND DISCUSSIONS

Characteristic of septic tank sludge

Mostly septic tank sludge contains organic waste material, traces of many pollutants used in our modern society. Apart from those components of concern, sludge also contains useful concentrations of nitrogen, phosphorus and organic matter. Some physical parameters and some important chemical constituents were determined. The experimental results are presented in Table 1.

Table 1: experimental results of septic tank sludge

Physical Parameters	Concentration	Chemical Constituents	Concentration
Total solid (gm/l)	3.66±0.22	Iron (mg/l)	3.74±0.27
Dissolved solid (gm/l)	0.75±0.10	Chloride(mg/l)	41.45±1.37
Suspended solid (gm/l)	2.91±0.31	Total Nitrogen (mg/l)	36.62±2.37
Organic content (gm/l)	0.925±0.07	Total Phosphorus (mg/l)	4.21±0.33
Ash content (gm/l)	2.73±0.11	Potassium (mg/l)	2.68±0.13
p^H	7.8±0.15	COD (mg/l)	351.6±7.3
EC (mhos/cm)	487±6.3	BOD (mg/l)	216.7±4.9

So far our knowledge goes; study on septic tank sludge is not available. However, little study carried out by several researchers on domestic wastewater septic tank effluent (Sauer and tyler, 1996; Sherman and Anderson, 1991; Harkin *et at.*, 1979; Siegrist *et al.*, 1976). Mahadevaiah and Council (1987) have found VOCs such as benzene, ethylbenzene, and toluene in catch basin wastewater. The concentrations of detected VOCs ranged from 5.0-150,000 gm/l.

The CODs, total organic carbons (TOC), chlorides, and conductivity of septic tank effluent varied considerably (Cantor and Knox, 1985). The chemical oxygen demands (CODs) in septic tank effluent at each site varied due to the differences in concentrations of chemically oxidizable materials input into the wastewater stream (Metcalf and Eddy, 1979). Jantrania and Gross (2006) found that the total solids of 300-1200 mg/l, total suspended solids of 155-330 mg/l, BOD_5 of 155-286 mg/l, ammonium-nitrogen, NH_4-N: 4-13 mg/l, total nitrogen of 26-75 mg/l, total phosphorus of 6-12 mg/l, Conductivity of 600-19800 umhos cm^{-1} and Chlorides 76-9309 mg/l.

Growth of fungal strains

The growths of fungal strains were identified by visual observation of pellet formation during the bioconversion of septic tank sludge. Total protein content of the biomass after bioconversion of septic tank sludge was determined to quantify the amount of growth. The changes of colour and density of septic tank sludge in flask culture were observed at second day of bioconversion and pellet was observed after three days of bioconversion. The protein content was measured after six days of bioconversion and the results are shown in Table 2.

Table 2: Protein content as growth indicator in STS after bioconversion

Strains	IBO-102MNB	IBO-103MNB	IBO-109MNB	IBO-114MNB
Protein content (gm/gm)	0.36	0.42	0.27	0.47

The results show that all the tested strains were able to grow in septic tank sludge in liquid state. The maximum growth in terms of protein content was found to be 0.47 gm/gm of dry biomass for the strain *Aspergillus niger* IBO-114MNB. Moreover, the growth of strains IBO-102MNB and IBO-103MNB were nearly same to IBO-114MNB. However, the growth of IBO-109MNB was almost half of IBO-114MNB.

Enzyme production

The product formation of exo-cellulase was found at second day of bioconversion for IBO-103MNB and IBO-114MNB while IBO-102MNB and IBO-109MNB showed at third day. The maximum production observed of 0.84 FPU/ml was at day 4 of bioconversion for IBO-114MNB (Fig. 1) while, production of 0.67 FPU/ml was observed for IBO-103MNB at same day of bioconversion. The second highest was 0.78 FPU/ml at day 5 for IBO-102MNB where starting of product formation was delayed. Production of cellulase suddenly dropped after reaching at the peak in the case of these three cultures. However, the product formation continued till to the end of bioconversion for IBO-109MNB and production was 0.51 FPU/ml.

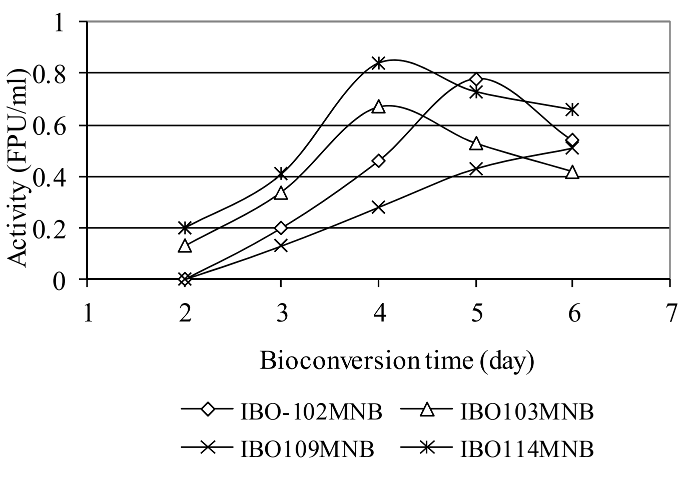

Fig. 1: Production of exo-cellulase in septic tank slaudge

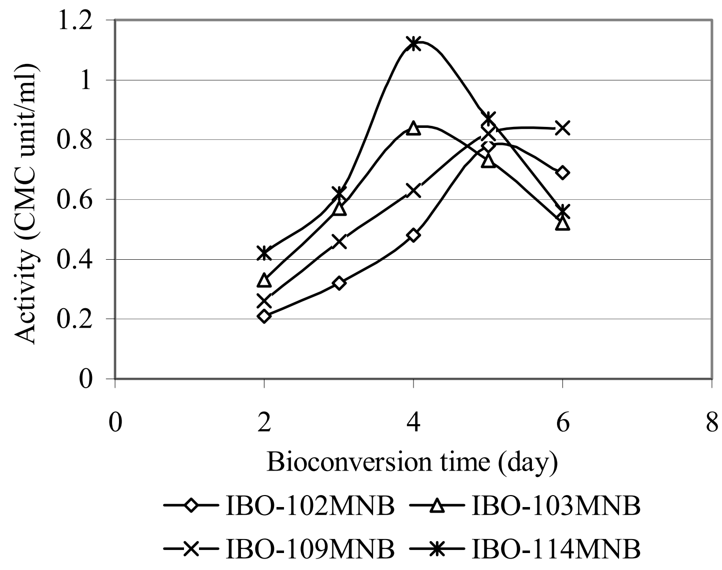

Fig. 2: Production of endo-cellulase enzyme during the bioconversion

Fig. 2 shows the production of endo-cellulase for the selected four strains of *Aspergillus niger* in liquid state bioconversion of septic tank sludge. The endo-cellulase product formation was stated from second day of bioconversion for all strains. However, the trend of product formation followed the same trend as exo-cellulase production. The highest endo-cellulase productions were of 1.12 CMC/ml, 0.84 CMC/ml, 0.84 CMC/ml and 78 CMC/ml for IBO-114MNB, IBO-103MNB, IBO-109MNB and IBO-102MNB, respectively.

CONCLUSION

The aim of this study was to determine the characteristics of septic tank sludge and evaluation of septic tank sludge as potential substrate for microbial product formation. In this study, the laboratory experiments show that the septic tank sludge contains source of carbon as organic content of 0.925±0.07 gm/l and micro and macro nutrient as nitrogen of 36.62±2.37 mg/l, phosphorus of 4.21±0.33 mg/l, potassium of 2.68±0.13 mg/l, chloride of 41.45±1.37 mg/l and iron of 3.74±0.27 mg/l. The pH of 7.8±0.15 shows the favorable condition for fungal growth. The culture experiments show that the fungal strains IBO-102MNB (IMI396648), IBO-103MNB (IMI396649), IBO-109MNB (IMI396650), and IBO-114MNB (IMI396651) are capable to grow in septic tank sludge and produce cellulase enzymes of varying from 0.51 FPU/ml to 0.84 FPU/ml and from 78 CMC/ml to 1.12 CMC/ml in the present experimental conditions through liquid state bioconversion.

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LINE SOURCE NOISE PROPAGATION PREDICTION MODEL FOR A CONTINUOUS STREAM OF NOISE SOURCES

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ABSTRACT

Roadway noise is the most important example of a line noise source, since it comprises about 80 percent of the environmental noise exposure for humans worldwide. This paper presents the results obtained from environmental line source noise measurement for continuous stream of noise sources along the Polashi to Nilkhet route in Dhaka. During the line source survey, noise was measured in both side of the road at a certain interval along the length of the route. Data was collected from the edge of the road for continuous stream of noise sources. The data was analyzed to develop the propagation of noise contour circle along the route. It is observed that the increase in noise levels is very steep near the intersections but besides the random changes the fluctuations at the middle roadway seems moderate. There is difference in the variations of line source noise level between day-time and night-time. These data are very useful to be used as reference and guideline for future regulations on noise limit to be implemented for urban areas in Dhaka.

Keywords: Line source; Noise sources; Propagation model

INTRODUCTION

Noise pollution causes undesirable effects on human health and well-being in urban areas varying from simple problems such as trouble falling sleep, reading, talking, concentration to severe physiological & psychological harm (Dawson, 2005; Muzat, 2007; Ronen et al., 2004). In modern societies noise pollution is identified as a serious public health problem (Doui, 2001). Environmental pollution such as noise & air pollution are considered as being risk factors for human health which is followed by urban technological development (Salvato et al., 2003). Traffic, urban and industrial activities are among important sources of noise pollution (Barbosa, 2005). During last few decades the number of motor vehicles in densely populated urban areas have increased significantly which endangers the health of the residents due to traffic noise pollution (Akhtar et al., 1997). In these areas due to the lack of land and financial resources, many of the highways are built in residential & commercial areas which cause undesirable physiological & non physiological effects on people who reside in the vicinity of these highways. Noise pollution from motor vehicles is expanding at an alarming rate and will become a critical issue in the near future (Alimohammadi et al., 2005). In recent years new laws have been enacted to control the traffic noise pollution. Knowing of traffic noise pollution is one of the prime source which leads to the development of models for reduction of its effects (Golmohammadi et al., 2009).
There are two simple methods of noise level predictions: one for point source emissions and one for line-source emissions. A point source is a single identifiable localized source of something. A point

source has negligible extent, distinguishing it from other source geometries. Sources are called point sources because in mathematical modeling, these sources can usually be approximated as a mathematical point to simplify analysis. A line source is a source of noise that emanates from a linear (one-dimensional) geometry. The most prominent linear sources are roadway air pollution, aircraft air emissions, roadway etc. Though point sources of pollution were studied since the late nineteenth century, linear sources did not receive much attention from scientists until the late 1960s, when environmental regulations for highways and airports began to emerge.

In our study, we established noise prediction propagation model for the Polashi to Nilkhet route. There is a very few study available for line source nosie and in the context of Bangladesh it is first approach. Data obtained from this study will be useful for further research and establishment of noise limit in Dhaka city.

METHODOLOGY

Line source noise was measured along the Polashi to Nilkhet route. During the line source survey, noise was measured in both side of the road at 10 ft interval along the length of the route. Data was collected in the position of 8 ft from the mid of each lane which was 2 ft. from the edge of the road. The total length of the route is about 800 ft. Each lane of both roadway is 12 ft.

The entire route of Polashi to Nilkhet was divided into four sections. Each section was 200 ft. in length (Fig. 1). For the data collection from the study areas, a SL - 4001 noise level meter for intermittent data collection was used. The day time noise levels were measured between 3pm to 5pm and the night time noise levels were measured between 7pm to 9pm . Assuming the position of vehicle was at the mid of the lane, contour circle was drawn with 8 ft. radius by AUTOACD software. The 3D wireframes of noise levels were drawn by SURFER software.

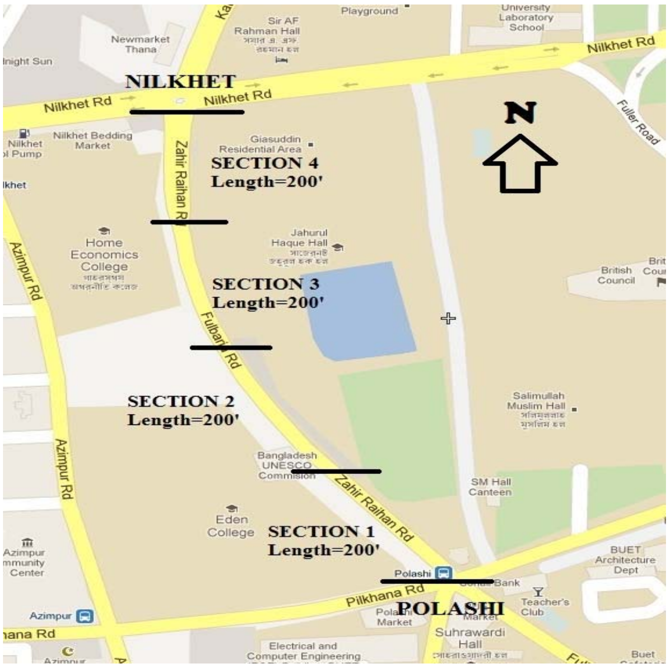

Fig.1. Line source data collection route

Along the proposed route, noise levels were measured 10ft. interval. Noise sources are basically roadway traffic such as car, bus,CNG, motorcycle and non motorized vehicles. The data are collected both at day and night time to compare the noise level variations depending on the time.

Line source propagation occurs when there is a continuous stream of noise source. The propagation is no longer characterized by a spherical or hemispherical spreading of sound; rather the reinforcement by the line of point sources makes the propagation field either a cylinder-shaped or a half-cylinder-shaped area. The contour circle of vehicles indicates the circular range of the noise level which determines the shape of noise propagation.

As the noise levels were collected at the edge of the road, the noise levels at mid-overlapping zone would be the combination of the noise levels at both corners. The formula of resultant of noise levels would be logarithmic in nature. Noise Level at the overlapping areas was calculated by the following formula:

$$\text{Noise Level, } L = 10 \times Log_{10}[10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}}] \qquad (1)$$

Where, L_1 and L_2 are the noise level measured at both edge of the road

Noise contours along the sectoins of the route at day and night time are shown in the Fig. 2 – Fig. 9.

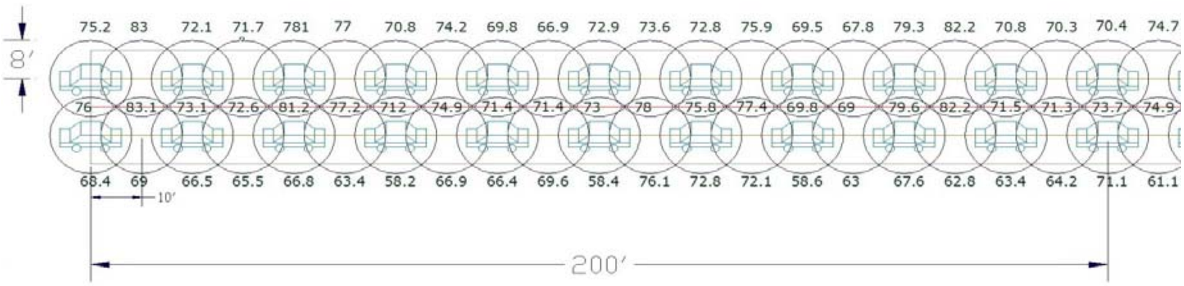

Fig. 2. Line source noise modeling of section 1 (Day)

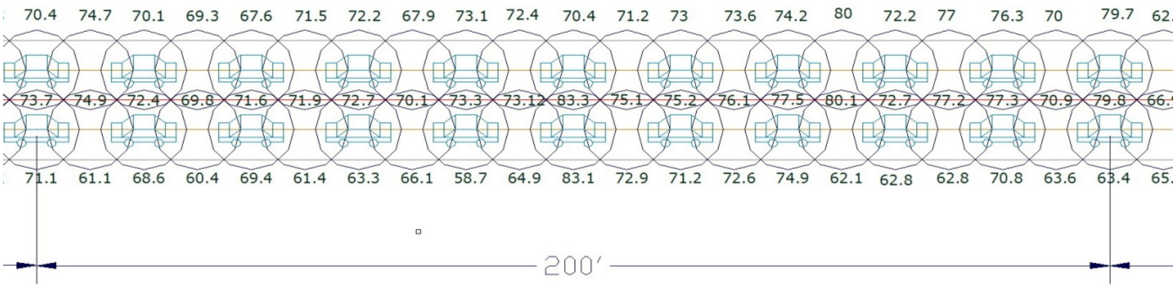

Fig. 3. Line source noise modeling of section 2 (Day)

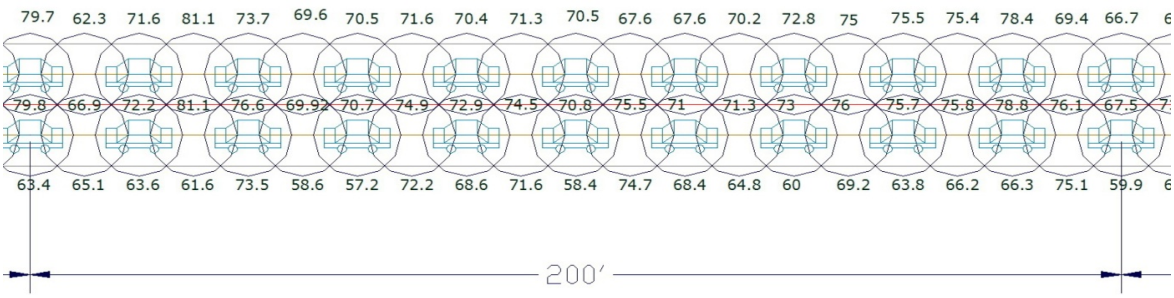

Fig. 4. Line source noise modeling of section 3 (Day)

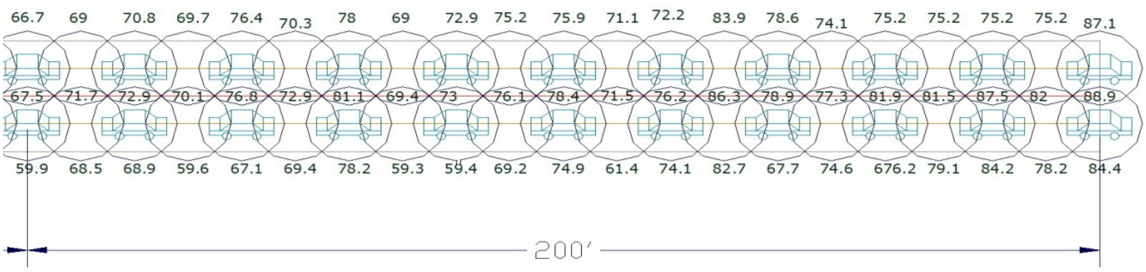

Fig. 5. Line source noise modeling of section 4 (Day**)**

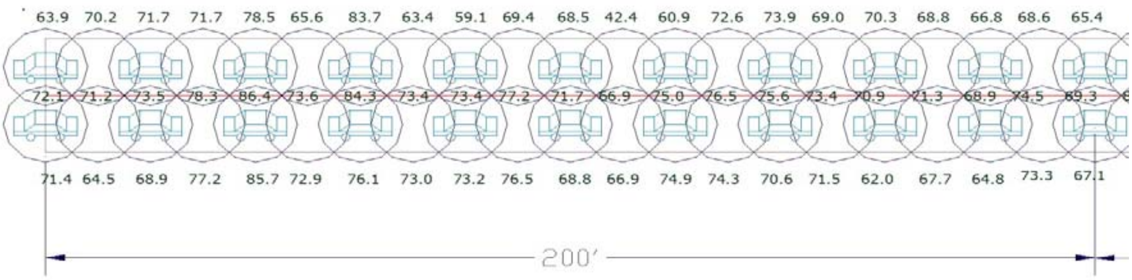

Fig. 6. Line source noise modeling of section 1 (Night)

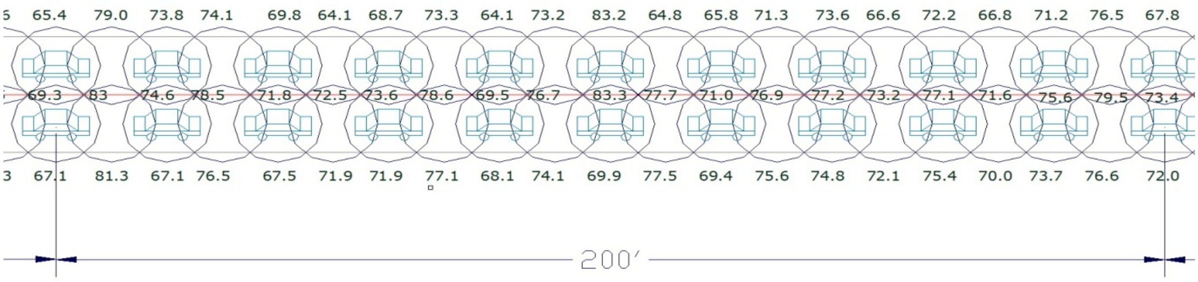

Fig. 7. Line source noise modeling of section 2 (Night)

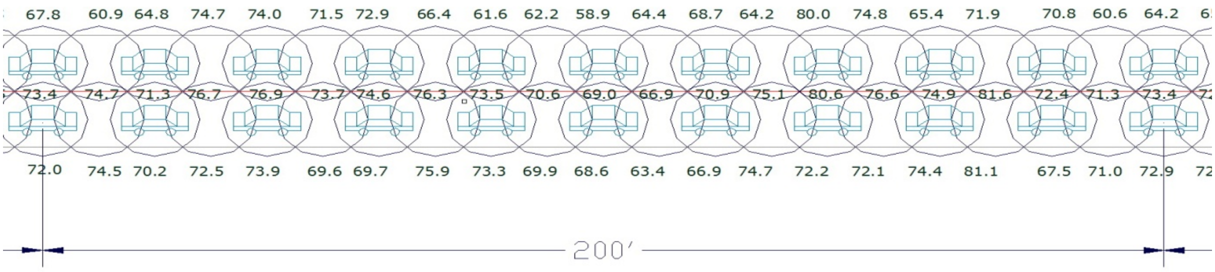

Fig. 8. Line source noise modeling of section 3 (Night)

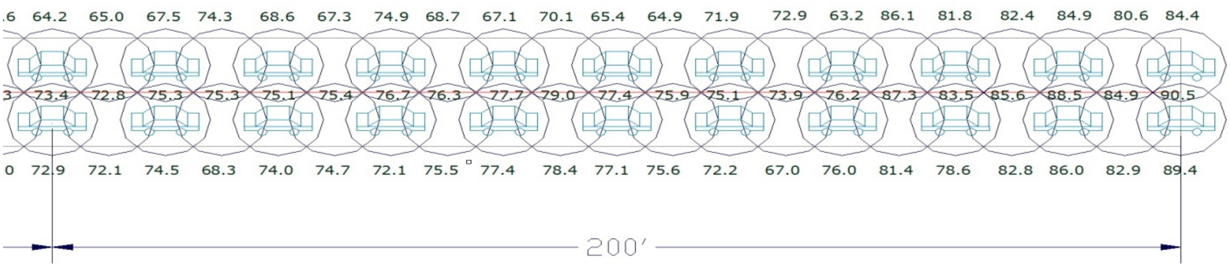

Fig. 9. Line source noise modeling of section 4 (Night)

RESULTS AND DISCUSSIONS

The analysis of collected data represents the increasing and decreasing fluctuations of noise levels along the route. The variations are quite visible in the figures. In the figures, it is observed that the increase in noise levels is very steep near the intersections but besides the random changes the fluctuations at the middle roadway seems moderate. There is difference in the variations of line source noise level between day-time and night-time.

Fig. 10 and 11 indicates 3D Wireframe analysis for day-time and night-time line source noise level respectively. It is seen that the increase in noise level at Polashi intersection is less sharp than at

Nilkhet intersection because the movement of traffic is greater in Nilkhet compare to Polashi. It has been seen on 3D wireframe for both day and night time. The average noise level at night-time is mostly greater than the average noise level at day-time. It is due to data collection at the time of commuter rush at night. The highest level of line- source noise at day-time is 88.9 dB A which is little less than highest night-time noise level of 90.5 dB A. Along the middle of the road, there are number of peaks- some of them indicate very sharp increases and decreases and some of them are minor changes. The noise level at mid-width is apparently greater than at the corners of route because the mid-width noise level is the logarithmic resultant of the noise levels at corners because of overlapping of noise contour circles. The color scale indicates the color variation with magnitude of noise in the 3D wireframe.

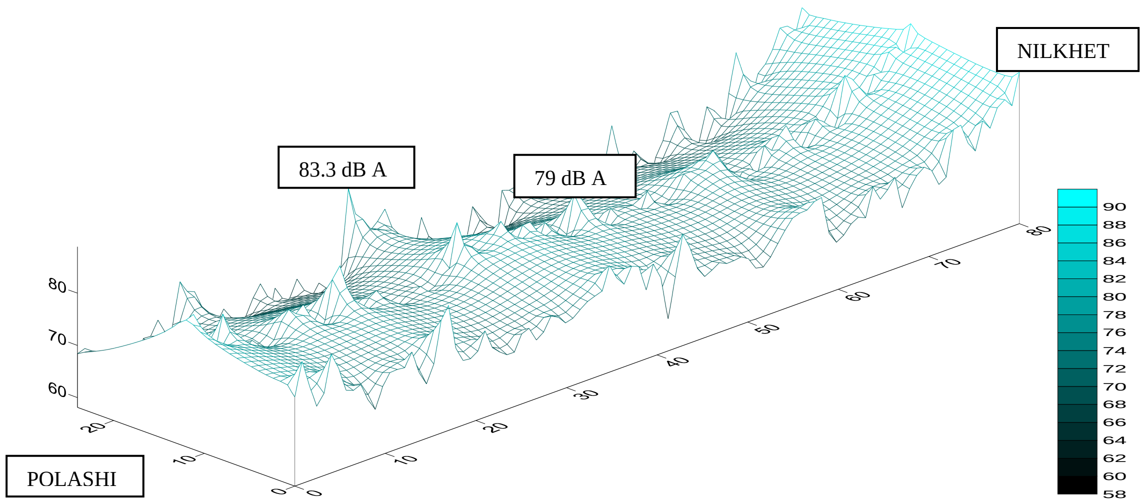

Fig. 10. 3D Wireframe for line source noise (Day)

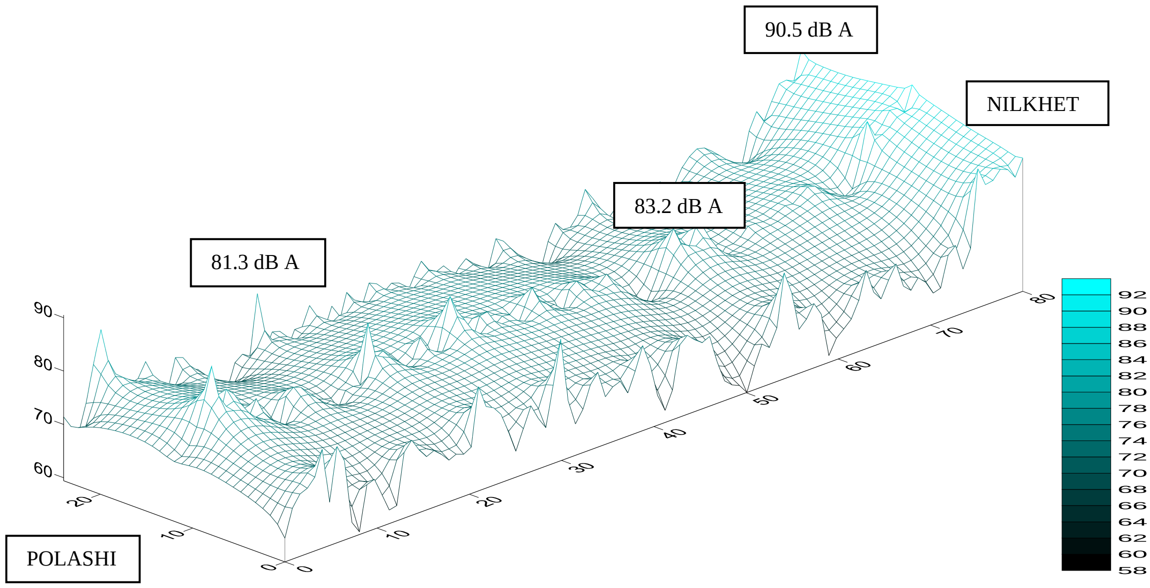

Fig. 11. 3D Wireframe for line source noise (Night)

CONCLUSION

In Dhaka, more attention is now being paid to noise pollution. In most of the studies conducted on noise pollution so far all over the world, it was found that noise pollution reached considerably high levels; thus, noise pollution is the candidate for the most important environmental problem of the city.
The established line source noise prediction model for continuous stream of noise sources is very valuable sources for future research on line source modeling. The collected data are also considered very useful resource for establishment of noise control measures in the study area. And the approaches of the study may be used for other research on noise.
Noise protection propagation model is related to planning, technical, biological, legislative and educational issues that should be taken in order to avoid negative effects of noise pollution on environment. Noise pollution levels should be measured continuously, and the critical levels should be kept. Indeed, the most effective noise control measure is to promote awareness of the population about the risks of daily exposure to high noise levels.

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BASELINE NOISE LEVEL FOR THE PROPOSED ELEVATED EXPRESSWAY IN DHAKA

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ABSTRACT

Traffic noise is one of the most important components of the urban environmental pollution in densely populated areas all over the world. Noise pollution is emerging as a new threat to the inhabitants to Dhaka City. Exposure to high level of noise may cause severe stress on the auditory and nervous system of the city dwellers specially the children. Government of the People's Republic of Bangladesh has taken all out efforts to construct an Elevated Expressway in Dhaka City to reduce the acute traffic congestion of Dhaka. For this project, baseline noise levels were measured from Polashi to Tongi Diversion Road. At first, Reconnaissance Survey was carried out along the study route to identify key locations. Noise level data was measured at fifteen major locations along the route during day and night. The data was analysed to calculate various noise parameters such as L_{eq}, L_{10}, L_{50} and L_{90}. It is observed that the level of noise remains far above the acceptable limit for most of the time at most of the locations. The paper suggests that vulnerable institutions like schools and hospitals should be facilitated with special arrangements to alleviate noise.

Keywords: Baseline noise, Elevated Expressway, Traffic noise

INTRODUCTION

Noise pollution is recognized as a major problem for the quality of life in urban areas all over the world. Because of the increase in the number of cars and industrialization, noise pollution has also increased. Noise in cities, especially along main arteries, has reached up disturbing levels. Residences far from noise sources and near silent secondary roads are currently very popular. People prefer to live in places far from noisy urban areas (Yılmaz, 2005). Motor vehicles, which are a very significant part of this urban environment, are also the main source of urban noise emission, contributing about 55% to the total noise (Pandya, 2002; Sinha, 2003).The growing vehicle population gives rise to unrestrained noise pollution and associated health effects and can cause both short term as well as long term psychological and physiological disorders. Noise is a very complex phenomenon in its physical aspect, as well as in its psychological and medical dimensions. In consequence, it is practically indispensable to measure, predict or describe noise in a simplified way (Canter, 1996).

In a study conducted in London, England, high percentage of the residents picked noise pollution as the most important problem of their city and 23% of them chose the traffic noise as the main source of the noise pollution (Alesheikh, 2010). In Bangladesh, in recent years new projects have been undertaken by the government for improving the transportation infrastructure all through Dhaka city. Among them Elevated Expressway is the most innovative one.Elevated Expressway is being built across Dhaka City for the first time. Due to inexperience in handling such huge construction, traffic congestion has become a daily phenomenon. The primary objective of this research is the collection of baseline noise level data at different key locations along the route Polashi to Tongi Diversion Road (a link to Elevated Expressway). Additional objective includes graphical comparison of different statistical parameters such as median, maximum, minimum, L_{10}, L_{50}, L_{90}, average, L_{eq}etc. between day and night noise levels, daily variations of those parameters for both day and night for specific location. Maximum & Minimum Noise level variations are established along the route for day and night time. Besides, due to lack of noise data in Bangladesh, the data obtained from this study will also help others - related to any projection in the vicinity of our study route.

MATERIALS AND METHODS

The four-lane 21 km (13 miles) Elevated Expressway will link Dhaka's Hazrat Shahjalal International Airport in the north of the capital to a point in the southeast to connect a highway leading to the port city of Chittagong. The proposed Elevated Expressway of Dhaka will be 26 kilometers in length. The main road will be 21 kilometers in length. There will be added two more link roads of 5 kilometers with this. One link road is from Manik Mia Avenue to Tejgaon Rail Crossing and another will be from Nilkhet to Moghbazaar. Later, in addition, the Elevated Expressway will be increased up to Narayanganj in the south and Gazipur in the north.

At first a route visit and reconnaissance survey was done to identify the critical structures vulnerable to noise like schools, colleges, hospitals, market places, government and non-government organizations, bus stops, intersections etc. Then based on this reconnaissance survey noise level data was collected on the critical points along the route. Then analysis of these collected data to assess the noise condition was done to visualize the noise condition along the route.

This study was conducted in 2011. In order to determine the sound level, 15 locations were selected based on reconnaissance survey. Sampled stations covered all important locations along the route. The noise levels were measured with the help of a portable precision digital sound level meter (Model- SL-4001, made in England). This instrument is primarily designed for traffic noise surveys. In these stations, different noise factors such as L_{Max}, L_{Min}, L_{eq}, L_{90}, L_{50} and L_{10} were measured on every day over the week both day and night. Data were collected for different days in different week instead of continuous collection to gather total overview of the noise level data of a week. Day time was in between 8:00 am to 6:00 pm and night time was in between 6.01 pm to 11:59 pm. Data were taken at one minute interval and 20 data were collected. Before each measurement, the sound level meter was calibrated and was set on a weighting network and fast response with every 5 min measurement time. For the proper assessment and analysis of the results the following Noise Indices were computed:

- L_{eq}: Hourly A-weighted equivalent sound level;
- L_{10}: Noise level exceeded for 10% of the time;
- L_{50} : Noise level exceeded for 50% of the time;
- L_{90} : Noise level exceeded for 90% of the time;
- L_{Max} & L_{Min}: Max. & Min. noise level during sampling

RESULTS AND DISCUSSIONS

Graphical Comparison of Parameters at Karwan Bazaar Intersection
Due to high volume of traffic this intersection has great impact on noise level and it is an important part of major roadway of capital city Dhaka. It will influence largely to the noise level of Elevated Expressway in future.

The daily variations of maximum, minimum and average noise level at Karwan Bazaar Intersection for day time are shown in the Fig.1. The maximum noise levels at Karwan Bazaar Intersection over the week occurred highest at Sunday (99.5 dB A) and lowest at Friday and Thursday (94 dB A). The minimum noise levels found highest at Monday (76.1 dB A) and lowest at Saturday and Sunday (73.7 dB A). And the average noise levels found highest at Wednesday (87.5 dB A) and lowest at Thursday (83.9 dB A). Friday had the least and Sunday had the most noise level variation over the week. In the figure-2, it is observed reduction of the number of passing vehicles at Karwan Bazaar Intersection in Friday (holiday) compared with Sunday for lesser noise levels in holidays.

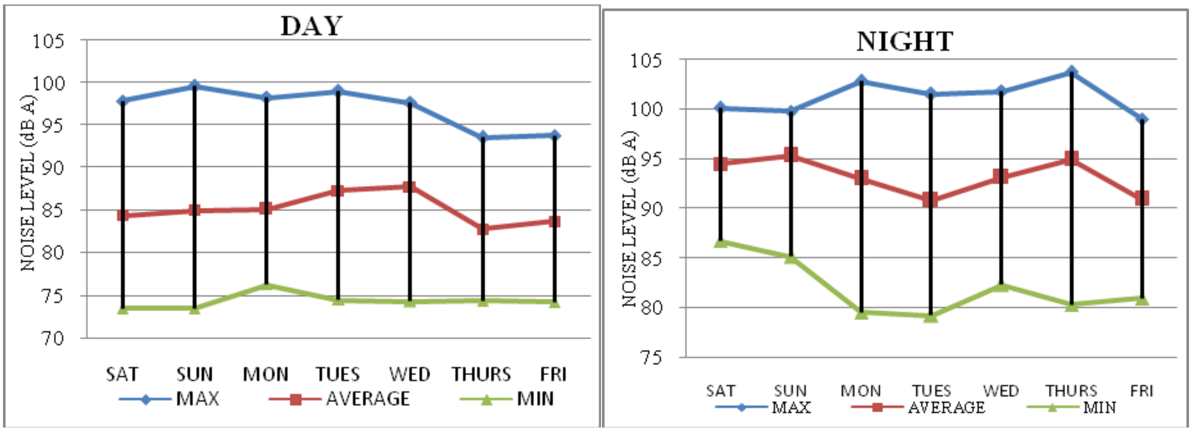

Fig. 1. Average, maximum and minimum noise level at Karwan Bazaar Intersection

Fig. 1 also shows the daily variations of maximum, minimum and average noise level at karwan Bazaar Intersection for night time. The maximum noise levels at Karwan Bazaar Intersection over the week occurred highest at Sunday (104 dB A) and lowest at Friday and Thursday (98.7 dB A). The minimum noise levels found highest at Monday (86.2 dB A) and lowest at Tuesday (79.5 dB A). And the average noise levels found highest at Sunday and Thursday (95 dB A) and lowest at Friday (91.7 dB A). Saturday had the least and Thursday had the most noise level variation over the week. Due to extra out-bound trips generated just before weekend, increasing number of passing vehicles was significantly visible at Karwan Bazaar Intersection in Thursday compared with Saturday.As we have two holidays, people generally tend to go to their homes outside of Dhaka. Though Friday is a holiday, the noise level variation at night is higher than Saturday and Sunday due to recreational and shopping trips.

Comparison among L_{10}, L_{50}, L_{90}, L_{eq} over the week

L_{eq} is the preferred method to describe sound levels that vary over time, resulting in a single value which takes into account the total sound energy over the period of time of interest.Fig. 2. shows comparison among L_{10}, $L_{50,}$ L_{90} and L_{eq} both at day and night over the week. For both day and night the value of L_{eq} was bit higher than the values of L_{10}, L_{50} but just lower than L_{90}. And the value of L_{eq} for night time is quite larger than that of day time over the week at Karwan Bazaar Intersection. It is mainly due to the high traffic volume from evening commuter rush. Besides, truck, trailer, semi-trailer etc. are allowed only to enter at evening in Dhaka City.

Graphical Representation of Parameters along the Route

Fig. 3 & 4 show the variation of L_{eq} both at day and night over the week from Polashi to Tongi Diversion Road respectively. Among the locations, Karwan Bazaar Intersection showed the highest equivalent sound level (L_{eq}) due to the high rate of heavy vehicle traffic in both figures. It is visible that night time noise levels were well above than day time noise levels.

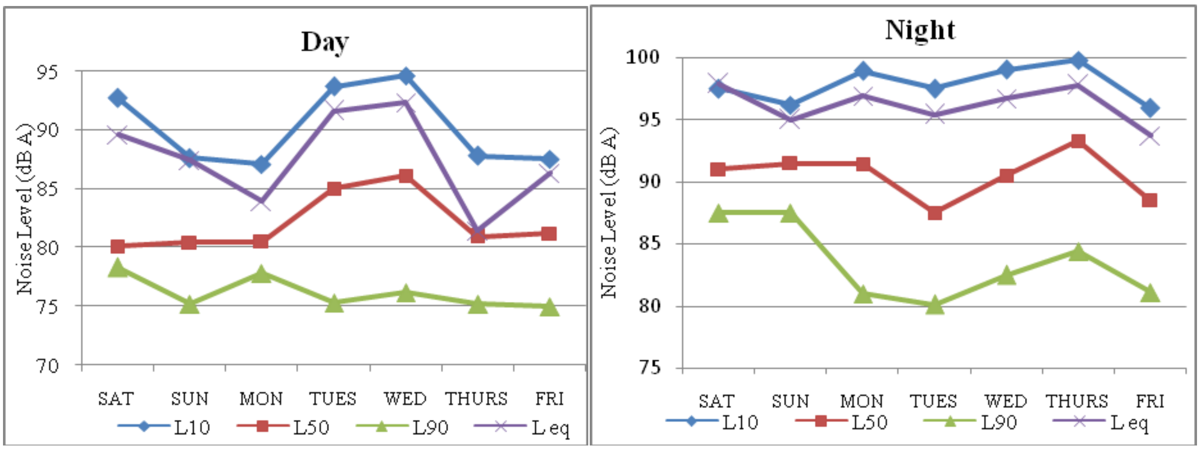

Fig. 2. Comparison among L_{10}, L_{50}, L_{90}, L_{eq} at Karwan Bazaar Intersection

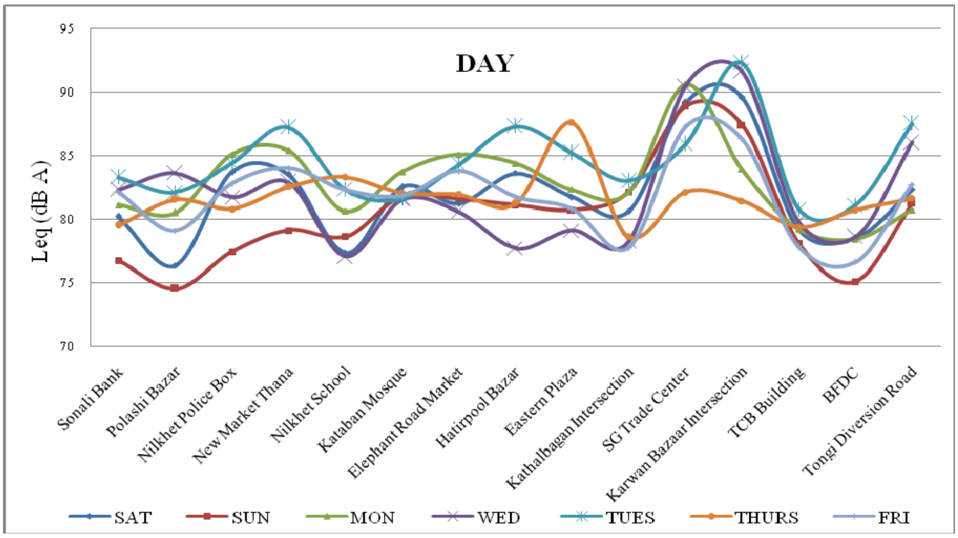

Fig. 3. Variation of L_{eq} from Polashi to Tongi Diversion Road (Day) over the week

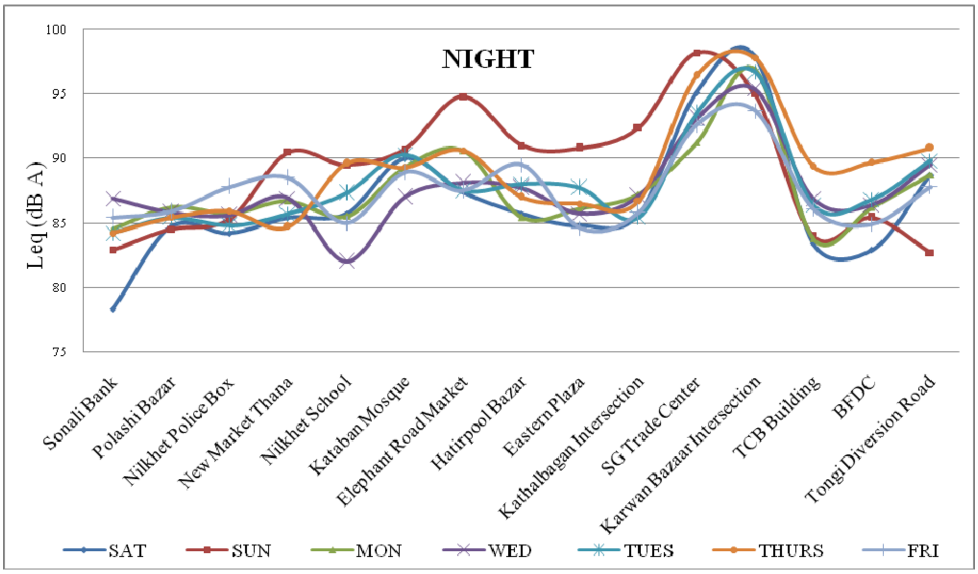

Fig. 4. Variation of L_{eq} from Polashi to Tongi Diversion Road (Day) over the week

CONCLUSION

Baseline Noise study were done to represent typical equivalent noise level at several selected locations along the route of Elevated Expressway in Dhaka, Bangladesh. Baseline noise study for Elevated Expressway in Dhaka citybeing presented in this paper will benefit the researchers and policy makers in this field, especially forthose who are directly involved with the study of noise pollution for environmental impact assessment (EIA) with the Department of Environment (DoE) Bangladesh.It is observed that the level of noise remains far above the acceptable limit for most of the time at most of the locations.To prevent this kind of threat, the following important measures should be undertaken.

i) Noise Control at Source: The noise pollution can be controlled at the source of generation itself by employing techniques like- a) Reducing the noise levels from domestic sectors, b) Maintenance of automobiles, c) Control over vibrations

ii) Roadside Plantation: Planting trees in streets is expected as one of the efficient artificial methods to mitigate environmental impacts caused by road traffic.

iii) Noise Barriers: Noise barriers are solid obstructions built between the highways and the homes along a highway.

iv) BufferZone: A naturally vegetated or replanted area around the perimeter of the aggregate site, or adjacent to an environmentally sensitive area such as a stream, wetland or urban development is called buffer zone.

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SALINITY INTRUSION PATTERN THROUGH BRICK SAMPLES

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ABSTRACT
Brick, the most popular construction material is highly affected with salinity. Not only in coastal regions but also in the areas where rivers come in vicinity of the sea. Most of the water in our surrounding environment contains a percentage of salt which causes serious damage to the structural elements. When, water comes in contact with the brick, pores contained in brick work as transferring media for the water. Water passes through the brick because of the capillary action and salt deposits on the surface due to hygroscopic nature, cause efflorescence. It highly damages plaster, mortar or distemper overlaid on it. The present study aims to show the intrusion pattern of water through brick samples and also the salt transferring mechanism. Firstly, one directional flow was considered for determining the water transport pattern. Brick slices were made for testing the level wise salt retention. The result shows the % chloride content at level 0 for sample 1(A) 0.016, for sample 2(A) 0.005, for sample 3(A) 0.19 and for sample 4(A) 0.93. Moreover, the variations of salinity with different parameters were identified. This study also helps to know if there is any affinity in the pores or attraction for water in any specific zone. The study was carried out for both distilled water and salt water. In case of distilled water, only the salt contained in brick was passed through the pores but the salt contained both in brick and water was passed through the pores from salt water.

Keywords: Brick, Salinity, Intrusion, Affinity, Efflorescence

INTRODUCTION

Brick is one of the most important building materials which is also used as a ceramic material (Aziz, 1995). In constructional purpose no other materials such as cement, fine aggregates, and reinforcements are required in a great quantity. In ancient ages when the concept of brick was not established; stone was used for the construction purposes. Today almost all the structures such as buildings, bridges, roads are made of concrete and brick. Brick is the main component of concrete. Brick is preferable because it is lighter, stiffer, economic and available than stone. It is lighter because it contains voids in pore spaces entrapped inside during burning. Practical applications prove that it can be widely used as a traditional building material due to its mechanical properties (Jubran et al., 1988). Due to the presence of these pore spaces brick is unable to resist water intrude in. Intrusion of water from ground or other sources is caused through capillary action.
Brick itself carries salt as it is made of clay containing a percentage of NaCl. When water comes in contact with the salt, it passes through brick and deposits salt on its free surface. It affects the plaster or mortar overlaid on in and causes dampness and deterioration. Dampness causes efflorescence which may ultimately result in disintegration of bricks and it does not illustrate a satisfactory thing (Kumar, 2001). Most of the industrial buildings and bridge piers are constructed near watercourses for easy transport. When these bricks are exposed to salinity, it causes a white crust over the brick surface called efflorescence. This is caused mostly due to the capillary action of seawater containing salt

water. So, it is therefore worthy to look the pattern and quantity of salt transport through brick samples under controlled laboratory condition.

IMPORTANCE OF THIS STUDY

When a structure is constructed in contact with water, water passes through the pores of the bricks and causes efflorescence or sub-efflorescence occurs as a consequence of some sequential, happenings. The entrapped salt and weathered salt cause disintegration of bricks and plasters overlaid on it. Bricks and plasters get turned into dust and cement flakes off. Rising damp occurs where ground moisture is drawn into mortar and masonry surfaces by capillary action. The extent of the rising damp is determined by the hygroscopic indices of the salts, the availability of moisture, and degree of evaporation. The purpose of this research is to show the pattern of intrusion of water through brick samples and also the transportation and deposition of salt on the surface of the brick. The natural problems caused by the bricks have also discussed here. For taking counter-measures it is very much important to know about the reasons of brick damages and the salt holding pattern of the brick pores.

OBJECTIVES OF RESEARCH

- To determine the initial salinity of the brick samples.
- To determine the moisture absorption capacity of brick samples set to absorb water.
- To determine the intrusion pattern for both distilled water and salt water (35000 mg/L NaCl) through one directional flow.
- To evaluate the level wise salt deposition after allowing controlled amount of water through specific samples.

MATERIALS AND METHODS

For initiating the test, eight brick samples were taken. They were prepared from four bricks. There initial salinities and the properties (porosity, % moisture content) were determined. The bricks were cut with mechanized saw to prepare the samples.

Four samples were then set to suck distilled water and another four to suck salt water (35000 mg/L NaCl) in watertight pots. The salt water was prepared by mixing 35 gm NaCl with 1 liter distilled water. The test was continued for more than five months. Complete setups for the tests are shown in [Fig 1].Salts deposited on the top surface were collected periodically. The test was performed in the laboratory and the factors (temperature, sunlight, air) were considered.

Fig. 1 Complete setups for one directional flow

Then the samples were cut into small pieces and grinded to perform Cl^- test. For this test the grinded samples were kept sunken into distilled water for 24 hours. Then level wise salt detections were performed to determine % chloride content at each level shown.
Again another eight samples were prepared from four bricks in the same process described before. In case of distilled water the setup was continued for 81 days and for salt water 78 days. Then 4% Gypsum was added with both distilled water and salt water and the setups were continued for another 5 days and 7 days respectively.
Then the samples were cut and grinded to make small crumbs and level wise salt detection was performed.

RESULTS AND DISCUSSIONS

The results of this research contain a detailed information about the brick samples used, including volume, porosity, initial salinity, moisture content, amount of water sucked, salt deposition on the surfaces and in each level of the bricks. Initial chloride content of brick 1, 2, 3 and 4 were 330 mg/L, 350 mg/L, 270 mg/L and 410 mg/L respectively. Properties of the brick samples are shown in Table 1.

Table 1: Properties of brick samples

Items	Set to Suck Distilled Water		Set to Suck 3500 0 mg/L Salt Water	
Brick Samples	Sample 1	Sample 2	Sample 3	Sample 4
Brick Dimensions (cm)	23.45×11.86×6.02	24.23×11.25×6.02	24.15×10.99×5.76	23.62×11.12× 5.97
Brick Volume (cm^3)	102.42	100.16	93.47	95.72
Oven Dry Mass (gm)	2620.4	2786.7	2694.9	2680.0
SSD Mass (gm)	3165.8	3306.7	3127.7	3199.6
% Moisture Content	20.81	18.66	16.06	19.39
Volume of Void (cm^3)	84.53	80.59	72.87	80.54
Porosity	0.325	0.317	0.307	0.331

Comparison of Distilled Water Absorbed by Different Samples

Though water was added to the samples at a same interval, the amount of water absorbed by the samples were not same. Different samples absorbed different amount of water as the porosity was different. As the bricks were not uniformly porous, water absorbed by the two parts of brick 1, (1(A) & 1(B)) and brick 2, (2(A) & 2(B)) were also different. The amount of water absorption in case of brick 2 fluctuates more than in case of brick 1. The test was continued for 170 days. The comparative representation is graphically shown in Fig 2.

Fig. 2 Comparative Representation of Absorbed Water (Distilled Water) by Different Samples

Level wise salt detection for distilled water in different samples is graphically shown below.

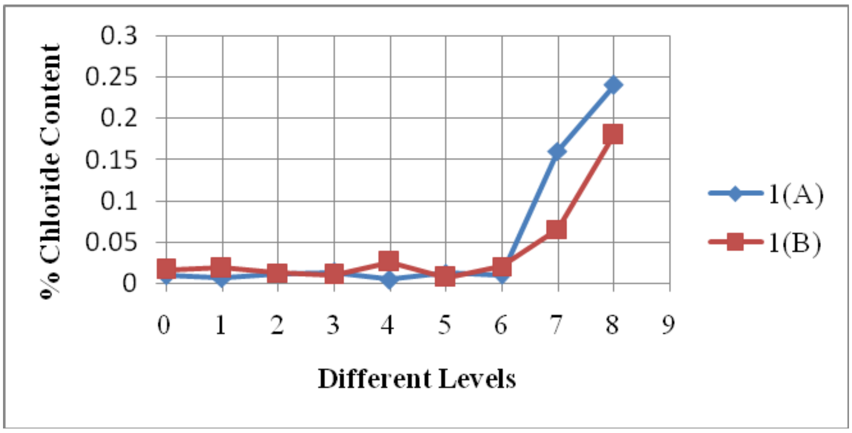

Fig. 3 % Chloride content VS different levels for sample 1(A) and 1(B) (set to absorb distilled water)

The graphical representation shows that the salt accumulation at the contact levels with water is less than the deposition at the layers near free surfaces. The amount of deposition is almost same from layer 0 to 6 and then suddenly rises at level 7. In this case only the salt contained in the brick moves with water.

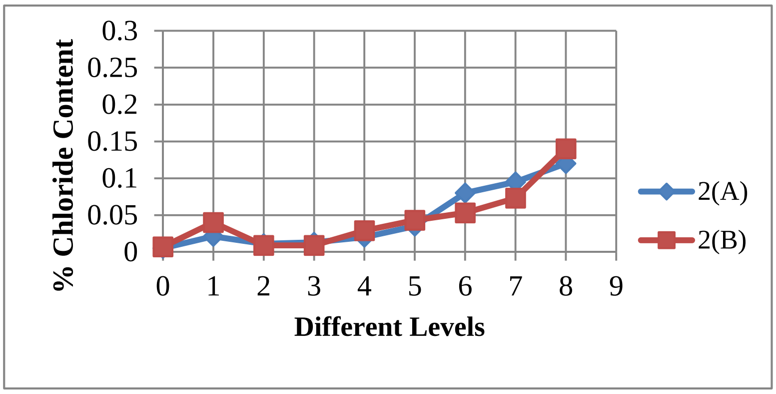

Fig. 4 **%** Chloride content VS different levels for sample 2(A) and 2(B) (set to absorb distilled water)

Again fig 4 shows the % of chloride deposition in two parts of brick 2. The amount of deposition varies with levels. The percentage of deposition is minimum at bottom and maximum at top layers. And the amount of salt deposition increases with the increasing level. The percentage of chloride content in sample 2(A) is not completely same to 2(B). This is because the brick was not uniformly porous. The deposition increases with the porosity.

Comparison of Salt Water Absorbed by Different Samples

In fig 5 it has clearly shown that water absorbed by different samples were different. For this reason water was not added on a daily basis. The test was started on 20 February 2012 and continued for 105 days. The amount of water absorption was more on March because of much evaporation. Amount of water passed through brick 4 was more than brick 3.

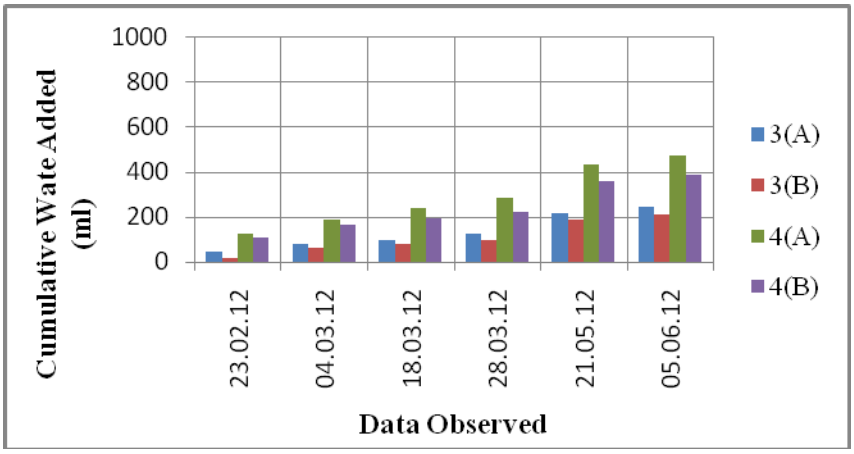

Fig. 5 Comparative Representation of Absorbed Water (Salt Water) by Different Samples

Level wise salt detection for salt water in different samples is graphically shown below.

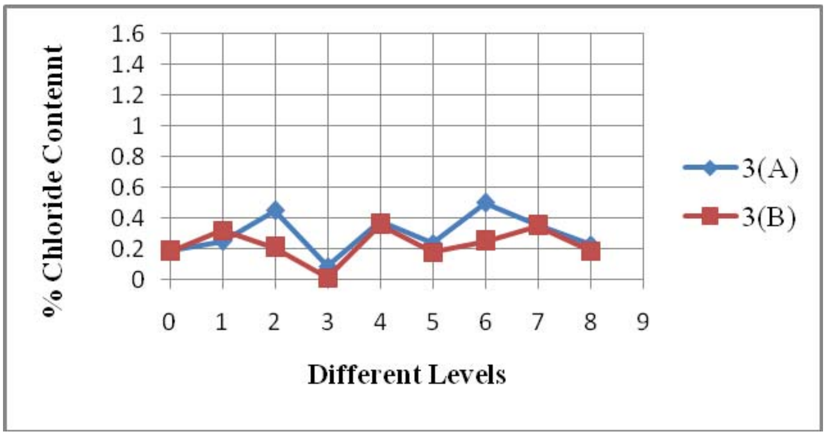

Fig. 6 % Chloride content VS different levels for sample 3(A) and 3(B) (set to absorb salt water)

From Fig 6 it is clearly observed that the % chloride content fluctuates with levels. The salt deposition is maximum and minimum at alternate levels. Here some sharp points have found because of the passage of high salinity water. Deposition of chloride content is more in sample 3(A) than sample 3(B). Again Fig 7 shows the level wise deposition of the two parts of brick 4. At free surface the deposition is less than the contact surface. The salt deposition is minimum at level 3 and maximum at level 2 and 5.

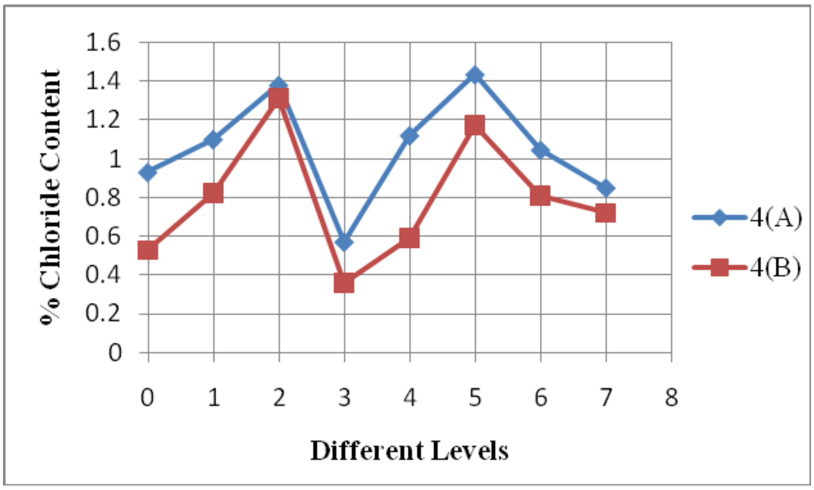

Fig. 7 % Chloride content VS different levels for sample 4(A) and 4(B) (set to absorb salt water)

CONCLUSION

The present study aims at showing one of the most serious problems of brick. Salt damage to brick is so familiar to all today. Salt mix with water and intrude into the bricks and turn them into dust. It has become an emergency to take necessary steps against salinity. Before taking any action, it is obvious to know the intrusion pattern of water and the movement of salt through bricks. From the research it is observed that the % chloride content at the levels near contact of water (in case of distilled water for one directional flow) are less than the free levels and it suddenly rises above 15 to 16 cm above the surface which is in contact of water. Again in case of salt water it is more in the contact level than the free level and the percentage fluctuates at different levels. When Gypsum was added to distilled water, the percentage of chloride content was increased. This is because the Gypsum contained a small amount of NaCl. When Gypsum was added to the distilled water, NaCl got into the samples and increased chloride content.

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The author is expressing profound gratitude and heartiest thanks to all the teachers and staffs of Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), for their enthusiastic vision, encouragement, and guidance, cooperative and constructive criticism in making this project success.
Thanks to the parents who gave completeness to the work by their continuous mental support.
The results found eventually would become fruitful if they can be applied to the case the study was aimed for.

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CONCEPTUALIZATION OF HYDROLOGICAL PARAMETERS: SIMULATION OF HYMOD AND HBV MODEL IN PREDICTING UNGAUGED BASINS

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ABSTRACT

Hydrologic models are simplified, conceptual representations of a part of the hydrologic cycle. In this study HYMOD and HBV are used as a Hydrological Model to predict ungauged basins.The prediction of the hydrologic response of ungauged catchments is an inherent problem in hydrology. In spite of considerable advancement in hydrology, the prediction of stream flow for ungauged or poorly gauged catchments still remains as most important challenge. Still now different studies produced different results. Firstly, the methodologies used in each type of approach depend on a number of unavoidable arbitrary choices made by the researchers, which can influence the performance of the regionalized model (number of donor catchments, density of gauged catchments, and use of poorly modeled catchments as donors). Secondly, the accessible catchment descriptors vary from one study to another. Thirdly the performance of each regionalization approach may depend on the structure and parameterization of the rainfall-runoff models used. Catchment properties and Hydrological Model parameters are used consistently to predict ungauged catchments. Unluckily this intermingle was not used properly to find the appropriate solution. In this regard, data transfers from gauged "donor" catchments to ungauged catchments are seen as superior to the estimation from catchment descriptors alone. A donor or analogue catchments (e.g. close to subject catchment, of similar size, physiography, land use, soil, etc.) offer gauged data of good quality. In our study, we identify the gauged donor catchments to predict ungauged catchments. Data depth function plays key role in identifying donor catchments. We applied Robust Parameter Estimation (ROPE) algorithm to ensure all parameter vectors robust with hydrologically representative, insensitive as well as transferable with good model performance. Sensitivity of hydrological model parameters (HYMOD and HBV Model) are evaluated to find unique solution in predicting ungauged basin. Distribution pattern of HYMOD model parameter with the change in number of catchment properties is discussed in the paper.

Keywords: Prediction, Spatial Proximity , Robust Parameter, Data depth, Ungauged basin

INTRODUCTION

In the last few decades hydrologists have made tremendous progress in the development and application of watershed models for the analysis of hydrologic systems and to provide accurate flood forecasting techniques. Predictions with these models are often deterministic, focusing on the most probable forecast, without an explicit estimate of the associated uncertainty. However, uncertainty arises from incomplete process representation, uncertainty in initial conditions, input, output, and parameter error. Quantifying these uncertainties is necessary to assess model quality and predictive capability.

Quantification of the hydrological cycle is done by Hydrological Modelling. Broadly there are three types of hydrological models: (i) conceptual, (ii) physically based and (iii) empirical. (iv) Conceptual Models show good performance at large scales, contain a certain physical foundation. It's used in simple application. This type of model needs low input data and parameter. On the other hand application to ungauged basin is very difficult and good forecast possible, only when the real situation is close to assumption condition. (ii) Physically based Model is the best option in small scales. Physical rigor, universality, Low number of calibration parameter, ability of extension made this model popular. Good for forecast and application to ungauged basins possible. Conversely requirement of high number of input data and parameter, Complex structure, highly non-linear problem, difficulty in estimation of initial value, boundary value and parameterization inhibit it's use frequently.(iii)Empirical model is very simple in parameter estimations process with simple structure. Lack of physical fundamentals (No understanding of insight and process), bad universality and ability of extension made this type of model unpopular.

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MATERIAL AND METHODS

In this study two conceptual Model (i) HYMOD (ii) HBV are Used.

HYMOD Rainfall- Runoff Model

HYMOD is a conceptual rainfall-runoff model based on the probability-distributed principle of R.J. Moore [1985]. Figure 1 represents the overall structure of the model. This model performs firstly by characterizing the runoff production process at a point within the basin. Secondly, probability distributions describing the spatial variation of process parameters over the basin are used to derive algebraic expressions for the integrated flow response from the basin. In this study, modified HYMOD model [Bardossy & Singh, 2010] was used. The major modification was the addition of snow routing. The snow routine represents, snow accumulation and melt by a simple degree-day concept, involving the degree-day factor DD and Threshold temperature for snow melt initiation Th.

The main structure of the model contains a relatively simple rainfall excess model, connected with two series of linear reservoirs (three identical quick and a single for the slow response). It requires the optimization of eight parameters to observed stream flow data: the maximum storage capacity in the catchment, the degree of spatial variability of the soil moisture capacity within the catchment, the factor distributing the flow between the two series of reservoirs, and the residence time of the linear quick and slow reservoirs. The soil moisture routine represents runoff generation and changes in the soil moisture state of the catchment and involve three parameters: the maximum soil moisture storage Cmax, a parameter in the nonlinear function relating runoff generation to the soil moisture state, termed the nonlinearity parameter Beta (β). Figure 1 shows the systematic representation of the HYMOD. For more details about the model see Wagener and Wheater 2006; Bárdossy and Singh, 2011. Parameter range used for the simulation of the HYMOD model is given in Table 1

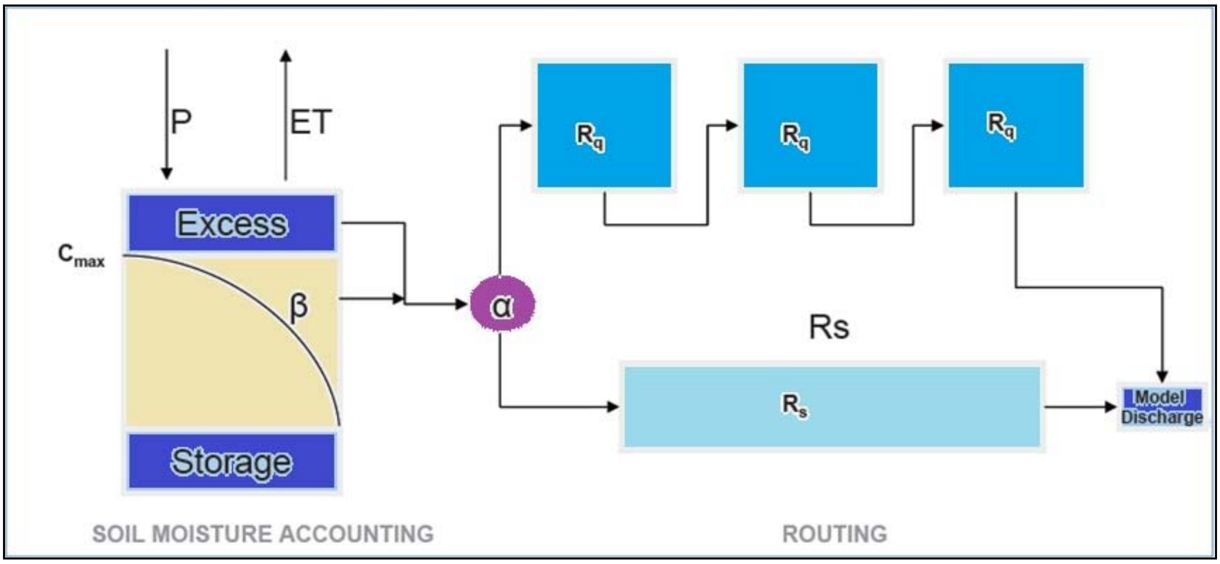

Figure 1 Representation of Conceptual Hydrological Model: HYMOD

Table 1: Model Parameters range for the HYMOD

Parameter	Description	Max	Min
Cmax	Maximum soil moisture storage	600	150
Beta	Degree of spatial variability of the soil moisture capacity	8	3
DD	Degree - day factor	3	1
Dew	Precipitation/ degree-day relation	2	0
Th	Threshold Temperature for snow melt initiation	1.500	-1.000
Alpha	Flow distributing factor	0.8	0.2
R_S	Residence times of the slow reservoir	0.200	0.010
Rq	Residence times of the quick reservoirs	0.7	0.3

Sensitivity of the HYMOD Model Parameters

Low values for Cmax result in higher modeled peak runoff values compared to high values for Cmax. A high value for B implies a relatively large amount of low storage capacities, while a low value for B means the catchment consists of a relatively large amount of high storage capacities. Runoff routing is represented by three identical quick and a single for the slow reservoirs. The partitioning over the quick and slow reservoirs of the water that exceeds the water storage capacity depends on the value for Alpha. The higher the value for Alpha, the steeper the resulting curve. Excess rainfall enters the upper zone quick reservoir and leaves this reservoir through three identical path based on residence times of the quick reservoirs (Rq). Flow on lower zone slow reservoir is based on residence times of the slow reservoir (Rs).

HBV Rainfall- Runoff Model

On the other hand the HBV model [Bergström, 1992] is a conceptual rainfall–runoff model which simulates daily discharge using as input variables daily rainfall, temperature and daily or monthly estimates of ETo.The HBV model consists of different routines representing the snow accumulation and snowmelt by a degree–day method, recharge and actual evapo-transpiration as functions of the actual water storage in a soil box, runoff generation by two linear reservoirs with three possible outlets (i.e., runoff components), and channel routing by a simple triangular weighting function. Parameter range used for the simulation of the HBV model is given in Table 2

Table.2: Model Parameters range for the HBV

Parameter	Description	Max	Min
DD	Degree - day factor	5	0.5
Dew	Precipitation/ degree-day relation	2	0
T_{crit}	Threshold Temperature for snow melt initiation	2	-2
β	Model parameter (shape coefficient)	6	1
L	Threshold water level for near surface flow	30	1
k_0	Near surface flow storage constant	20	0.5
k_1	Interflow storage constant	50	5
K_{perc}	Percolation storage constant	100	20
k_2	Baseflow storage constant	1000	10

Sensitivity of the HBV Model Parameters

Individual sensitivity of the HBV model parameters will be discussed in this section. Increase of near surface flow storage constant (K_0) only increase the peaks in the wet season, but has no influence on the water balance. Increase of K_1 also increase the peaks but reduce the storage which contributes to dry season discharge. Increase of Permanent wilting point (PWP) means the soil need more water to sustain the plants and more water will be kept in the soil and less water will be evaporated, in turn the overall discharge is increased. But it has no influence on the dynamics of the discharge. In general, increase of PWP decrease the actual evapotranspiration which in turn increase the discharge. Since L1 determines, when surface runoff occurs, it reflects the storage capacity of the reservoir system. It should be scaled according to the ratio of the different temporal resolutions. If the temporal resolution of HBV calculation is refined from daily to hourly, then water level for near surface flow L1 in HBV reservoir model should be reduced approximately by a factor of 24. On the other hand DD or Cmelt reflects how much snow will be melted if the actual temperature is 1^0C degree lower than Tcrit. It has not much to do with the temporal resolution of the model, it take the time for the snow to melt even if the actual temperature is below Tcrit, after a critical time the snow starts to melt. Increase of Tcrit has impact in snow accumulation-peak discharge decrease, but during snow melt peak discharge increases. Increase of K_0 and K_1 will increase the peaks in wet seasons but decrease the discharge in dry seasons. Increase of base flow storage constant K_2 almost has no influence in peak discharge, but discharge in dry periods decreased slightly.

RESULTS AND DISCUSSION

We applied the ROPE algorithm in parameters estimation of HYMOD and HBV. In figure 2(a) to 2(c) change of the different parameter of HYMOD and in figure 3 (a) to 3(b) change of the model efficiencies and model parameters are illustrated. In step 1 we generate 100000 parameter sets within the range given in Table 1& 2.

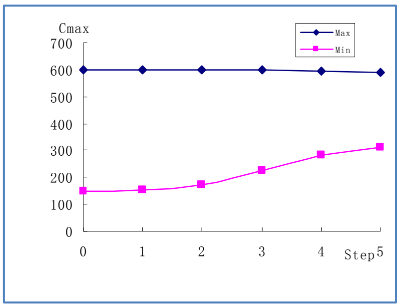

Figure 2(a)

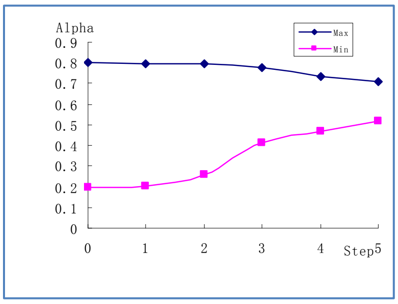

Figure 2(b)

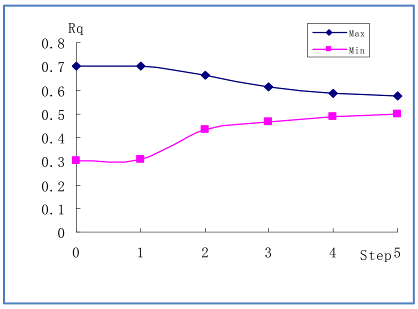

Figure 2(c)

Figure 2(a), 2(b) 2(c) : Conceptualization of Hydrological Model Parameters: HYMOD

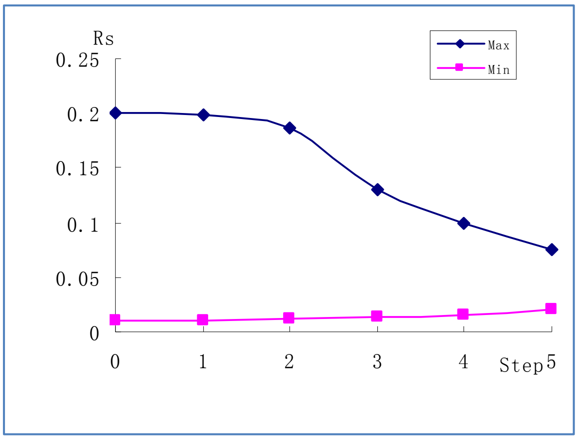

Figure 3(a)

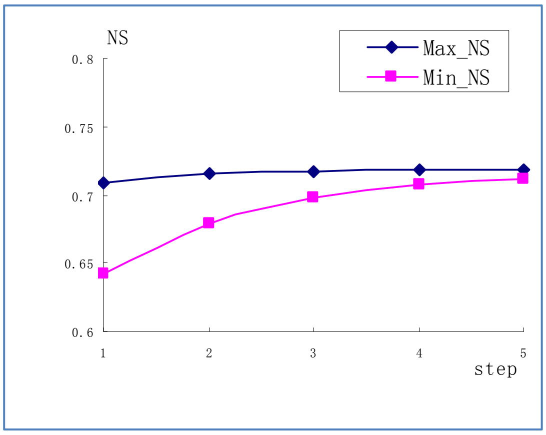

Figure 3(b)

Figure 3(a) Conceptualization of Hydrological Model Parameter and 3(b) Model Performance

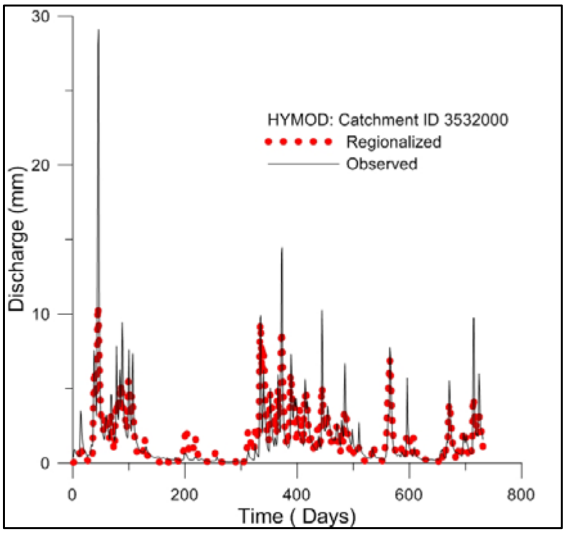

Figure 4 (a)

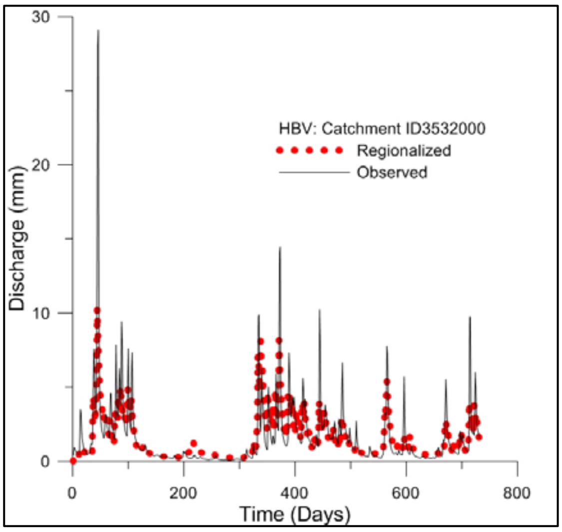

Figure 4 (b)

Figure 4. (a) HYMOD Model Performance with observerd data; (b) HBV Model Performance with observerd data

After that we select 1000 good parameter set through HYMOD with the optimization of the objective function. Then we generate 5000 deepest parameter using Data Depth. The process continues until difference between the maximum and minimum of the objective function close to zero. Figure 4(a) and 4(b) shows the hydrograph comparing regionalized and observed data using HYMOD and HBV model. Both the model shows perfect correlation in predicting ungauged basins. Considering model efficiency HYMOD shows significantly improved performance than HBV.With this observation shown in figure 4(a) and 4 (b), we applied the concepts in 84 different catchments of Eastern USA. Observed and Regionalized data shows significant resemblance. This idea could be applied in predicting ungauged basins.

CONCLUSION

Parameters of hydrological models cannot be recognized as unique sets of values. The reason behind tthe fact that changes of one parameter can be compensated by changes of one or more others due to their interdependence. The non-linearity of the models results in interpolation between parameter values possibly leading to unreasonable results. The presented approach is a kind of trial and error procedure. For some catchments it delivers good results, while for others, no parameter vectors can be found. In order to have a general methodology based on these ideas, further research on the dependence of parameters and catchment properties is required. Comparing two conceptual model, HYMOD is best for small size basins (1 to 200 km^2) and used for all arid ,semi arid region. On the other hand HBV is more flexible-Small to large basins (1 to 400000 km^2) and excellent for snow-influence climates.

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IMPACT OF BRICK KILNS IN BANGLADESH: A CRITICAL ASSESSMENT IN ACHIEVING SUSTAINABILITY

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ABSTRACT
Brick is one of the major construction materials that have been widely used all over Bangladesh. Bangladesh is witnessing a rapid boom in construction sector and the increasing demand for bricks have resulted into unplanned and uncontrolled number of brick kilns all over the country. There are around 5,000 registered brick kilns in the country with the total annual production of 12 billion. The industry is growing with more than 5% annually. It is estimated 25 to 26 % of the country's wood production are used for burning bricks every year, causing deforestation. The study focuses on the adverse environmental impacts of brick production, as well as associated health and safety impacts. An Environmental Impact Assessment (EIA) was undertaken for assessing physical, environmental, human use and socio-economic parameters of the surrounding environment of the area**.** It has been observed that total Environmental Impact Value (EIV) of +84 for without any brick kiln industry and -127 for after the brick kiln industry was established. The overall EIA report also shows positive impacts upon all environmental sectors before any brick kiln was established.

Keywords: Brick Kilns, Environmental Impact assessment, Environmental Impact Value

INTRODUCTION

In developing countries, urban clusters of manufacturers which are “informal”—small scale, unlicensed and virtually unregulated—can have severe environmental impacts (Bartone and Benavides 1997). There are nearly 5,000 brick kilns operating in Bangladesh and contributing about 1 % to the country’s gross domestic product (GDP) and generating employment for about 1 million people (BUET 2007). In aggregate starved Bangladesh, fired clay bricks form a significant portion of the materials used in the construction industry, which has been growing at about 5.6 percent annually between 1995 and 2005 (World Bank 2011). In Bangladesh despite the importance of the brick sector, about 90 % of brick kilns use outdated technologies. New technologies, such as the Vertical Shaft Brick Kiln (VSBK) and the Hybrid Hoffmann Kiln (HHK), are substantially cleaner than the Fixed Chimney Kiln (FCK) that is currently used. These improved technologies consume less energy and emit lower levels of pollutants and greenhouse gases (GHGs) (BUET 2007; Heirli and Maithel 2008) but they are not always cost effective. The brick making industry (BMI) in Bangladesh is best described as a “footloose” industry (World Bank 2010). Production is seasonal, close to the five to six bone dry months of the year only; technology is outdated; labor productivity is low; capitalization non-existent, mostly operating on equity capital; and management is informal. Small and medium enterprises (SMEs) dominate the ownership pattern with little or no cooperative or large-scale operations. Most brickfields are on leased land with no permanent sites and fixtures. Considering the increasing demand and the prospect for higher profits from brick kilns, it is clear that there is a scope for developing more sustainable practices of producing bricks in Bangladesh. Brick making is a significant activity in Bangladesh, albeit not formally recognized as an industry (Ministry of Industries, 2010). So, it is important to assess the pollution level for the protection of environment and natural resources that requires sustainable interventions in the brick kiln industries. Therefore, this study focused on the environmental impact assessment in the surroundings of Gazipur area (Figure 1) on the basis of relevant environmental parameters and made an EIA report based on it.

So, the overall objectives of this study were:

1) To describe present scenario of the existing surrounding environment of brick kilns.
2) To identify the source of environmental degradation and other environmental concern related to brick kilns.
3) To determine the extent to which brick kilns could be designed and recommend ways in which emission free environment could realistically be achieved.
4) To suggest an abatement plan to comply with Environmental Conservation Rules (ECR), 1997 of Bangladesh.

Figure 1 the location map of the study area (Source: Google Map)

STUDY METHODOLOGY

The study was conducted by a series of tasks which includes field survey, analysis and prepartion of an EIA report. We visited Joydevpur area as part of our field survey which is also close to the Dhaka-Mymensingh highway. Hundreds of brickfields were seen in some 10-square-kilometre area on a recent visit to Joydevpur area. On-site assessments and interviews were conducted with relevant personnel including workers, managers, and other stakeholders. We also interviewed 50 people in Joydevpur area. The data obtained through the field survey was analysed as input for EIA. The relative importance among various environmental parametes was conducted by pairwise comparison. The pairwise comparison method is applied to reduce individual judgment errors by requiring multiple pairwise comparisons of relative values. Almost 50 professionals including chemists, biologists, civil engineers, environmental engineers, agricultural scientists, social scientists and urban planners were asked to give weightage using the pairwise comparison. An Environmental Impact Value (EIV) was calculated based on the weightage and maginitude of the concerened parameter and an EIA report was prepared. A number of mitigation measures were proposed to save the surrounding environment from further degradation based on the outcome of possible impacts resulting from EIA.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Environmental Impact Assessment (EIA) is the assessment of the beneficial and adverse changes in environmental resources or values resulting from an industry or any development project. The EIA process of an industry essentially comprises of three sequential elements:

i. Identification of all potential positive and negative impacts on the natural and human environment resulting from an industry.

ii. Evaluation or assessment which includes quantification of the identified impacts with respect to a common base and with respect to impacts from other industrial actions.

iii. Preparation of a mitigation plan which upon implementation, will reduce or offset the potentially significant negative impacts to acceptable levels. This reduction may result from implementation of an industry production process alternatives or modifications or environmental protection measures. The plan simply reduces the number or magnitude of adverse impacts.

Methodology for EIA:

Considering the situation prevailing in the country, a simple methodology was taken for Environmental Impact Assessment of brick kiln industry. The methodology used for EIA due to 'Brick Kilns industry' is Environmental Evaluation System (EES). Relative importance of the parameters is selected based on 'LGED guideline, 1992'. The environmental parameters are grouped into four categories which are: Physical resources, Ecological resources, Human use values and Quality of life values. The environmental impact was assessed by Environmental Impact Values (EIVs) which may be defined mathematically as equation (1):

$$EIV = \sum_{i=1}^{n} Vi \qquad (1)$$

Where V_i is the relative change in the value of environmental quality of parameter i with respect to existing situation. W_i is the relative importance or weight of parameter i, and n is the total number of environmental parameter related to the project. The computation of EIV of brick kilns industry needs determination of V_i, the value representing the magnitude of alteration of the environmental parameters, and W_i, the value representing relative weight or importance of the respective parameters. EIV has been calculated for two cases: (i) before any brick kiln was established as shown in Table 1 and (ii) after brick kiln was established as shown in Table 2.

Table1: EIA undertaken before any brick kiln was established.

Environmental Parameters	**Relative importance value**	**Degree of impact**	**Relative impact**		**EIV**
			POSITIVE	**NEGETIVE**	
Physical resources					**+52**
Water Quantity	8	+1	+8		
Water Quality	10	+2	+20		
Soil Erosion	6	+1	+6		
Flooding	10	0	0		
Wind Effect	10	+1	+10		
Drought	8	+1	+8		
Ecological Resources					**+13**
Fisheries	6	+1	+6		
Wildlife	7	+1	+7		
Human use value					**+19**
Agriculture	4	+1	+4		
Cutting & Burning of trees	4	+1	+4		
Excavations	4	+1	+4		
Drainage Capacity	7	+1	+7		

Quality of life values					**0**
Health Effect Employment	8 8	+1 0	+8	 0	
Total Environmental Impact Value (EIV)					**+78**

***Magnitude of Environmental parameters*:**

The beneficial and adverse changes in environmental parameters resulting from brick kiln, usually expressed in qualitative terms are plotted in a scale to quantify the environmental alterations in Table 1 and Table 2 . Since the changes of environmental parameters are measured with respect to background conditions, no change has 0 values. The adverse changes have been given values -1, -2 to represent low and high impacts respectively. Similarly +1and +2 represent low and high positive impacts respectively. A value from the scale representing effect of the project on each parameter was taken to compute the EIV of the brick kiln industry.

Table 2: EIA undertaken after the brick kiln was established

Environmental Parameters	**Relative importance value**	**Degree of impact**	**Relative impact**		**EIV**
			POSITIVE	**NEGETIVE**	
Physical resources					**-70**
Water Quantity Water Quality Soil Erosion Flooding Wind Effect Drought	8 10 6 10 10 8	-1 -1 -1 -1 -2 -2		-8 -10 -6 -10 -20 -16	
Ecological Resources					**-26**
Fisheries Wildlife	6 7	-2 -2		-12 -14	
Human use value					**-31**
Agriculture Cutting & Burning of trees Excavations Drainage Capacity	4 4 4 7	-2 -2 -2 -1		-8 -8 -8 -7	
Quality of life values					**0**
Health Effect Employment	8 8	-2 +2	 +16	-16	
Total Environmental Impact Value (EIV)					**-127**

Relative Importance of Environmental Parameters:

The importance of a parameter varies from country to country depending on the environmental concerns of the country. All environmental parameters influenced by the brick kiln industry are not of equal importance or weight. EES methodology is based on the assignment of an importance unit to each parameter by judgment of professional experts consists of chemists, biologists, civil engineers, environmental engineers, agricultural scientists, social scientists and urban planners. The judgments complete the pair wise comparisons that are needed at this stage, and are entered in a pair wise comparison matrix. The data in the matrix can be used to generate a good estimate of the criteria weights (Nydick et al. 1992). The weights provide a measure of the relative importance of each criterion .This values representing importance or weight of the parameters. They are used to compute the relative impacts of the parameters which are then summed up to obtain the total EIV of brick kiln industry.

RESULT AND DISCUSSION

At first the values indicating magnitude of environmental changes influenced by the brick kiln were placed in the appropriate columns in Table 1 and Table 2 then multiplied them to obtain positive and negative impact of the parameters. Finally all these impacts were summed up to obtain the total EIV of +84 for without any brick kiln industry and -127 for after the brick kiln industry was established. The overall EIA report also shows positive impacts upon all environmental sectors before any brick kiln was established. EIA of brick kiln undertaken after the project completed shows the negative EIV value. Despite some human interest related factors as positive impacts on physico-ecological environment made the total EIV is negative. Based on the interviews it was found that the physical parameters gave the highest negative value of -70. Employment opportunities earned positive degree of impact because people living there are very poor and are eager to earn rather than remaining unemployed even under adverse working condition.

MITIGATION AND MEASURE FOR SUSTAINABLE DEVELOPMENT

Industrial pollution is a major issue in the major industrial cities of Bangladesh (especially Dhaka and Chittagong). Despite of its adverse effects; its contribution to the GDP (Gross Domestic Product) in a poor country like Bangladesh is not negligible. Most of the Brick kilns industries accommodate in cluster and there is an association of those other industries regarding the combined environmental contribution. Rather a sustainable approach should be taken to minimize the adverse effects of Brick kilns. Following steps may be taken for sustainable practice of brick kilns industry in Gazipur area.

1. Use alternative fuel such as organic wastes (rice husks or sugar biogases) can supplement scarce fuel sources without sacrificing efficiency.
2. Raise kiln temperature using improved firing techniques. Adding combustible material around the bricks or between clamps can increase temperatures and lower traditional fuel needs.
3. Install filters in chimneys.
4. For the unprocessed emission of the smoke and gases there should be proper exhaust system.
5. Prepare a safety and health plan to minimize adverse respiratory effects and physical stress on kiln workers.
6. Tree planting also helps to prevent soil erosion, reduce siltation of water bodies and maintain soil fertility.
7. Improve input quality. Bricks that crack during firing may have too much organic material in them or too much topsoil mixed in with clay. Train workers in identification of clay, and monitor quality regularly.
8. Provide workers with face masks and instruct them to use masks in high-dust operations.
9. If possible, use water-based acrylic glazes to minimize adverse environmental impacts.
10. Consolidate or remove brick waste once production ends. This waste may be scattered over a large area and impede future farming.

CONCLUSION

Bangladesh's brick sector is characterized by outdated technologies with low energy efficiency and high emissions, low mechanization rate, dominance of small-scale brick industries with limited financial capacity, and dominance of single raw material (clay) and product (solid clay brick). Adopting gas-based cleaner technologies is hampered by serious energy shortage and land scarcity. The current status is by no means sustainable. Bangladesh has every reason to upgrade its brick sector in order to save valuable natural resources, reduce air pollution, and increase energy efficiency. The government has already established regulations that ban the use of fuel wood and FCKs and has reconsidered the location and height of brick kiln chimneys. Introduce regulations and policies that encourage adoption of cleaner technologies, such as: (a) revise emissions standards for brick kilns under ECR97 to make them technology independent and to encourage brick diversification (e.g., perforated or hollow bricks for partition walls); (b) establish proper emission monitoring for brick kilns; (c) impose an emission levy based on "polluter-pay principle"; (d) design rules and standards for the entire brick value chain: from raw materials to production processes and equipment and final products to building designs and construction processes. Improve working conditions by introducing higher levels of mechanization, social programs to reduce child labor, occupational safety and health measures in kilns. Create brick kilns as a formal industry. This would enable easier access to financial resources and will help to build the structure of the industry. The need now is to implement this policy and demonstrate the use of environment friendly technology.

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ASSESSMENT OF ELECTRONIC WASTE (E-WASTE) IN BANGLADESH

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ABSTRACT

A trend today is the growing dependence on information technology. Consumption and the fast rate of technological change have led to the rapid obsolescence rate of electronic gadgets generating electronic waste (e-waste) in the process. Waste management is one of the key concerns in Bangladesh, a developing country of Asia. Like other countries use of electronic equipments in Bangladesh is increasing day by day and in some cases the rate is comparatively higher. This paper is an attempt to identify the source of e-waste and its flow pattern to the recycling industries in Bangladesh. It has also presented the estimated rate of e-waste generation in urban area and prediction of e-waste load in future throughout the country. E-waste generation rate in urban area have been found 0.32 kg per capita per year from field and questionnaire survey. On the other hand life cycle data analysis of electrical appliances has given two separate values for the whole country. Applicability and significance of these three scenarios have been compared finally.

Keywords: E-waste, Waste generation, Estimation, Life cycle.

INTRODUCTION

Most of the electronic products contain different types of elements, including valuable components (gold, silver, platinum, etc) as well as hazardous materials (cadmium, mercury, lead, brominated flame-retardants, etc). These materials are complex and difficult to recycle in an environmentally sound manner even in developed countries. The highly toxic chemicals found in the different components of electronic products can contaminate soil, groundwater and air, as well as affect the workers of the unit and the community living around it which is found in China, India, Pakistan and other developing countries.

Hence there is a clear reason to be concerned if the present rate of e-waste generation is high. An assessment of e-waste is very important as only then can interventions be suggested to check the polluting systems of recycling and give viable options for better management of e- waste. The aim of this study is to reveal the present practice of reprocessing of e-waste components and estimation of e-waste generation in urban areas also throughout Bangladesh. In this study the recycling flow pattern and production rate of e-waste have been assessed from field and questionnaire survey in urban Dhaka city. While, the scenario of e-waste generation rate and its future load throughout the country have been estimated by life cycle data analysis.

STATES OF E-WASTE

There are some records of per capita, per day or total generation of municipal waste of different categories from different urban areas in Bangladesh. Physical composition of waste in residential and commercial areas as well as high-income and low-income areas is also available. But there are very negligible numbers or may be none of documents of e-waste generation and the percentage of this waste in total municipal waste. Moreover e-waste term is almost new here. For this, some field and questionnaire survey have been performed to get the real picture of e-waste generation and its movement path to recyclers.

Survey area

Selection of a suitable area is the first task to get the representative information of e-waste. So a reconnaissance survey was performed in Dhaka and Naraynganj. From the survey results, some specific areas were selected where e-waste related works are going on. The areas listed in Table 1 were selected depending on the types of information collected, which are also shown in Fig 1.

Table 1- Selected areas for the collection of e-waste related information.

Area	Related information
Khilgaon, Goran, 28 No. Ward of Dhaka city corporation, Meradia, Mugdapara	Source, accumulation place, price and amount of e-waste
Islambag	Plastic, printed circuit board (PCB) and cable cover (PVC)
Mridhabari, Matuail	Glass
Dholai khal, Waseghat	Battery
Bacharam dauri, Armanitola	Copper wire
Dholai khal	Secondary market

Questionnaire survey

For the information of the source of e-waste questionnaire survey was done in residential areas of Khilgaon, Goran, 28 No. Ward of Dhaka City Corporation, Meradia and Mugdapara. These places were selected because the density of electronic repairing shop, e-waste accumulation shops whose local name is vangari shop is comparatively higher here. It is required to mention that the dealers of secondary scrap shops collect e-waste from vangari shop where equipments are broken, separated and stored in separate bags of glass, plastic, cable, PCB, metal etc. for sale.

Local plastic industries have been developed in Islambag. In Matuail and Bacharam dauri, Armanitola many traders involved with the collection and supply of glass and metal waste respectively. A secondary market of electronic products has been developed in Dholaikhal and in Dholaikhal, Waseghat many businessmen collect old battery, extract lead and sell them. Thus the areas specified in table 1 were selected. From the field and questionnaire survey in the selected areas, a flow pattern of e-waste in Dhaka city was drawn (Fig 2).

E-waste generation

In this study maximum information was found from 28 No. Ward of Dhaka City Corporation and was selected for determination of e-waste generation. There were approximate 140 electrical and electronic repairing shops. The land area of this ward is 9.63 sq. km and approximate population was 0.2 million in 2008.

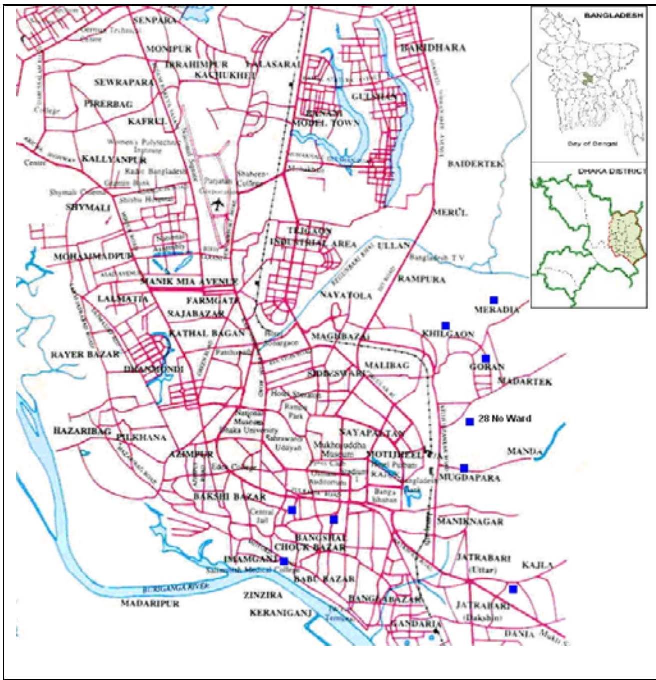

Fig. 1: Surveyed areas in Dhaka (Blue marked)

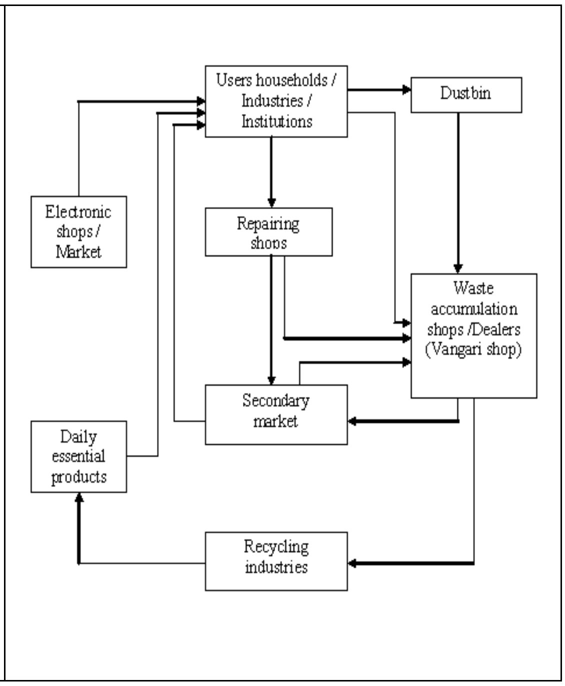

Fig. 2: Flow pattern of e-waste in Dhaka city

Table 2- Approximate quantity of different electronic waste sold from electrical and electronic repairing shops in residential areas.

Type	Quantity (Kg)	Type	Quantity (Kg)
Plastic frame or plastic materials	15-25 (Per 3-4 months)	Mobile phone	5-10 (Per 1-2 years)
Iron, steel, silver	20-30 (Per 3-4 months)	Whole body (steel or plastic)	3-5 piece (Per year per shop)
Copper material & Cupper wire	5-7 (Per 3-4 months)	Circuit board/parts	10-20 (Per 3-4 months per shop)
Glass material	10-20 (Per 3-4 months)		

Table 3: E-waste generation in 28 No. Ward of Dhaka City Corporation

28 NO. WARD OF DHAKA CITY CORPORATION	
Population	0.2 million
Land area	9.63 sq. km
Number of electrical and electronic repairing shop	140
Selling amount of e-waste from each shop	23 kg per month (approximate)
Percentage of e-waste generation in repairing shops of the total generation	60% (considered)
Per capita e-waste generation	0.32 kg per year (S1)

Electrical and electronic repairing shop is one of the main sources of e-waste generated by local people. Approximate quantity of different components of e-waste from these shops has been listed in Table 2. 28 No. Ward of Dhaka City Corporation is a residential area. Here most of the people enjoy the facilities of urban area and e-waste generation is higher comparative to the whole Bangladesh. So, the value 0.32 kg (table 3) is quite higher than the representative value of e-waste generation by the people of Bangladesh, which has calculated taking only one source without considering some important factors like level of income, accessibility of electricity etc. But it can be considered as the representative value of per capita e-waste generation per year in urban areas of Bangladesh.

PREDICTION OF E-WASTE IN BANGLADESH

There are a lot of literatures and study about the arising problem of e-wastes, the hazardous components that they contain directives and policies on how to minimize this problem but there are only few which discuss on the estimation of how much e-waste are we going to generate in the near future. Waste statistics is a very complex process, since appliances have different end of life and the complex pathways of the waste stream. The estimation on the accumulated waste of electronic products in Bangladesh is a very complex task. Appliance generation refers to the number of estimated units present in a household and businesses. These estimates are derived from product sales personal consumption expenditures, data from the Family Income and Expenditure

Estimation process

The estimation for the amount of wastes is based on the following concept:

a. End-of-life
b. LCDA (Life Cycle Data Analysis)

End-of-life

The different reasons for a product reaching its end-of-life are (Manalac, 2004):

a. Technical obsolescence - the product itself is worn out and no longer function properly
b. Economic obsolescence -new products in the market are more economic in terms of cost; they have a lower cost of ownership
c. Feature obsolescence - new products have come onto the market that offers more or better features
d. Ecological obsolescence - new products have less harmful impact on the environment
e. Aesthetic obsolescence - new products in the market have a nicer look or more fashionable design from the point of view of the consumer
f. Psychological obsolescence - a new product has greater emotional value or the present product has a negative emotional value.

LCDA (Life Cycle Data Analysis)

According to Manalac (2004), Matthew Simon, Graham Bee, Philip Moore, Jun-Sheng Pu and Changwen Xie of the School of Engineering at the Sheffield University and De Montfort University in UK suggested the Life Cycle Data Acquisition (LCDA) technology in the estimation on the end-of-life before disposal of electrical appliances. The principle is to add a system, which records data about use to a product. They studied the disposal rate of new appliance. Expressed mathematically if p_j is the probability of disposal in j^{th} year after sale such that $\Sigma_j(p_j) = 1.0$ and S_i are the sales for year i, then the total arising N of end-of-life of appliances in any year j is given by $N_j = \Sigma_i S_i p_{(j-i+1)}$

Assumptions made in the estimation of e-waste

a. The calculation will focus on the following e-wastes: refrigerator, radio/stereo player and television.
b. The disposal rate of the three e-wastes will be the same.
c. The baseline data or the appliances presently owned and the appliance data from sales will have the same disposal rate.
d. The factor f or the fraction of the household owning a particular appliance that was used in India are also applicable for Bangladesh.

Mathematical analysis

$N_j = \Sigma_i (S)_i p(_{j-i+1}) + B(p_j)$

$B = \Sigma\ (He_i * f_i)$, i (income decile) = 1,2,3,4,5…….10

N_j = total e-wastes at a certain time t

B = total e-waste at time t=0 or the baseline data which represents the appliances which are presently owned regardless of their date of purchase
S = number of sales
p = probability or disposal rate
He = household in a decile with access to electricity
f = fraction of the household owning a particular appliance
Total population in year 2000=13 crore (estimated)
Household with electricity= 31.2% in year 2000 (BBS, 2006).
Households 25.3 million in year 2000, (BBS, 2006).
Consumption expenditure = 4,537 Tk per person per month, (Ahmed, 2004).
Expenditure for household electronic products = 4% of per capita income (estimated)
No of person in each household = 5 (BBS, 2006).

Table 4 - Presence of e-wastes in Bangladesh per National Deciles, 2000

Deciles	DHE	He	f	Refrigerator	f	Radio	f	TV	TOTAL
1	3.58	282590	0.31	87603	0.91	257158	0.46	129992	474753
2	4.75	374946	0.47	176225	0.95	356199	0.53	198721	731145
3	5.54	437305	0.48	209907	0.97	424186	0.56	244891	878984
4	6.37	502822	0.56	281580	0.94	472653	0.62	311750	1065983
5	7.25	572286	0.67	383432	0.97	555117	0.66	377709	1316258
6	8.24	650432	0.62	403268	0.98	637424	0.68	442294	1482986
7	9.61	758575	0.72	546174	0.95	720646	0.81	614446	1881266
8	11.52	909343	0.76	691100	0.99	900249	0.83	754754	2346103
9	14.89	1175357	0.83	975546	1	1175357	0.91	1069575	3220478
10	28.22	2227574	0.91	2027092	1	2227574	0.9	2004817	6259483
Total				5781927		7726563		6148949	19657439

Here, DHE means distribution of household expenditure (Ahmed, 2004)
He = Household in a decile with access to electricity
= Households * DHE * Household with electricity.
To perform the analysis some problems have been faced. There is no information of the quantity of refrigerator, television and radio sold in local market, which is necessary to determine the generation of e-waste from appliances sale. So, a questionnaire survey was performed at different places in Dhaka and Naraynganj to collect the information of some households owning those three particular appliances, which has listed in Table 5. To collect the information, households living at the center of the cities were avoided to get the values that would be acceptable comparing to the demographic condition of this country.

Table 5 - Number of refrigerator, television and radio/ Stereo player and their average price owned by the households in Dhaka and Naraynganj.

No. of households	Households owning					
	Refrigerator		Television		Radio/Stereo player	
	No.	Price (Tk)	No.	Price (Tk)	No.	Price (Tk)
24 in Dhaka	2	20,000	12	12,000	18	1,500
24 in Naraynganj	1	16,000	6	9,000	17	2,000

1 USD = 83 Tk

CONSIDERATIONS

From the number of appliances and their price listed in Table 5, the following considerations have been made to estimate the number of units of refrigerator, television and radio/ Stereo player that the households of Bangladesh want to purchase in one year. The values have chosen remaining in conservative side. Price of Refrigerator 18,000 Tk, Television 10,000 Tk, Radio 1,500 Tk and Total

29,500 Tk. In 24 households, 1 household wants Refrigerator, 8 households want TV and 15 households want Radio and cassette

If, all available money is used to purchase these three categories of products then:
Number of Refrigerator sold in market would be 120,056 units, TV 960,452 units and Radio/ Stereo player sold 1,800,847 unit. Thus the total number would be 2,881,355 units (equivalent)
Considering all these units sold in year 2000 (2000 is the base year), equivalent total units of three electronic products sold from year 2001 to 2005 have shown in Table 6. Here, the percentages of products sold on base level have been taken on the basis of Manalac (2004). Table 7 expresses Electronic waste generated from total appliance sales (2000-2005) and from household owing with the rate of disposal based on LCDA and Table 8 represents the expected e-waste per year from 2002-2005 appliances sale and household owning.

Table 6 - Total units of electronic products sold from year 2001 to 2005

Year	Percentage [(a)]	Unit
2001	42	1210169
2002	43	1238983
2003	43.5	1253389
2004	44	1267796
2005	44.5	1282203

[(a)]Percentage of products sold on base level

Table 7 - E-waste generated from total appliance sales (2000-2005) and from household owing with the rate of disposal based on LCDA

RATE	SALES	2001	2002	2003	2004	2005	2000Households	2000Sales
	YEAR	1210169	1238983	1253389	1267796	1282203		
0.01	1	12102	12390	12534	12678	12822	196574	28814
0.005	2	6051	6195	6267	6339	6411	98287	14407
0.005	3	6051	6195	6267	6339	6411	98287	14407
0.005	4	6051	6195	6267	6339	6411	98287	14407
0.005	5	6051	6195	6267	6339	6411	98287	14407
0.01	6	12102	12390	12534	12678	12822	196574	28814
0.03	7	36305	37169	37602	38034	38466	589723	86441
0.07	8	84712	86729	87737	88746	89754	1376021	201695
0.08	9	96814	99119	100271	101424	102576	1572595	230508
0.12	10	145220	148678	150407	152136	153864	2358893	345763
0.14	11	169424	173458	175474	177491	179508	2752041	403390
0.15	12	181525	185847	188008	190169	192330	2948616	432203
0.17	13	205729	210627	213076	215525	217975	3341765	489830
0.13	14	157322	161068	162941	164813	166686	2555467	374576
0.07	15	84712	86729	87737	88746	89754	1376021	201695

According to Table 8, the total equivalent number of appliances in year 2007 is 1,739,218 unit if scenario: 2 is considered and it is 20,049,891 unit if scenario: 3 is considered. In year 2007 estimated populations in Bangladesh is 150,448,340. If average weight of refrigerator, television and radio, these three kinds of electronic waste is 12 kg then per capita e-waste generation in year 2007 will be, S2 = 0.14 kg per capita per year (Considering scenario: 2) and S3 = 1.6 kg per capita per year (Considering scenario: 3). Scenario: 2 of Table 8 has been analyzed on the basis that the household owing at year 2000 will have the same rate of disposal as the new ones and scenario: 3 of Table 8 that all the households owing will have an end of life of 7 years. All the equipment's remain at year 2000 will be obsolete all at the same time of year 2007 is quite impractical. So, S2, which has followed scenario: 2 is more accurate. All the values of different cases has been shown in table 9.

Table 8 - Expected e-waste per year from 2002-2005 appliances sale and household owning

Scenario 2-Baseline same rate of disposal as new appliance			Scenario 3-Baseline End of life =7		
YEAR	UNIT	CUMULATIVE	YEAR	UNIT	CUMULATIVE
2001	225388	225388	2001	58067	58067
2002	124796	350184	2002	26509	84576
2003	131135	481319	2003	32848	117424
2004	137474	618793	2004	39187	156611
2005	143885	762678	2005	45598	202209
2006	263062	1025740	2006	66488	268697
2007	713478	1739218	2007	19781194	20049891
2008	1645428	3384646	2008	269407	20319298
2009	1950268	5334914	2009	377673	20696971
2010	2944890	8279804	2010	585997	21282968
2011	3538363	11818167	2011	786322	22069290
2012	3926404	15744571	2012	977788	23047078
2013	4528163	20272734	2013	1186398	24233476
2014	3751805	24024539	2014	1196338	25429814
2015	2465028	26489567	2015	1089007	26518821
2016	828533	27318100	2016	828533	27347354
2017	657525	27975625	2017	657525	28004879
2018	470525	28446150	2018	470525	28475404

Table 9 - Per capita e-waste generation per year following three processes

Scenario	E-waste generation (Kg per capita per year)
S1	0.32
S2	0.14
S3	1.6

S1 = Per capita e-waste generation per year obtained from field survey in 28 No. Ward of Dhaka City Corporation (Considered as urban e-waste generate rate)

S2 = Per capita e-waste generation per year obtained from scenario: 2 (Most applicable e-waste generate rate throughout the country)

S3 = Per capita e-waste generation per year obtained from scenario: 3

CONCLUSIONS

Electronic goods are becoming widespread in homes and ubiquitous throughout business organizations. Most of those electronic products contain different types of elements, including valuable components as well as hazardous materials. Flow pattern of e-waste in Bangladesh shows that the major recycling of e-waste is occurring here in non-government level. But growth of e-waste will be increased rapidly since consumption rate of different electronic products especially television, computer, refrigerator, radio, CD/DVD player and mobile phone are increasing day by day. There was very limited information of the amount of e-waste generated every year in our country earlier. The estimation and prediction of e-waste generation presented in this paper from survey and statistical analysis respectively is an attempt to indicate and help the policy makers to think about its future management before it will be a concern.

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ESTABLISHING PLANNED WATER SUPPLY NETWORK IN AN URBAN AREA OF BANGLADESH: A CASE STUDY

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ABSTRACT

This paper presents a state-of-the-art methodology for designing and establishing planned water supply networks in Muksudpur Paurashava under Gopalganj district in Bangladesh, which have no existing water supply system. The main objective of this study is to simulate three different arrangements of pipe networks (option-1: surface water source with treatment plant, option-2: groundwater source without treatment plant, option-3: groundwater source with treatment plant) for selecting the best one. Network simulation is carried out in the framework of ArcGIS using its analytical capability. The simulation indicates that for first and third option, a high lift pump (abstracting water from clear water reservoir) having capacity of 187.17 m^3hr^{-1} with a delivery head of 10 m is enough to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to selected design year 2040. However, only two production wells having 150 mm diameter, which considers a safe yield of 102 m^3hr^{-1}, are required in case of option-2 to satisfy daily water requirement of 4,492 m^3d^{-1}. The analysis in case of option-3 suggests that production wells should be located evenly within Paurashava area as well as closer to proposed treatment plant and minimum distance should be maintained between them. Since different simulations are performed for alternative combinations of surface water and groundwater sources with and without considering water treatment plant, the study emphasizes that special attention should be given for selecting suitable water source based on socio-economic aspects of locality, water quality, system cost-effectiveness and other environmental issues.

Keywords: ArcGIS, Muksudpur Paurashava, Water supply network, Water treatment plant

INTRODUCTION

Globally a large amount of budget is invested for providing and/or upgrading the piped water supply facilities. Even then, a vast population of the world remain without safe piped water facilities. Around 80 to 85 percent cost of a water supply project have been used in the distribution system (Swamee and Sharma, 2008). Therefore, design of water supply system has attracted many researchers because of its involvement with high cost. The main objective of designing a water distribution system is to size and configure it properly so that it can meet existing and future demands while providing pressures at desired level. In order to facilitate the process somewhat, geographic information systems (GIS) are increasingly being co-opted to assign water demand to network nodes based on user classifications such as residential, commercial, industrial, institutional, etc (Filion et al., 2007). In Bangladesh, urban population is increasing rapidly as a result of natural urban growth and migration from rural areas. The current urban population is about 38 million and will be reached to about 74 million by 2035 (BBS, 2005). Such growth of population in urban area will certainly impose huge burden on urban water supply facilities, which may cause a large number of people to be lived without access to safe water supply. The declining trend of available water supplies is one of the most important environmental concerns faced by the country at present. Department of Public Health Engineering (DPHE) in cooperation with City Corporation or Paurashava has installed distribution networks for water supply necessary to deliver water to the urban dwellers in major cities of Bangladesh (Karim and Mohsin, 2009). Therefore, the objective of the present study is to establish a planned water supply network in Muksudpur Paurashava of Muksudpur upazilla under Gopalganj district in Bangladesh (Figure 1) based on available demand and supply scenarios, which has no piped water supply system at present.

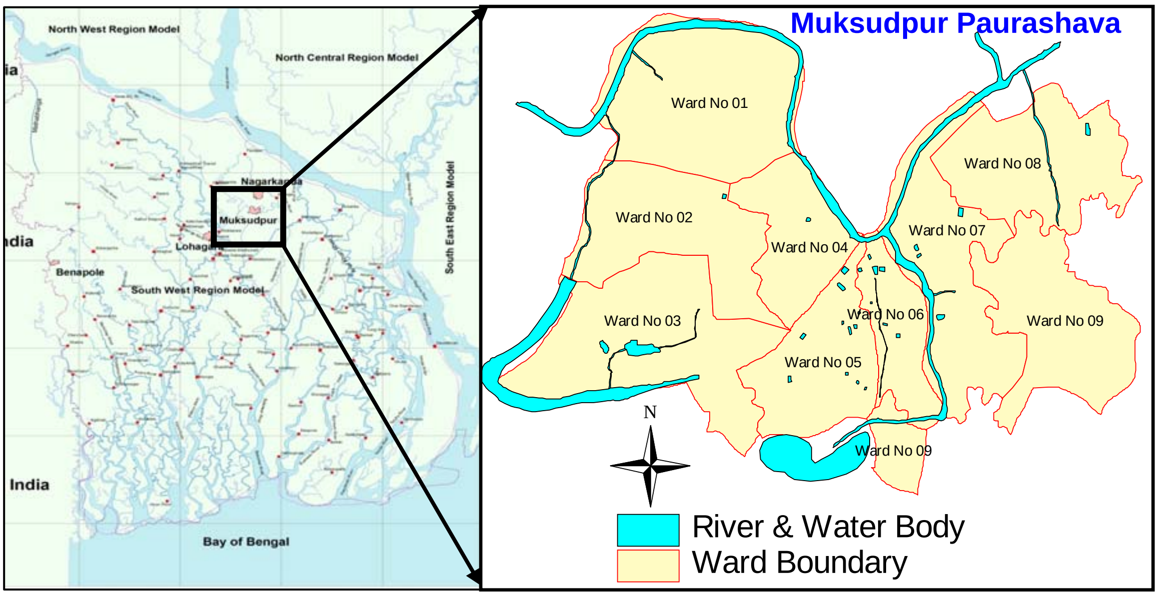

Figure 1: Location of Muksudpur Paurashava (study area) in Bangladesh

METHODOLOGY

Simulation of water distribution network requires input data from many sources. The necessary data and information includes population projection, land use plan, available water sources, and topographic information etc. Extensive surveys are carried out to collect these data from the field However, some data such as present water consumption and population cannot be measured directly and it is rarely known precisely. In that case, several well-recognized techniques are employed for estimating and quantifying the data and information. For example, geometric progression method is used to forecast the projected population based on available census data. Accurate assessment of domestic water consumption is not possible, where there is no piped water supply because the consumers meet their daily water requirement from both groundwater and surface water sources even sometimes from rainwater source. It is one of the most difficult parameters to determine while modeling the drinking water distribution networks (Alcocer-Yamanaka et al., 2012). Therefore, domestic water consumption has been proposed on the basis of the published literatures of previous projects or studies on water supply and water consumption analysis. However, different design criteria have been assumed on the basis of the adopted design criteria of previous DPHE projects, field surveys, and available literatures on water supply system. Water demand up to the end of design period (2040) has been estimated considering intended population coverage by piped water supply system, consumers per connection for different types of service connections, population served through each type of service connection, non-domestic demand including fire demand, water loss and backwash water (in case of water treatment plant). The step-by-step methodology followed to carry out this study is presented in Figure 2.

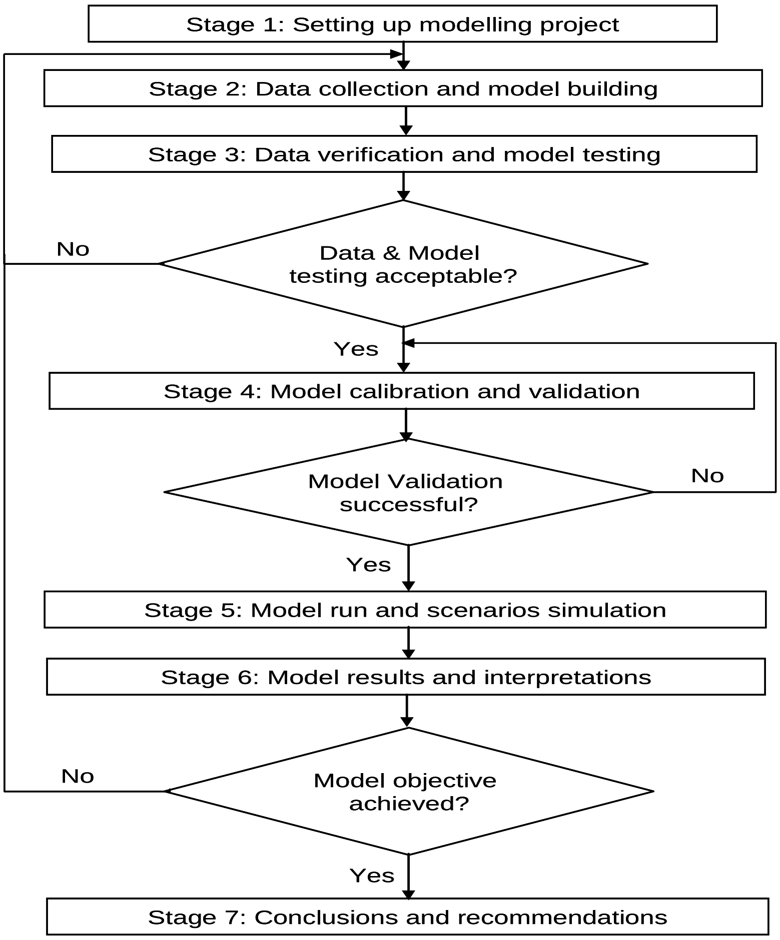

Figure 2: Methodological framework used for pipe network simulation

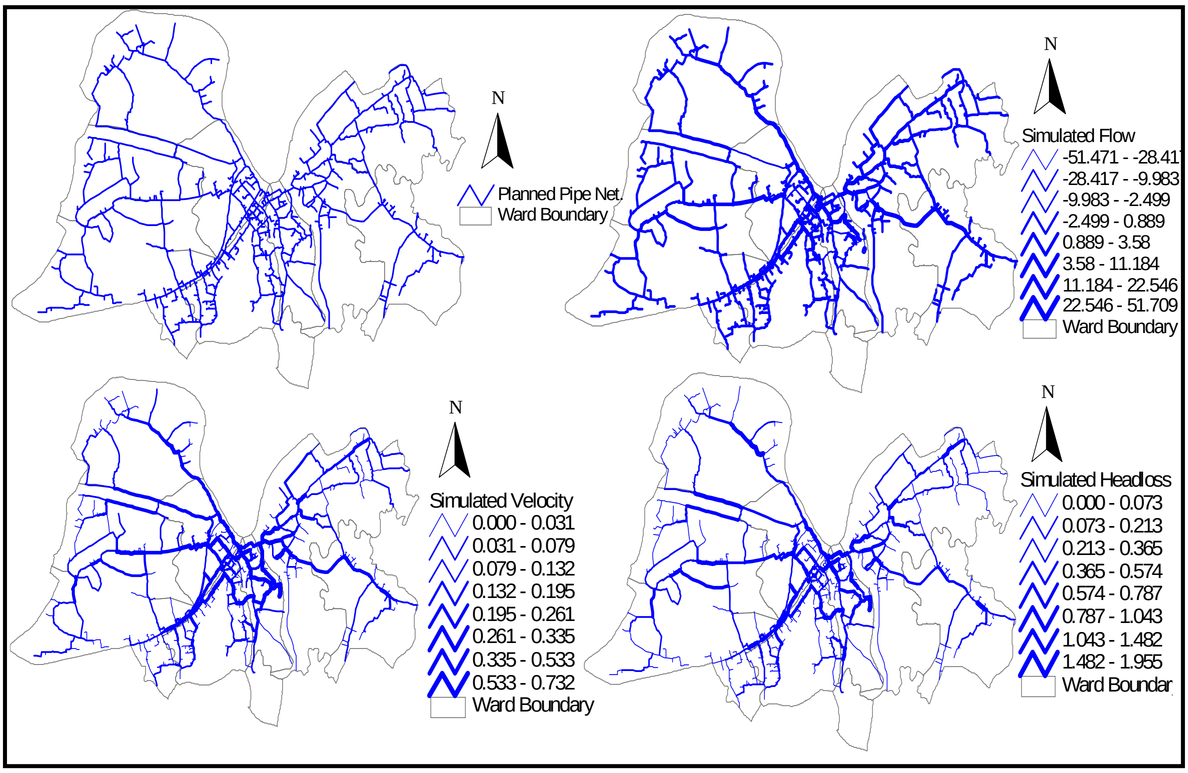

Figure 3: Simulated hydraulic parameters for proposed distribution network of Muksudpur Paurashava

For nodal demand assessment, the area under each node, population density, assessment of service connections of each type and flow through each type of connection is needed. Digitizing and linking of all these spatial and non-spatial data has been done by using the analytical ability of ArcGIS toolkit. Nodal demand calculation has been performed by a customized program developed in MS Excel spreadsheet. Three types of data such as pipe network, water demand, and operational data are necessary for assembling a water distribution model. The network model is assembled by applying two basic data entry procedures. At first, data is manually created by typing it into the model and then data has been transferred between various files by simply importing the data from one file to another, which also requires some additional manual editing techniques. The model is then calibrated and calibration process involves adjustments of different parameters such as roughness coefficient of pipe, spatial distribution of nodal demand, altering pump operating characteristics, pipe diameter and some other model attributes until the model results reasonably satisfies the study objectives. After that, the model is validated using extra sets of additional data under different operational conditions. In performing validation, system demands, initial conditions and operational regimes need to be adjusted to match the conditions at the time the additional field data set was collected. The different hydraulic properties of simulated networks for planned water supply scheme are presented in Figure 3.

RESULTS AND DISCUSSIONS

Scenario-based Arrangement of Network Model

Kumar River and Kamlapur Khal are flowing through Muksudpur Paurashava and the water is suitable as surface water (SW) source for drinking water supply to the Paurashava. The test results indicate that groundwater (GW) is also feasible for the Paurashava. As both surface and groundwater sources are available, three alternative models of water distribution pipe network for Muksudpur Paurashava have been built.

- Option-1: model is built for SW source with water treatment plant,
- Option-2: model is developed for GW source without water treatment plant and
- Option-3: model is constructed by considering GW source with water treatment plant.

For both SW and GW source with water treatment plant (WTP), one high lift pump (abstracting water from clear water reservoir) of capacity 187.17 m^3hr^{-1} at one bar (10 m) delivery head is enough to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to design year 2040. For GW source, the pipe network models have been built on the basis of the secondary data and the past experience in the field. Safe yield from one 150 mm diameter production well is 102 m^3hr^{-1} has been assumed, and the location of these well are evenly distributed within the Muksudpur Paurashava area. On the basis of the above assumption, total two production wells are required to meet the daily water demand of 4,492 m^3d^{-1} at the end of design period 2040. Based on the simulation, it is also estimated that a pump of 102 m^3hr^{-1} at one bar (10 m) delivery head, is sufficient to maintain minimum residual pressure of 5 m water column at any point of the distribution system up to the design year of 2040.

Scenario-1: Surface Water Supply Model

In case of SW source for water supply, treatment of raw water is a must. Pipe network model for SW source starts from the clear water storage reservoir located on the ground of the SW treatment plant. High lift pumping station will be required to add required quantity of treated water with certain discharge head to achieve the targeted minimum residual pressure (5 m water column) at any point of the distribution pipe network. Output of the model is presented in the form of junction data, pipe data and high lift pump data. High lift pump situated on the ground surface just after the clear water storage tank of the WTP abstracting required quantity of treated water from the clear water storage tank will add into the distribution system with certain discharge head to maintain the minimum residual head (5 m water column) at any point of the pipe network. Then, the pipe network model is simulated and after each run of the pipe network model, the network is calibrated with pump discharge head and suitable pipe diameters to satisfy the design criteria. The proposed pipe length for water supply in Muksudpur Paurashava is presented in Table 1.

Table 1: Ward-wise proposed pipe length for SW supply model (scenario-1)

Ward No.	Pipe Length (km)					Grand Total (km)
	100 mm Dia	150 mm Dia	200 mm Dia	250 mm Dia	300 mm Dia	
Ward No: 01	6.83	0.51	0.00	0.00	0.00	7.34
Ward No: 02	8.05	0.68	0.00	0.00	0.00	8.73
Ward No: 03	13.27	0.31	0.00	0.00	0.00	13.59
Ward No: 04	4.62	3.72	0.08	0.00	0.00	8.42
Ward No: 05	8.94	1.71	0.21	0.00	0.00	10.87
Ward No: 06	3.78	1.35	0.78	0.95	0.50	7.36
Ward No: 07	6.78	2.13	0.37	0.28	0.00	9.56
Ward No: 08	9.75	0.00	0.00	0.00	0.00	9.75
Ward No: 09	4.98	1.39	0.00	0.00	0.00	6.37
Total (km)	67.01	11.80	1.44	1.23	0.50	81.99

Scenario-2: Ground Water Supply Model without WTP

A GW model generally consists of reservoirs, pumps, junctions and pipe network. In absence of GW source assessment result, model has been simulated by reservoirs only instead of pumps and reservoir combination as source. Like the SW supply model, similar representation approach has been followed in output for junction data and pipe data. Reservoir data is an additional output for GW supply model. Considering these points, the pipe network model is run and after the run, the network is calibrated with pump discharge head and suitable pipe diameters to satisfy the design criteria. The proposed pipe length with their dimensions is presented in Table 2.

Table 2: Ward wise Proposed Pipe Length for GW Supply Model (scenario-2)

Ward No.	Pipe Length (km)				Grand Total (km)
	100 mm Dia	150 mm Dia	200 mm Dia	250 mm Dia	
Ward No: 01	6.83	0.51	0.00	0.00	7.34
Ward No: 02	7.61	0.40	0.56	0.17	8.73
Ward No: 03	10.00	1.53	1.80	0.30	13.64
Ward No: 04	6.73	1.69	0.00	0.00	8.42
Ward No: 05	10.63	0.24	0.00	0.00	10.87
Ward No: 06	6.65	0.68	0.00	0.00	7.32
Ward No: 07	7.28	0.94	1.20	0.22	9.64
Ward No: 08	9.66	0.09	0.00	0.00	9.75
Ward No: 09	4.98	1.39	0.00	0.00	6.37
Total (km)	70.37	7.46	3.56	0.70	82.08

Scenario- 3: Ground Water Supply Model with WTP

In case of GW source, if the GW quality is not suitable for direct supply to the consumers, WTP is required to bring the water quality according to the WHO/Bangladesh water quality standard. As the source selection was not finalized during the model built up, another model has been simulated for GW source with WTP. Pipe network model for GW source with treatment, starts from the clear water storage reservoir located on the ground of the GW treatment plant. In that case, high lift pumping station is necessary to inject required quantity of treated water with certain discharge head to achieve the targeted minimum residual pressure (5 m water column) at any point of the distribution pipe network. The pipe network model is simulation by pipe network modeller and output of the model is presented in the form of junction data, pipe data and high lift pump data. However, the location of the WTP for this case has been selected as same as that of SW model (scenario-1). This is why all model output remains the same (Table 1) for surface water model as described in scenario-1.

CONCLUSIONS AND RECOMMENDATIONS

In this study, three alternative models of water supply distribution networks have been simulated for water supply purposes in Muksudpur Paurashava of Gopalganj district in Bangladesh based on the collected data and information. The study deals with three alternative scenarios, among which the first scenario refers to the combination of SW source with WTP, second option is relevant to GW source without WTP, and third model is built by using GW source with WTP. The result obtained in first option concludes that one high lift pump having capacity of 335.54 m^3hr^{-1} having a delivery head of 10m is sufficient to maintain minimum residual pressure of 5 m water column at any point of the distribution network up to the end of design period at 2040. According to second scenario, the study concludes that the daily water demand of 8,053 m^3d^{-1} at the end of design period can be met by only three production wells, which consider a safe yield of 102 m^3hr^{-1} from each 150 mm diameter production well. However, water supply network is designed and proposed based on simulation results in all scenarios in the Paurashava area. Since the pipe network is simulated for different combinations of SW and GW sources with or without WTP, the study suggests that proper attention should be paid in selecting appropriate water sources based on the socio-economic aspects of the locality, environmental issues, taste of the consumers and cost effectiveness of the system. The study also concludes based on third option that production wells should be located closer enough to the WTP as well as minimum distance should be maintained among the production wells to reduce the cost of water withdrawal and/or water production. The study concludes that minimum water pressure at the consumers end should ensured not less than 5 m water column based on design criteria. This indicates that the owner of the multi-storied buildings requires underground water reservoir, but it is not necessary for a single storey building. Finally, the study emphasizes that the water supply network is totally dependent on projected population. However, if the projected population gets changed in future by any means, the designed diameter of the pipe networks will be changed. In addition, if the safe abstract rate of GW changes accordingly, number of production wells will be changed. Accordingly, the study recommends that the whole distribution network should be redesigned in those changing conditions.

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ASSESSSMENT OF WATER QUALITY IMPACTS ON FISH PRODUCTION IN RUPSHA-BHAIRAB RIVER

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ABSTRACT
Khulna city is in the south western part of Bangladesh and is mainly an expansion of trade centres close to the Rupsha and Bhairab rivers. This research specifically deals with the impact of water quality on fish production on these rivers due to industrial effluent with seasonal variation. Physicochemical and bacteriological water quality of the Rupsha and Bhairab rivers were investigated at seven different locations on the river. A range of water quality variables were measured in these rivers throughout June 2010 to May 2011. This research provides information about the fisheries diversity and water quality relation in both spatial and temporal dimensions. About 25 km length was divided into nine zones for sample collection. In total 33 samples have been analyzed. The river waters in Rupsha and Bhairab were characterized by high salinity and hardness in dry season. Conductivity and TDS varied seasonally with elevated levels in dry season. However, the results indicated that most of the physicochemical quality parameters of Rupsha and Bhairab rivers were within the acceptable limits for fish productions. BOD, DO and pH levels measured indicated a healthy river system as well. COD is much higher than BOD it indicates that most of the pollution in the study zones is caused by industrial discharge. Thus, a sustainable water management is becoming a necessity for development of fish production, livelihood of people and environment in the coming decades.

Keywords: Rupsha & Bhairab Rivers, industrial effluent, physio-chemical water quality, spatial & temporal dimensions, sustainable water management

INTRODUCTION

During the past several decades, there has been an increasing global concern on sustainable water resource management, and it is widely recognized as a major challenge to the world. The increasing urbanisation and industrialisation of Bangladesh have negative implications for water quality as well as fish production. The pollution from industrial and urban effluents in some water bodies and rivers has reached alarming levels. With the rapid development of economics and the speedy growth of population, sustainable water resource management for the increasing industrial, agricultural and domestic purposes is being a critical issue in Bangladesh. The rivers Rupsha and Bhairab play an important role for the overall socio-economic development of Khulna. A recent report said that, there are about 350 industrial units in the region. More than 22 shrimp processing factories are also polluting the environment of Khulna and Rupsha areas.

Fish production coupled with water scarcity and water pollution are some of the crucial issues in the world. In Bangladesh people derive as much as 75 percent of their daily protein from fish. The Rupsha-Bhairab river is a great source of fish production in Khulna as well as Bangladesh. The fisheries in Rupsha and Bhairab rivers have a long tradition of playing an important role in the local economy. In the mid 1990s fisheries contributed about 10 percent of Bangladesh's export earnings. The aim of the study is to assess the impacts of water quality on aquatic foods in Rupsha and Bhairab rivers, pollution factors affecting the river water quality, water quality parameters responsible for the spatial variations in river water quality and establish a relationship between water quality and aquatic foods. The overall aim of the present study is to investigate the water security issues and fisheries development in these rivers.

MATERIAL AND METHODS

Study Area

Khulna is the third largest city in Bangladesh. The city of Khulna is in the northern part of the district. The study area is bounded by the river of Bhairab on the northeast, Rupsha on the southeast and Pasur in further down south. The Atharobanki river meets with Rupsa and the Atai river meets with the bhairab river on the central east and the Mayur river-Hatia river lie on the west. The main rivers of the study area are Rupsha and Bhairab. It flows by the side of Khulna city, and connects to the Bay of Bengal through Poshur river at Mongla channel. These rivers are approximately 250 km long and 300 feet wide.

Geological location of the study area

Figure 1 Study area

Site Selection

For collection of water samples, the lower of about 25 km, from Shiromoni to Rupsa Bridge, was divided into nine sampling zones by considering the accessibility and availability of the operation and monitored once in a season over a period of one year. The first two sampling sites Shiromoni and Phulbarigate Ghat were located about 3, 2.5 km upstream side (US) of high industrial areas, the other three sampling sites Daulatpur Ghat, Burmah Shell Ghat (near Padma Oil Mill) and near Jute Mill were located near the highly influenced industrial areas, and other two sampling sites Launch Ghat and Jail Khana Ghat were located about 3, 2.5 km downstream side (DS) of industrial areas. There are a number of Fish Processing factories in between Rupsha Feri Ghat and Rupsha Bridge, two sampling sites were located US and DS of the Fish Processing factories.

Table 1 Geographical location of the river water sampling zones

Sampling Zones	Geographical position	
	Latitude °N	Longitude °E
Shiromony	22.9204527	89.5164299
Fulbarigateghat	22.8987901	89.5194340
Daulatpurghat	22.8697696	89.0528188
Burmah Shell	22.8695323	89.5373297
Jute Mill	22.8603385	89.5522670
Launch ghat	22.8236659	89.5592165
Jail Khana ghat	22.8184149	89.5713401
Rupsa Ferighat	22.8027495	89.5831418
Rupsha Bridge	22.8014637	89.5817900

Sampling

Water Samples were collected in both spatial and temporal basis. A range of water quality variables were measured in these rives, for all three seasons viz. winter (26-27 November, 2010), summer (15 March-17 April) and monsoon (13 July, 2010) over a period of 12 months. In total, 33 water samples have been analyzed over a period of June 2010 to May 2011. Fish production data have been collected both from field survey and secondary sources.

Laboratory Analysis

The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005) was followed for the analyses of all the physicochemical parameters.

RESULTS AND DISCUSSIONS

The pH ranges from 7.34 to 7.83 in monsoon (13 July, 2010), 7.82 to 8.15 in winter (26-27 November, 2010), and 6.42 to 7.1 in summer (15 March-17 April). In general the pH values are higher in winter than other seasons. Most sites had pH values in the neutral range at all stations for the study period, although water at some sites was slightly alkaline. The variation can be due to the exposure of river water to atmosphere, biological activities and temperature changes. It can be seen that the pH values for stations US to DS were very close to the acceptable limits (6.5-9.0) for fish production (WHO, 1984). The electrical conductivity (EC) varies from station US to DS; 195 to 262mS/cm in winter, 152 to 222mS/cm in summer and 155 to 178mS/cm in rainy season as shown in fig. 2. High Electrical conductivity indicates a larger quantity of dissolved mineral salts, thereby making it sour and unsuitable for fishing. The TDS determined in these studies ranged between 3100 to 4700 mg/l in winter, 6980 to 9560 mg/l in summer 1650 to 4290 mg/l in rainy season. The largest amount of TDS adds to the highest salinity, turbidity and electrical conductivity. The upstream level was always low probably due to the absences of heavy industries near the water sampling stations. The lowest value was found at DS stations Launch Ghat, Jail Khana Ghat, and Rupsa Ghat, due to dilution from another River which may include that the river had undergone self-purification. Dissolved oxygen (DO) mean levels varied between 5.75 and 8.10 mg/l.

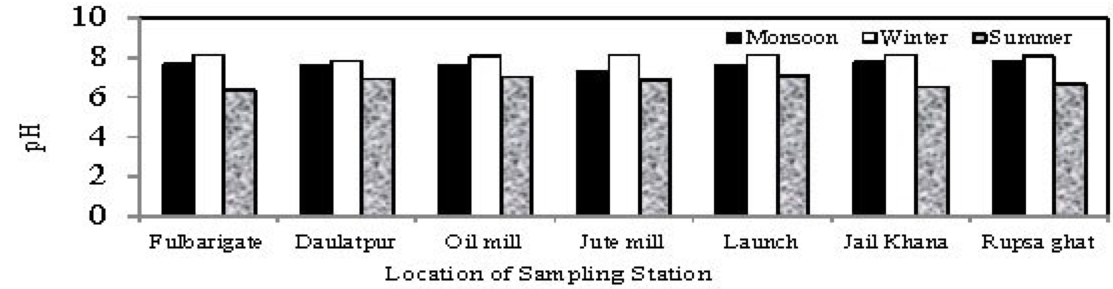

Figure2 Variation of pH at different water sampling stations

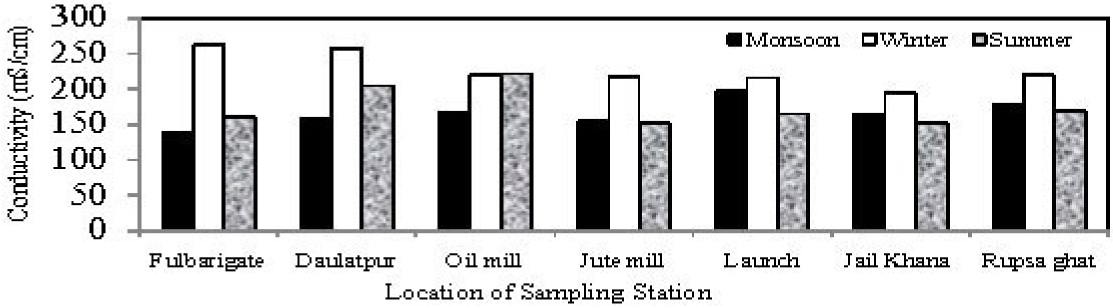

Figure 3 Variation of Conductivity at different water sampling stations

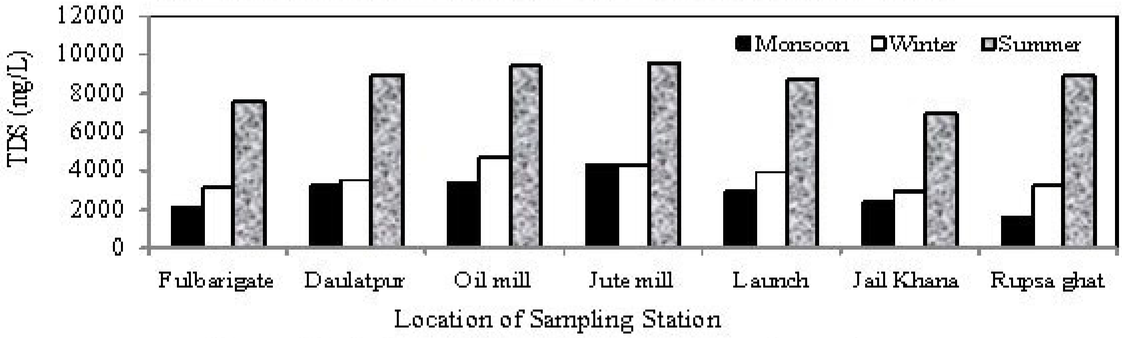

Figure 4 Variation of TDS at different water sampling stations

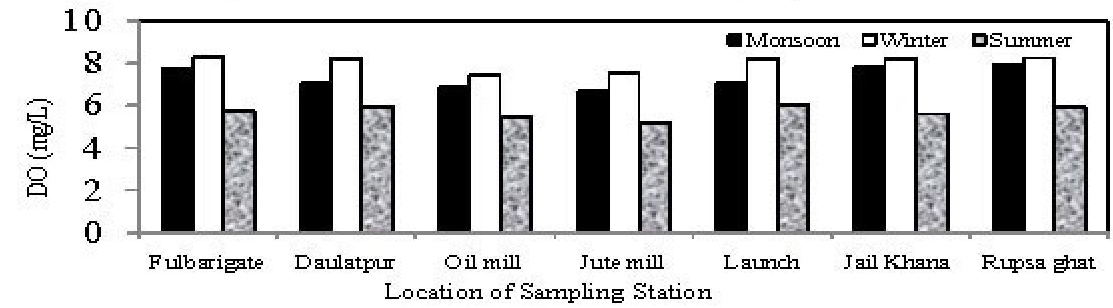

Figure 5 Variation of DO at different water sampling stations

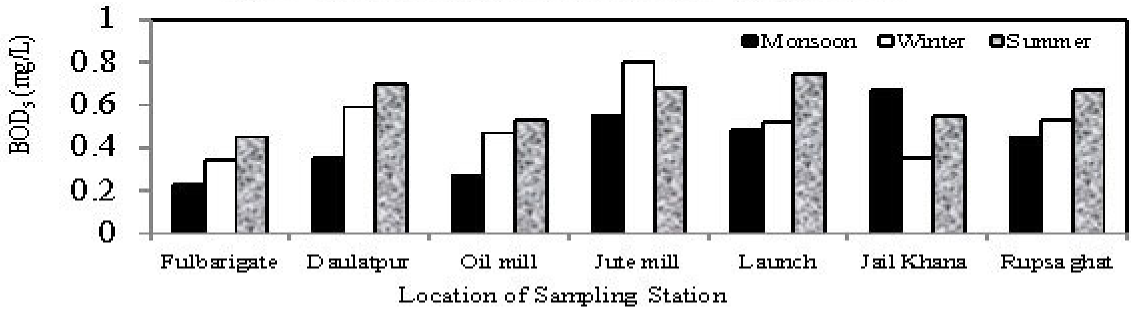

Figure 6 Variation of BOD_5 at different water sampling stations

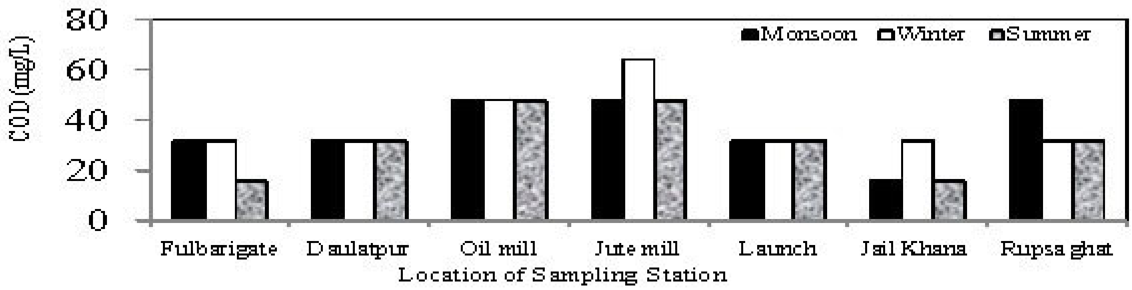

Figure 7 Variation of COD at different water sampling stations

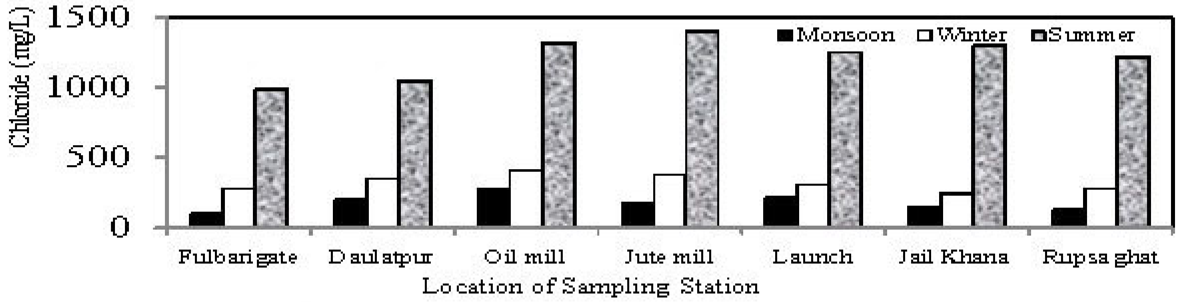

Figure 8 Variation of Chloride at different water sampling stations

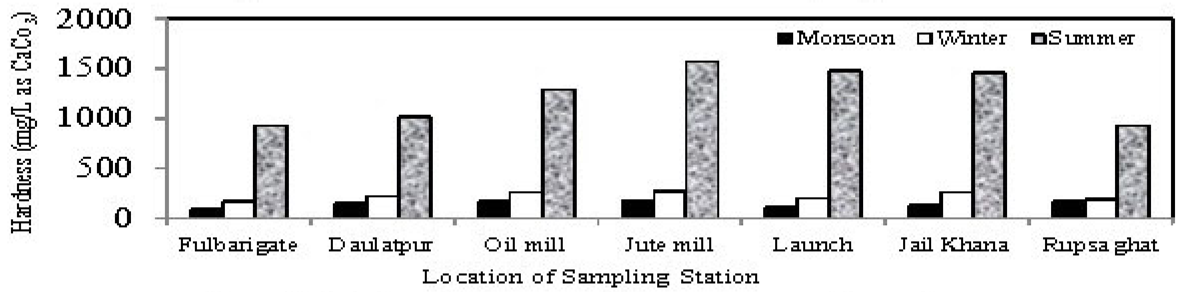

Figure 9 Variation of Hardness at different water sampling stations

Concentrations below 5.0 mg/L adversely affect aquatic life. The concentrations of DO in these rivers were above 5.0 mg/L and, therefore, the river water would be suitable for use of the aquatic ecosystem. The biochemical oxygen demand observations for the three seasons i.e. winter, summer and rainy season vary from 0.34 to 0.59 mg/l 0.45 to 0.75 mg/l and 0.23 to 0.67 mg/l, respectively. Like DO it also indicates presence of organic pollution which can be attributed to the non-point sources scattered over the entire study mill situated in zone. In present study the values vary from 32 to 64 mg/l in winter 16 to 48 mg/l in summer and 16 to 48mg/l in rainy season. The highest values of COD indicates that most of the pollution in study zone in caused by industrial effluents discharged by industrial units like pulp and paper mill, sugar factory etc. upstream. This is the most common inorganic anion present in water.

There have some types of boats that are used for catching of fish in these rivers. The common types of boats are: Small dingi(*i.e.,* country) boat, small motorised boat with 15 – 20hp engine (including boat, engine, and nets) and wooden trawler to fish in the Rupsha Bhairab rivers. From the interview of the fishermen, it was revealed that in a lunar month, there was a great variation on sizes of catch which is also applicable for ESBN catch. There are 4 quarters (7 day each) in a lunar month. Two quarters exist from new moon to full moon. By considering the view of local fishermen and previous data, fullmoon was chosen for taking samples when the catch is relatively high.

Annual fish production

The Rupsha - Bhairab river is a large river that offers a rich potential for fisheries species. Higher fish production value found in July, August, and September rather than other months in each sampling zone. The number of species present and the total abundance of fisheries species differed among times of sampling (Fig. 9). Monthly abundance (individuals) variation was significant in all sampling zones.

Highest number of individuals was recorded in July; where the peak was in August. The monthly abundance for each sampling zone sharply reduced from December to March and remained almost same for a month (April) and then gradually increased to July.

Estimation of Fish Production in a Year at Rupsa-Bhairab River:

No of Boat through the length = 150

Table 2 Estimation of fish production in Rupsa-Bhairab River at three seasons

	Winter	Summer	Rainy
Daily Fish catch rate per boat (Kg)	2.5	1.75	5.0
Monthly fish catch rate per boat (Kg)	37	25	75
Total amount of fish catch in a year (tonne)	22500	15000	50000

Among the environmental variables, water salinity, temperature, turbidity, dissolved oxygen, and their regular or irregular fluctuations at different time scales, have been identified as determinants in coastal fish ecology. The present study recorded at 7 fishermen community which have 150 boats for catching fish in the River.

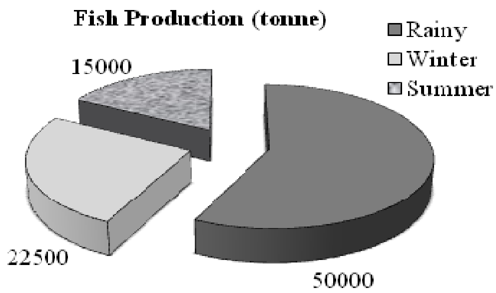

Figure 10 Seasonal Variation of fish production

In contrast, a total of 50000 tons catch were recorded in monsoon season and 22500 in winter and 15000 in summer. It is certain that any water quality improvement will directly benefit fish production.

CONCLUSION

A well - defined spatial and temporal heterogeneity in distribution of different water quality parameters was observed in the studied regions. The low pH value is due to less alkalinity, high DO and low rainfall. Most sites had pH values in the neutral range, although water at a few western sites was slightly alkaline. It is stated that waters having a pH range from 6.7 to 8.6 is support for a good fish population (Andrews et al.,1972). Seasonal patterns, however, were consistent across sites, with higher pH values recorded in August and September than December to February. Highest salinities were recorded during the low rainfall months. Turbidity was high throughout the study period. Seasonal patterns were evident at some sites, with higher turbidity levels during the wet months from December to April than from May to October. Turbidity values decreased at winter. TDS is very high at dry seasons because of high salinity. It is therefore recommended that the careless disposal of the wastes should be discouraged, strict restriction on pollutants and although the values in some cases were lower than the allowable limits, the continued discharge of the effluents in the river may result in severe accumulation of the contaminants and, unless the authorities implement the laws governing the disposal of wastes, this may affect the lives of the people.

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ASSESSMENT OF GROUNDWATER POTENTIAL AND ITS AVAILABILITY FOR JOYPURHAT

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ABSTRACT
Despite of high dependence, accurate assessment of groundwater recharge potentials and its availability has not been done for the most of the part of Bangladesh and consequently management of groundwater is not properly practiced. In this study potential recharge as well as groundwater availability for 5 Upazillas (Akkelpur, Kalai, Joypurhat Sadar, Khetlal and Panchbibi) of Joypurhat districts have been assessed using MIKE SHE modelling tools. The main aquifers of the study area are dominated by medium sands, medium and coarse sands with little gravels. The top of aquifers ranges from 15 m to 24 m and the screenable thickness of aquifers varies from 33 m to 46 m within the depth range 57 m to 87 m. Heavy abstraction of groundwater for agricultural, industrial and domestic uses results in excessive lowering of water table making the shallow and hand tubewells inoperable in the dry season. The upazilawise potential recharge for the study area was estimated through mathematical model using MIKE SHE modelling tools in an integrated approach. The required data were collected from the different relevant organisations. The potential recharge in study area varies from 452 mm to 793 mm. Maximum depth to groundwater table in most of the places occurs at the end of April. At this time, groundwater table in the most of part of Kalai, Khetlal, Akkelpur and Panchbibi goes below the suction limit, causing HTWs and STWs partially/fully in operable.

Keywords: *River-Aquifer Interaction, Groundwater Potential, Specific yield, Recharge, DTW, STW*

INTRODUCTION

Groundwater is very important for agro-socio-economic development of Bangladesh. Supply of safe drinking water to 97% of the population and attaining self-sufficiency in rice production are the two major successes achieved with the utilization of groundwater. Easy availability, good quality and cheap development technologies made groundwater exploitation very popular all over the country and abstraction has increased manifold over the last 30 years. This increasing trend would remain unchanged for the years to come.
Despite of high dependence, accurate assessment of groundwater recharge potentials and its availability under various yield criteria has not been done for the most part of Bangladesh and consequently management of groundwater is not properly practiced.

This paper highlights the assessment of potential recharge as well as groundwater availability for 5 Upazillas (Akkelpur, Kalai, Joypurhat Sadar, Khetlal and Panchbibi) of Joypurhat districts using MIKE SHE modelling tools. Drought is one of the major problems of this area where groundwater is the only dependable source of drinking and irrigation purposes. Almost in all of the area, groundwater is being abstracted on an unplanned way and indiscriminately. Surface water sources are very limited for this area. In dry season, most of the hand tube wells (HTW) and shallow tube wells (STW) become inoperable during dry season.

The main aquifers of the study area ranges from 15 m to 24 m and the screenable thickness of aquifers range from 33 m to 46 m within the depth range 57 m to 87 m. The survey indicated the existence of a 40 m thick aquifer at the depths varying from 20 m to 40 m in the study area (Depperman ,1956). Estimated the specific yield for the Bogra district including the area which varied between 8% and 18% (Karim, 1972). They recommended the hydraulic design parameters of aquifers, permeability ranges between 11 m/day to 32 m/day, transmissivity between 800 m2/day to 1350 m2/day and specific yield between 8% to 20%. However, later on MacDonald (1980) revealed the transmissivity values of the aquifer ranges between 1000 m2/day and 2000 m2/day. For general planning, a constant storage coefficient value of 13% was suggested in the report for typical water level fluctuations in the range of 5 to 9 m. In Khetal, Joypurhat, Kalai, Panchabibi and Akkelpur upazillas of Joypurhat district transmissivity varies from 1240 m^2/day to 1700 m^2/day (IWM, 2009).

APPROACH AND METHODOLOGY

Every modelling study involves the iterative development of a model. Model refinements are based on the availability and quality of data, hydrogeological understanding and modelling study scope. For this study purposes, the general approach has been adopted as shown in the Fig 1.

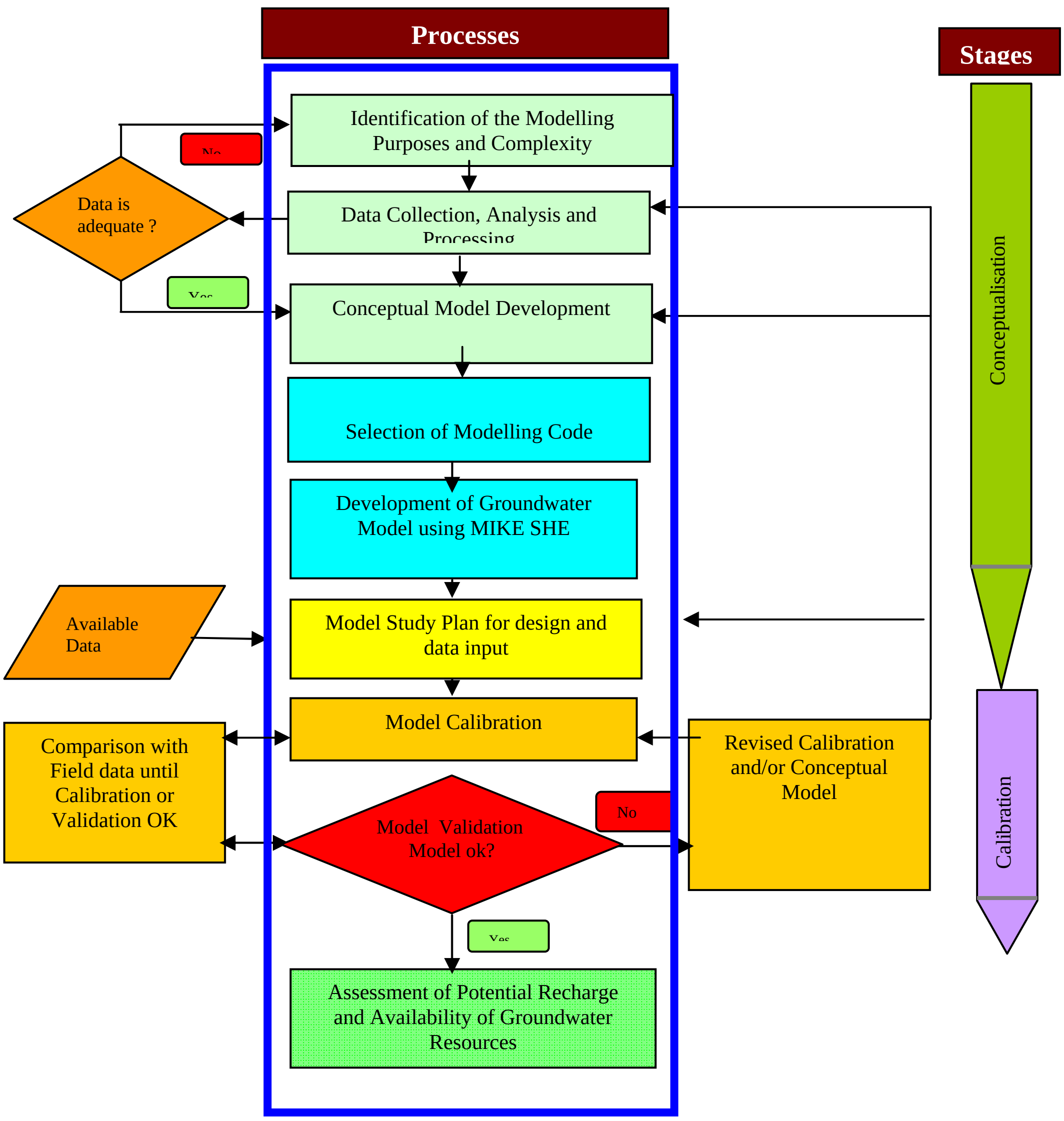

Fig. 1: Flow chart of the general methodology for the study

Data collection

The following data were collected from different sources:

- Rainfall and Evaporation data for the period of 1975 to 2009 for 9 stations.
- Groundwater level data from IWM and BWDB.
- Geological data from IWM
- Land use and vegetation data from IWM
- Upazilawise number of DTW and STW from BADC Report

Model Calibration

Calibration is the process in which the simulated result is matched with the observed date through adjusting the calibration parameter within a realistic limit. A set of 3 observation wells was selected for calibration matching. Due to the huge number of input data, the parameters are also numerous. During the calibration it is therefore important to adjust the parameters within acceptable ranges determined from field measurements, and also to minimize the number of adjustment of parameters. The model has been calibrated for the period 2001 to 2006. During calibration overland leakage co-efficient, soil properties, hydraulic conductivity and storage coefficient have been adjusted.

To measure the performance of the model, calibrated water levels were compared with the observed water levels for 3 observation wells. Sample calibration plot is shown in Fig. 2. In general, the overall calibration of the present model is acceptable, but there is scope for further improvement. Some of the reasons of deviation between observed and simulated groundwater levels have been identified as follows.

- Insufficient irrigation information; the conceptual description of the irrigation abstraction might not be sufficient.
- Missing description of pumping systems close to the observation wells.

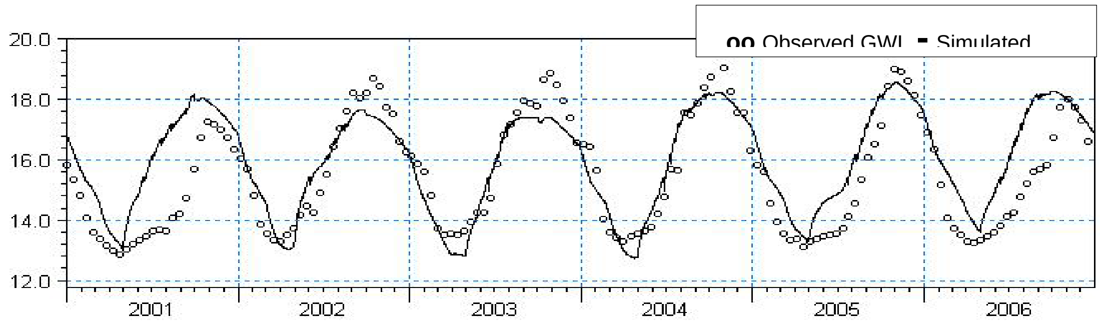

Fig. 2: Calibration of groundwater level of BO-007 at Joypurhat

Model Validation

To check whether the calibrated model is an adequate representation of the physical system or not, validation is carried out on the calibrated model. It is customary that the calibrated model should be

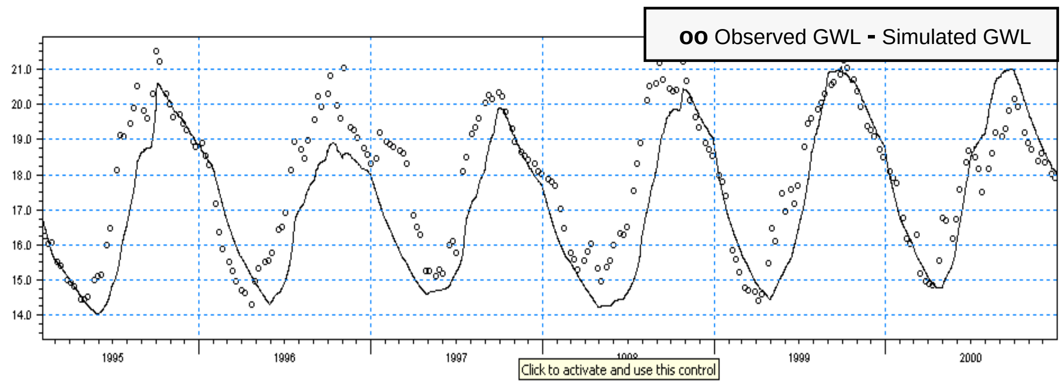

Fig. 3: Validation of groundwater level of BO-008 at Panchbibi

verified outside the calibration period. As such verification has been done for a period 1995 to 2000. In validation, all the calibration parameters were the same as for the calibrated model, only the input parameters were changed. In general the validation plots reveal a good correlation between the observed and the simulated values as shown in the Fig. 3.

Overall validation results show similar trend of groundwater fluctuation and good matching of groundwater levels between observed and simulated values for both of the validation periods. From the results of the model validation, it can be concluded that the parameters used in the calibrated model are acceptable, thus the model can be used for prediction purposes.

Selection of Design Year

Generally, irrigation projects are planned considering average hydrological conditions. In the present study, design year has been selected based on return period of mean annual rainfall of the study area. Observed annual rainfall for a period of 32 years (1975-2006) has been considered for statistical analysis. Data has been fitted to Log Normal distribution to find out the average dry year. The statistical software HYMOS 4.0 has been used for this purpose. From the statistical analysis 2002 has been selected as the design year.

Groundwater Resource Assessment

Reliable assessment of groundwater resource is essential for effective irrigation management and preservation of environment. Groundwater resource of the study area has been assessed based on recharge characteristics, potential recharge and safe yield criteria. The starting of December has been chosen for the assessment of groundwater resources. To estimate groundwater resource, the availability of groundwater within the allowable depths are estimated based on available saturated thickness up to these depths multiplied by specific yield of the area: $V_w = A \times \Delta h \times S_y$

Where V_w is the volume of water, Δh is the saturated thickness within allowable depths and Sy is the specific yield of the aquifer. The availability of groundwater resources within the 7 m depths are estimated based on available saturated thickness up to 7 m depths multiplied by specific yield. Upazilawise resources under different yield criteria has been estimated.

RESULTS AND DISCUSSION

Potential Recharge and Usable Recharge

Upazilawise potential recharge has been estimated from model results simulated for average year (2002). The end of April is the end of irrigation period when the lowest water table generally occurs, after that water table starts rising due to recharge to groundwater from rainfall. The components that influence the groundwater storage after April are mainly rainfall, runoff, overland flow, overland storage, drain to river, evapo transpiration, boundary inflow and outflow. Potential recharge for the study area has been estimated using the water balance obtained from model simulation. A sample water balance chart for Joypurhat Upazila is shown in Fig. 4.

Potential Recharge = 503mm (SZ-Storage change)-51mm (UZ-Storage change) = 452 mm.

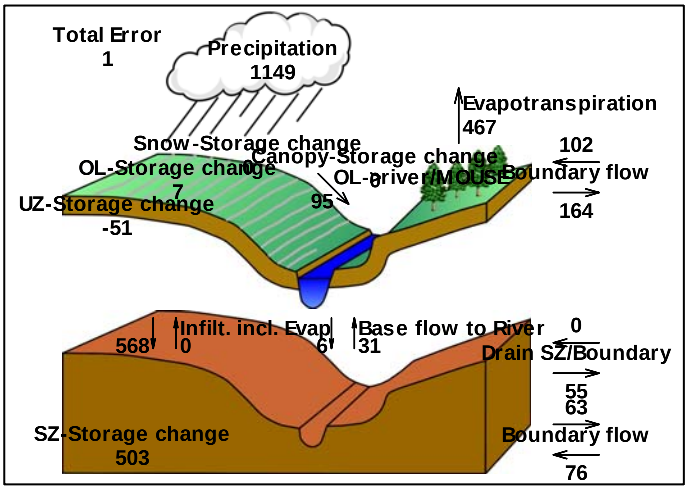

Fig. 4: Water balance of Joypurhat Upazila

Upazilawise estimated potential recharge has been shown in Table 1. According to the MPO and NWMP guideline, 75% of potential recharge has been taken as usable recharge for development consideration. It is due to the fact that various uncertainties are inherent in different assumptions for the estimation of potential recharge.

Table 1: Upazilawise potential recharge of the study area

District	Upazila	Potential Recharge		Useable Recharge	
		mm	Mm^3	mm	Mm^3
Joypurhat	Akkelpur	516	76	384	57
	Joypurhat Sadar	452	111	339	83
	Kalai	793	130	595	98
	Khetlal	677	97	508	73
	Panchbibi	601	165	451	124
Total		**3039**	**579**	**2277**	**435**

The estimated potential recharge has been compared with the potential recharge of MPO, NWMP and IWM study. The comparisons indicate that present study result has good conformity and consistency with those of MPO, NWMP and IWM study. However, there are slight variations in Upazilawise estimation. Comparison of Potential Recharge obtained by the model study and other organization is shown in Table 2. The potential recharge of the present study varies from 452 mm to 793 mm while the values of MPO study varies from 400 mm to 500 mm and the values of NWMP study varies 552 mm to 772 mm and the values of IWM studies ranges from 453 mm to 799 mm. The slight

Table 2: Comparison of potential recharge

District	Upazila	Potential Recharge (mm) Estimated by			
		Present Study	MPO	NWMP	IWM
Joypurhat	Akkelpur	516	425	552	581
	Joypurhat Sadar	452	400	558	453
	Kalai	793	500	772	799
	Khetlal	677	400	746	677
	Panchbibi	601	450	636	635

variation of results is due to variation in approaches and parameters used and boundary effect for comparatively small area. Distributed modelling approach and parameters were estimated through carefully data analysis. Furthermore, groundwater reserve has extensively been used over the recent years that create scope for higher recharge.

Available Groundwater Resources before Irrigation Period

Based on safe yield criteria, Upazila-wise available groundwater resources have been assessed considering the saturated thickness and the values of specific yield from the calibrated model. Upazila-wise available groundwater resources upto 7m from the surface is shown in Table 3. It has been observed from the table that the potential recharge is lower than the available resource in Joypurhat Sadar. This is due to the fact that, potential recharge of this Upazila is less due to clay formation in upper geological layer. While the potential recharge is higher in other upazilas.

Table 3: Upazilawise available groundwater resources up to 7 m depth

District	Upazila	Available groundwater resource	
		(mm)	Mm^3
Joypurhat	Akkelpur	365	53
	Joypurhat Sadar	587	144
	Kalai	621	102
	Khetlal	571	82
	Panchbibi	530	146
Total		**2674**	**527**

CONCLUSIONS AND RECOMMENDATIONS

The study aims to explore the modern technique for assessment of groundwater resources and its sustainable development. In this connection a dedicated groundwater model for the study area hase been developed which has been calibrated for the period of 2001-2006 and validated for the period of 1995-2000. The calibrated and validated model has been applied for various scenarios. Based on the study findings, conclusion and recommendations are summarized below:

Conclusions

- Groundwater resource for the study area has been determined for four safe yield criteria; (i) maximum groundwater table 7 m from ground surface, (ii) potential recharge and (iv) useable recharge . The usable recharge has been determined considering 75% of potential recharge as suggested by MPO.
- Groundwater resources for the entire study area for those yield criteria are found to be 406 Mm^3, 527 Mm^3, 579 Mm^3 and 435 Mm^3 respectively. Whereas the present irrigation requirement is 484 Mm^3. This indicates that as a whole, if potential recharge is considered, there is no shortage of water to meet the present water demand.
- When usable recharge is considered, little shortage of water is observed in Joypurhat Sadar, Khetlal and Panchbibii Upazila. This is due to the fact that boro coverage is already more than 80% in these Upazilas which implies to higher water requirement.
- Maximum depth to groundwater table in most of the places occurs at the end of April. At this time, groundwater table in the most of part of Kalai, Khetlal, Akkelpur and Panchbibi goes below suction limit causing HTWs and STWs partially/fully in operable.
- In Zoning Map, considering the depth to groundwater table, the are has been divided into STW zone and DTW zone. Kalai, Khetlal, Akkelpur and Panchbibi upazilas are DTW zone and Joypurhat sadar upazila is STW zone. However STW zone is not restricted for STW use only, it is considered as a mixed zone of STW and DTW.

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FIELD INVESTIGATION OF WATER SUPPLY, SANITATION AND SOLID WASTE MANAGEMENT STATUS OF KARWANBAZAR RAILWAY SLUM IN DHAKA

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ABSTRACT
In Bangladesh every year a large number of people became homeless due to natural disaster and river attrition. On the arrival of these homeless people along with the rural poor increase the slum population rapidly as the cities are expanding, but the required water supply, sanitation and solid waste management facilities are not sufficient in the city. As a result the major portion of excreta is dumped in open places and nearby water bodies which contaminate the slum area as well as the surrounding environment. For that reason, the aim of the study is the field assessment of the water supply, sanitation and solid waste management system of karwanbazar slum which is located at one of the important place in Dhaka city. During the study period data and information were collected by questionnaire survey in karwanbazar slum. It is found from the study that water supply and sanitation were not satisfactory. Among the slum dwellers, knowledge and practice about hygiene was low. The major water sources were supply lines provided by DWASA but the water quality was not satisfactory due to bad condition of supply lines. For the inhabitants of the slum there were some pit latrine as well some hanging latrine which contemning nearby water bodies. No specific solid waste management and drainage system was present there at all. Some NGOs along with different government organization working there to increase awareness level of the slum dwellers and helping them to lead a more healthy living. Therefore, this paper critically access the water supply, sanitation and solid waste management situation of Karwanbazar railway slum and therefore provide recommendation to overcome the situation to improve the lives of slum dwellers.

Keywords: Slum, Karwanbazar, Water Supply, Sanitation, Solid Waste.

INTRODUCTION

Dhaka City has emerged as a fast growing megacity in recent times. It began with a manageable population of 2.2 million in 1975 which reached the threshold of 10 million in 2000. The growth rate of the population during 1974-2000 was 6.9%.[1] There is no city in the world, which has experienced such a high growth rate in population during this period. The United Nations (1999) describes the rapid population growth of this city as ‘exceptional’. During 2000-2015 it is expected to grow at a 3.6% annual growth rate and reach a total population of 21.1 million in 2015. This will put it in 4^{th} position on the list of the world's megacities.[2] Understandably, these additional people have created tremendous pressure on the urban utility services and other amenities of urban life. This has resulted in an adverse effect on the urban environment where a large number of people have settled in slums and squatter settlements where they live below the poverty line.[3] In the slums of Dhaka no specific utility services like water supply, sanitation and solid waste management system has been established yet. Due to poverty the slum dwellers are not capable to overcome the circumstances and facing serious health problems especially the children.

METHODOLOGY

The primary information in this study are practical field observation and conducting formal and in-formal interviews of slum dwellers regarding water supply system, sanitation and solid waste management system in the slum. Some relevant data were collected from external sources. The study was undertaken to unfold the problems and environmental hazardous situation in the slum because no effective step was not hold to improve the slum dwellers faith, city planning, planning for slum areas, improving sanitation, water supply, solid waste management and so on. Therefore, this paper focuses on environmental assessment of three major indices of Karwanbazar railway slum: Water supply system, Sanitation and Solid waste management.

PROJECT LOCATION

In this study, Karwanbazar railway slum was selected to assess the situational analyses as it is located at the central portion of the city and also it is one of the major slum of the city. Particulars of karwanbazar railway slum area are as follows in the Table 1.

Table 1: Particulars of karwanbazar railway slum

Name of the ward	DCC ward no. 39
Location of the slum	Near the karwan bazar
Area of the slum	Near 1.75 acre
Number of population	Approximately 10000
Number of houses	Approximately 2000
Water supply organization	DWASA
Solid waste management	No
NGOs coverage	Not permanently

WATER SUPPLY SYSTEM

In this slum the major source of water was both the legal and illegal supply lines connected with main water supply of DWASA. Through the interview it was found that approximately 7 legal and illegal water lines (1" dia pipe) exist at different point of the slum. Around 72% people use DWASA supply water for drinking and 28% collect their drinking water from nearby other sources (mosque, hotel, residential buildings). Figure 1 shows the sources of water for Karwanbazar slum dwellers.

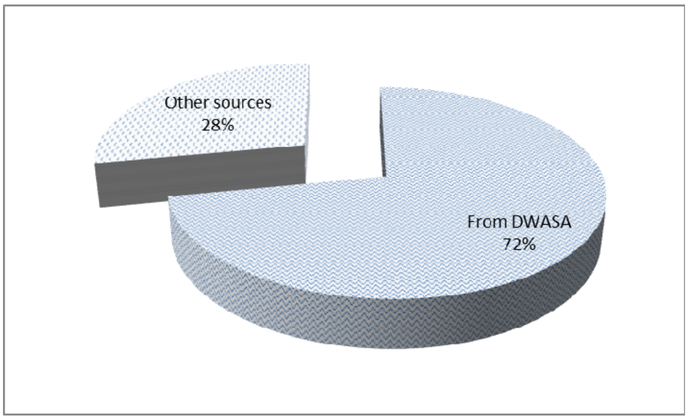

Fig 1: Sources of water for Karwanbazar slum dwellers

A comparative scenario of water supply, distribution and consumption of the slum shown below in the Table 2.

Table 2 : Comparative scenario of water supply, distribution and consumption of the slum

1	Quality	Good	Bad	Hygienic	Unhygienic
					yes
2	Distance of sources	Near	Far	Too far	
			yes		
3	Type of treatment	Boiling	Solar treatment	UV	Chemical
		Some	No	No	No
4	Demand	High	Medium	Low	Crises
		yes			
5	Gender of inhabitant carrying water	Male	Female	Children	
		12%	40%	48%	
6	No of inhabitant suffering from diseases transmit by water	Male	Female	Children	
		8% -10%	20% - 28%	70% - 80%	

#Near = 100m to 150m, #Far = 200m to 300m, #Too far = More than 500m.

SOLID WASTE TREATMENT AND DISPOSAL

Like the other slums in Dhaka there is no specific waste collection and treatment system present there. Usually the slum dwellers threw away the waste at nearby open places. A comparative scenario of solid waste treatment and disposal shown in the Table 3, below:

ABILITY AND INTEREST TO PAY FOR BETTER FACILITIES

At the time of study, the slum dwellers were interviewed about their interest to pay for potable water, more hygienic latrine facilities and better solid waste management system. 74% people told that they would prefer to spend money for other needs rather than for safe water and sanitation. On the other hand 26% people told that they are interested to spend money for safe water and sanitation if the amount is reasonable for them. The Figure 2, shows the index of interest to pay better facilities.

Table 3 : Comparative scenario of solid waste treatment and disposal

		Zone 1 (near the slum)	Zone 2 (inside the slum)
1	Abundant evidence of solid waste	yes	yes
2	Low percentage of waste treatment	yes	yes
3	Most solid waste never treated	yes	sometimes
4	Yard are relatively clean with few waste and empty land post	no	no
5	Some waste are being ecologically treated	no	no
6	Most bio waste are compost	yes	yes
7	Available of ecological treatment	no	no
8	Method of no biological treatment	no	no
9	No waste are available	no	no

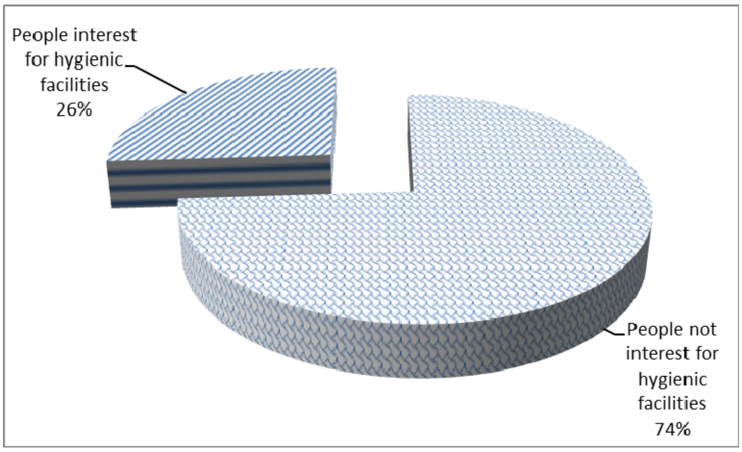

Fig 2: Index of interest to pay better facilities

SCALING BASED ON AVAILABLE FACILITIES

Poor quality of water supply, lack of water distribution, no hygienic sanitation, unimproved latrine and no solid waste disposal sites were found. Finally the Table 4, below shows the general scaling of the facilities in a range of 0 to 3 where point 0 means worst condition, point 1 indicates poor conditions, 2 indicate a condition which is not good enough and 3 means an adequate or sufficient environmental condition.

Table 4: General scaling of the existing facilities

Name of the facilities	Number of scaling			
	0	1	2	3
Water supply		√		
Solid waste management	√			
Sanitation system	√			

Therefore, it is evident from the assessment of the Table: 4 that the solid waste management and sanitation system is in worst condition. On the other hand the water supply system is not in well condition but better than worst.

CONCLUSION

The study has been done basis on primary questioner survey in the karwanbazar railway slum. On the survey, no permanent solid waste disposal sites were found, for which the wastes were disposed near the living area without the chance of recycling. Absence of hygienic and improved latrine causes offensive odor, contaminating water and causes air pollution. Water supply was found to be insufficient for the inhabitant. Majority of the sources are out of order. So people were suffering from diseases and therefore it causes child death. The drainage system is totally unsatisfactory in the slum area. It is observed that houses, shops, drains, roads etc have been constructed unplanned manner and solid waste stored in open places in slum area which made their life more vulnerable. Specific rules and regulations need to be established so that the slum dwellers may get adequate water supply and sanitation facilities.

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EXPLORATORY STUDY ON INDOOR AIR POLLUTION AND HEALTH PERCEPTIONS IN INDUSTRIAL AND EDUCATIONAL BUILDINGS

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ABSTRACT
The aim of the study is to assess indoor air quality in industrial and university areas and related health symptoms among the occupants. A field study was undertaken to assess the levels of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and TVOCs and these values were compared with the standard guidelines. Indoor air temperature and relative humidity were also measured. In addition, the occupants were requested to complete a questionnaire with the details of the indoor conditions and also the occupants' health history and present health conditions. The ambient air quality of some of the laboratories and classrooms of the University was measured during class hours under fully occupied condition. The same measurements were carried out during a semester break when there were no classes. The levels of CO, CO2, NO2, SO2, TVOC were found within the acceptd limit set by USEPA.But in those labs where acids were used, the level of SO2 and TVOC was found to be higher than the accepted limit. A power engineering industry, a textile industry and an automobile workshop were chosen under the category of industrial area. High amount of SO_2 was found . In the auto mobile workshop there were significant amount of CO, CO_2 and TVOC. The workers are not often provided with appropriate protective equipment. The survey reveals high level of occupational health problems like severe cough, headache, asthma, eye irritation etc. These chronic problems are particularly severe among welders and metal workers in the automobile workshop.

Keywords: Indoor air, university and industrial areas, health impact

INTRODUCTION

Clean air is essential for good health, and this is especially true when it comes to indoor air. Outdoor air pollutants may lead to unusually high indoor pollutant levels because outdoor air is delivered into indoor for fresh air supply and diluting the indoor air pollutants. Studies of human exposure to air pollutants by USEPA (US Environmental Protection Agency) indicate that indoor levels of pollutants may be 2 to 5 times – and occasionally more than 100 times – higher than outdoor pollutant levels.

Students spend almost quarter of the day in their institutions. Since work is considered as the basic part in our life almost all matured people spend one-fourth to one-third time of the whole day in their workplace. So the indoor air in the educational institutions and the industries is very important. The pollutants that mainly affect the indoor air are SO_2, NO_2, CO, CO_2, H_2S, and TVOC. Temperature and relative humidity is important for thermal comfort. Though relative humidity does not affect greatly if the ventilation system is adequate, long term high humidity cause growth of microbial contaminant. With a view to identifying any general contaminants associated with the indoor air quality, the assessment was undertaken in the educational institution and the industrial buildings. The educational institutional was within the Dhaka city and the industries chosen were ate the nearby district of Dhaka.

USEPA has ranked indoor air pollution as one of the top five urgent environmental risks to public health. Therefore the indoor environment is important when evaluating pollutant exposures .

MATERIALS AND METHODS

Indoor Air quality was monitored in five different locations of the engineering university. These locations included two classrooms and three laboratories: Atomic Absorption Spectrophotometry (AAS) lab, Undergraduate lab and post graduate lab. The university laboratories and classrooms were measured during classtime as well as during the period when there were no sessions in the laboratories and classrooms. The measurements were carried out for 8 hours in the classrooms and for 24 hours in the laboratories. Each laboratory was equipped with an active air conditioning system.

Air quality was examined in three different industries: a power engineering industry, a textile industry and an automobile workshop. Each industry was examined over the period of one workday. Data was taken in several units of that particular industry. Measurements were conducted as close to the centre of the room as possible. Every time the instrument was elevated to a height close to the Average 'breathing zone'.

An air monitoring device named 'Wolf Pack' which was used for this assessment provided instantaneous readings of pollutants.

'Wolf Pack' offers four different Photo Ionization Detector (PID) sensors to choose from; optimized for specific application. TG-502 probe also includes sensors for relative humidity, temperature and up to 3 specific gas electrochemical sensors, while the TG-503 probe offers sensors for NDIR carbon dioxide, relative humidity, temperature and up to 2 specific gas electrochemical sensors. Coupled with the power of mobile computing, end-users can efficiently log and annotate readings, while easily accessing on-board information about specific volatiles and potential sources.

Questionnaire surveys were conducted among the workers. Participants were assessed for exposure to occupational and environmental hazards, the use of protective equipment and health complaints by interview.

RESULTS AND DISCUSSIONS

Air Quality in Industrial Buildings

It was noted that CO concentration at repairing section of the automobile workshop was   higher than the permissible limit. This is because the repairing section receives automobiles all day long and often more than 5 cars are in operation at a time. All other locations were detected with low concentration of CO. High level of TVOC was found in painting and repairing sections of the Automobile workshop. The measurement was taken during an active session. These fumes generated were entrapped inside the entire area for a prolonged period. While not usually considered a pollutant CO_2 was measured because it is often used as a surrogate for measurement of ventilation rates in indoor air quality investigations. The CO_2 concentration found in repairing section exceeded the permissible limit of 1000 ppm. In our study NO_2 was absent almost in all locations except in the knitting section of the textile industry where the value of NO_2 was found to be almost 1 ppm.

Table 1: Results of Pollutant levels and other indoor parameters for the Industries

Industry	Sections	*Mean (SD)							
		SO_2 (ppm)	H_2S (ppm)	TVOC (ppb)	CO_2 (ppm)	CO (ppm)	O_2 (%)	*RH (%)	*Temp. (^{0}C)
Power Engineering Industry	Pre-treatment	26.9 (0.0)	0.5 (0.17)	403 (114)	601 (53)	1.8 (1.06)	19.1 (0.0)	59.8 (3.82)	39.5 (0.60)
	Electroplating	26.9 (0.0)	0.21 (0.01)	228 (8)	528 (6)	0.3 (0.04)	19.1 (0.0)	61.3 (0.1)	39 (0.06)
	Resin section	26.9 (0.0)	0.20 (0.01)	258 (9)	493 (5)	0.2 (0.07)	19.1 (0.03)	68.7 (1.12)	37.6 (0.23)
Automobile Workshop	Painting Section	1.2 (0.11)	0.75 (0.09)	4570 (2285)	650 (155)	8.1 (5.34)	19.1 (0.0)	76.4 (2.1)	33.9 (0.26)
	CNG conversion	2.5 (0.26)	0.41 (0.05)	708 (125)	787 (225)	10 (2.35)	19.1 (0.02)	64.6 (1.02)	36 (0.18)
	Repairing section	25.2 (5.75)	0.45 (0.28)	2714 (1906)	1028 (407)	58.7 (42.7)	19.1 (0.04)	64.2 (1.51)	36.2 (0.08)
Textile Industry	Knitting	0.9 (0.05)	1.1 (0.05)	1117 (28)	475 (10)	3.9 (0.57)	19.0 (0.05)	78.6 (2.84)	33.7 (0.47)
	Dying	26.9 (0)	0.5 (0.02)	765 (24)	655 (38)	3.9 (1.62)	19.0 (0.0)	65.7 (1.85)	38.3 (0.37)z
	Sewing	1.9 (0.2)	0.5 (0.02)	624 (24)	564 (7)	0.5 (0.09)	19.1 (0.0)	73.8 (0.1)	34.5 (0.08)
	Boiler	26.9 (0.0)	0.72 (0.02)	1026 (67)	574 (28)	5.4 (1.84)	18.9 (0.0)	66.5 (1.98)	39.1 (0.13)

*SD= Standard Deviation, RH= Relative Humidity, temp.= Temperature

Participants Health and Safety Issues:

The vast majority of the workers were male only except the sewing section of the textile industry. The work shift is 8 hours starting from 9 am to 5 pm. A questionnaire was conducted among the workers to assess the environment they exposed and their preventive measures including occupational history, health symptoms, past history of illness etc. The questionnaire survey was conducted among 112 workers from the three industries surveyed. They included welders (15), metal workers (11), spray painters (16), garage mechanic (17) and garment workers (53). The mean age was 29.7 years (range 12-57 years). About 65% of the workers had a work experience of less than 10 years: the maximum was 35 years.

The Survey revealed that use of personal protective equipment was poor, with only welders reporting significant use of face shields. Headache, red eyes, chest pain were reported by about 80% of the welders. Metal workers from the power engineering industry reported cough and burning of nose and chest from the fumes of gases used in the pre-treatment and electrolysis process. Spray painters reported headache and skin irritation when exposed to paint. Exposure to exhaust fumes from automobiles was associated with respiratory problems, cough and headache. About 90% of the garment workers in the knitting section reported to have respiratory problems as a result of inhalation of cotton dust resulting from cotton spinning. The most common respiratory problems were cough and chest pain. Besides, garment workers in the sewing section reported to have eye irritation problem since they are continuously engaged to sewing.

Air quality in the Educational Institutions:

The level of most pollutants in the classrooms was within the acceptable limit defined for the indoor environment. The CO_2 level was within the 500-550 ppm which assures proper ventilation. In the Undergraduate lab, high level of SO_2 (26.9 ppm) and H_2S (0.1 ppm) was found since it was a dedicated lab for testing sewer and waste water. These values remained somewhat constant during the entire data collection time as the lab is always occupied by various sewer samples. In all three labs TVOC level was found to be above the comfort range (<56 ppm). In AAS lab, a sharp increase of TVOC was noticed during the operation of the Atomic Absorption Spectrophotometry machine. This multifactorial exposure range of TVOC can cause irritation and discomfort if other exposures interact.

Table 2: Results of Pollutant levels and other indoor parameters for the Educational Institution

Location	Pollutant's Concentration : mean(standard deviation)							
	SO_2 (ppm)	H_2S (ppm)	TVOC (ppb)	CO_2 (ppm)	CO (ppm)	O_2 (%)	RH (%)	Temperature (^{0}C)
Classroom 1	0.1 (0.0)	0.0 (0.0)	180 (32)	524 (125)	0.3 (0.3)	19.9 (0.05)	45.1 (2.13)	27.5 (0.37)
Classroom 2	0.1 (0.0)	0.0 (0.0)	193 (23)	693 (240)	0.8 (0.2)	19.8 (0.05)	52.2 (3.02)	28.2 (0.51)
AAS lab*	0.3 (0.03)	0.0 (0.0)	369 (108)	748 (152)	1.8 (0.58)	19.8 (0.03)	58.9 (1.36)	28.5 (0.18)
Undergraduate lab	26.9 (0.0)	0.0 (0.0)	175 (41)	575 (56)	0.6 (0.6)	19.8 (0.03)	50.6 (2.78)	27.9 (0.54)
Post graduate lab	0.3 (0.0)	0.0 (0.0)	302 (43)	624 (67)	1.5 (0.68)	19.8 (0.01)	59.6 (1.37)	20.5 (0.27)

******AAS lab: Atomic Absorption Spectrophotometry laboratory*, RH: Relative Humidity

Table 3 Summary of Existing Guidelines

Pollutant	Guidelines for Institution	
	USEPA Standard	Comment
SO_2	<0.14 ppm	Recommended
H_2S	<0.01 ppm >0.01 ppm	Recommended Indicates presence of sewer gas inside the building
TVOC	<56 ppb 56 -852 ppb 852-7100 ppb >7100 ppb	Comfort range Multifactorial Exposure Range Discomfort Range Toxic Range
CO	0-5 ppm >5 ppm >35 ppm	Recommended Presence of exhaust gas Cause mild fatigue
NO_2	<0.05 ppm(24 hour average)	Recommended

Ventilation and Specific Physical Parameter of Industries and Educational institution:

Oxygen present in all industries was found to be 19.0 to 19.1% which is below the recommended value (19.5 %). This indicates that the ventilation system in those indoor environments is inadequate. CO_2 (1028 ppm) in repairing section in the automobile workshop was found above the acceptable range (1000 ppm). Oxygen level in classrooms and laboratories was found to be 19.8 to 19.9% which satisfied the recommended value.

Table 4: Ventilation Performance Indicator

Indicator	O2	CO2
Acceptable limit	19.5 %	1000 ppm

Table 5: Acceptable range for Specific Physical Parameter

Parameter	Temp.	Relative Humidity
Acceptable Range	$23\text{-}26^0$c	40-70%

Relative humidity showed within the acceptable limit for all of the locations tested in the educational institution. But in case of industries, painting section of automobile workshop, knitting and sewing sections of the textile industry showed an elevated level of relative humidity (70-75%).

CONCLUSION

In general finding of assessment of indoor air quality (IAQ) performed in educational and industrial buildings indicate that there are some issues that need further attention and rectification. The following issues are found significant:

- Inadequate ventilation rate at Painting and Repairing section of Automobile Workshop.
- High CO and CO_2 level at repairing section (automobile workshop)
- High NO_2 level at Knitting section (textile industry)
- High TVOC level at painting and repairing section (automobile workshop)
- High SO_2 in university laboratory
- Inadequate safety precautions for industrial workers

RECOMMENDATION:

Indoor air pollution has not been studied much in Bangladesh especially in Educational Institutions and Industries. Much work, therefore, is needed to better understand the assessment of Indoor Air Quality. Since there is not any established guideline for Indoor Air Quality in Bangladesh, it is recommended to develop the guidelines for indoor air as early as possible.

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RAINWATER IS AN EFFECTIVE ALTERNATIVE SOURCE OF DRINKING WATER

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ABSTRACT

Many of the major cities and rural areas of Bangladesh, face shortage of safe drinking water due to some adverse environmental reasons such as; Climate change, water pollution, ground water table depletion etc. With existing production of water, cities are unable to meet increasing demands. So there is a need of alternate safe drinking water sources. Rainwater is an effective source of safe drinking water in terms of availability because there is plenty of rain water in monsoon specially April to September in Bangladesh. Moreover, it is relatively safe, less costly, clear and free from pathogen, iron, and arsenic compare to other sources of water.
This paper describes an attempt to find out the quality of rainwater for drinking purposes. Rainwater have been collected from various representative places of Chittagong and evaluated in the laboratory for drinking water quality parameters. The test results have been compared with Bangladesh standards and WHO guide line values for drinking water parameters. It has been found that rainwater is free from health risk for some places. But rain water collected from some industrial and intersection areas found higher concentration of color, turbidity and total suspended solid compared to WHO guideline values and Bangladesh standards. So treatment is required to make rainwater drinkable and safe to health for those areas. And thus rainwater may be an effective alternate source of safe water in the city area as well as in rural area of Bangladesh.

Keywords: Rainwater, Climate Change, Drinking water parameters, Bangladesh Standards, WHO guideline values

INTRODUCTION

Large population of Bangladesh creates high pressure over the ground water for their drinking, domestic and irrigation purposes. The water table is lowering day by day which result scarcity of safe drinking water. The impact of climate change is vulnerable to the people of Bangladesh in terms of safe water, health, pure air, food, accommodation etc. Some ill effects of climate change are; increase in temperature, sea level rise, melting of glaciers and ice caps, increased rainfall in the short span of time in the monsoon and prolonged dry period. As a result of sea level rise, severe scarcity of drinking water is observed due to salinity intrusion both in ground and surface water.

Arsenic contamination of ground water affects many rural areas, whilst some urban areas including the Chittagong city suffer a lot due to lack of sufficient potable ground water to meet the demand.
Surface water of this city is polluted by industrial waste sewage and intrusion of sea water. So the water supply services remain inadequate in terms of both quality and quantity. On the other hand, the people of rural area cannot easily afford the cost of tube well placement for collecting safe drinking water from ground.
Three distinct seasons can be recognized in Bangladesh from climatic point of view: (i) the dry winter season from November to February, (ii) the pre-monsoon hot summer season from March to May, and (iii) the rainy monsoon season which lasts from June to October (Rashid, 1991). About 78% rainfall in Bangladesh occurs in monsoon, caused by weak tropical depressions that are brought from the Bay of Bengal into Bangladesh by the wet monsoon wind.
Although Bangladesh receives plenty of rainwater during its monsoon, both rural and urban areas, even people of Bangladesh suffers from shortages of safe drinking water during dry season. To overcome the present situation, it is necessary to find out alternate sources of safe water for drinking purposes and this may be the rain water which is easily available. It is comparatively safe and free from iron, arsenic and pathogenic micro organism. Maintenance cost of rainwater is also low**.** That is why this research explore: the feasibility of harvesting rainwater during monsoon as a source of safe drinking water
Mostafa (2009) stated that the rainwater quality in south Asian countries is quite satisfactory, but RWH facilities have yet to be widespread in this region. The study suggests that Government should take initiatives such as offering soft loan, and pass legislation to install RWH system in all new government and private buildings to promote RWH system. Moreover, publicity and training can be provided to the people about the benefits of rainwater quality and harvesting system. Dirrifo et al (2010) evaluated and stated that the rainwater from the industrial areas was contaminated by the emission of the industries and possibly emissions from automobiles. Islam & Kabir (2010) were constructed one ferro-cement rainwater harvesting tank with the capacity of 3.2 m^3 for a family of five members at the study area and proved that the rainwater harvesting is a very useful and acceptable potential source of safe water for drinking and domestic purposes. So to face the demand of safe water, it is necessary to evaluate the rain water quality collected from various representative locations of an area.

MATERIALS AND METHODS

Collection and sampling of rain water

Rain water are collected in clean plastic containers by washing it with rain water three to four times and placing the container on a raised platform in an open environment in order to ensure that the water have no contact with any object. The samples are analyzed on the same day of collection to preclude possible chemical reaction that may occur in the samples. Rain water collected from different representative locations of Chittagong are given in Table 1.

Analyzing procedure

After collection of sample from different places, the following parameters were tested in Environmental Engineering Laboratory: CE Dept, CUET and in BCSIR Laboratory Dhaka. The test procedures have been recommended by **Lenore S. Clesceri et al** for our laboratory evaluation.
Physical parameter:
1. Total Dissolve Solid 2.Odor 3.Taste 4.Color

Chemical parameter:
1. P^H 2. Chloride 3. Iron 4. Hardness 5.Sulphate 6. Turbidity 7. Nitrate
8. Arsenic 9. Alkalinity 10. Salinity 11. Acidity 12. CO_2 13.Total Organic Carbon

Biological parameter:
1. Total Coliform(TC) and Faecal Coliform (FC)

Table 1: Different locations from where rain water collected

Area		Location	ID No.
Rural	Har-Bazar	Pahartali	H1
		Goahchi noahat	H2
		Noapara	H3
	Village	Hathajari	V1
		Raozan	V2
		Rangunia	V3
Urban	Crowded intersection	GEC intersection	CI1
		Bahadharhat intersection	CI2
		Anderkilla intersection	CI3
	Midway between intersection	Between Bahadharhat & Muradpur	MI1
		Between Muradpur & 2 no. gate	MI2
		Between 2 no. gate & GEC	MI3
	Industrial	Kalurghat	IN1
		Sitakund	IN2
		Baizid	IN3
Coastal		Potenga sea beach	C1
		Parki sea beach	C2
		Fouzdarhat	C3
		Kumira	C4
		Kornalhat	C5
		Bhatiyari	C6

RESULTS

In order to find out of an alternate source of safe drinking water, rain water collected from different locations of Chittagong for its quality evaluation. Though samples from different location have been evaluated yet for some constraints, only few results of some locations have been depicted in Table 2. From Table 2, it has been observed that all the water quality parameters of rain water collected from industrial area and intersection area lie within the limit of Bangladesh standard and WHO guideline value except the concentration of turbidity and color of the sample collected from Bahadharhat intersection and Kalurghat industrial area. Also the value of total suspended solid exceeds the limit value except for few locations. Graphical presentations for color, turbidity and total suspended solid of collected samples shown in Fig.1, Fig.2 and Fig.3 respectively. The results of the water quality parameters of rain water collected from other locations which are not mentioned in Table 2, were within the limit value except the value of total suspended solid.

DISCUSSION

This study considered the physical, chemical and biological properties of rain water collected from different locations of Chittagong as shown in Table 1. Samples collected from rural areas, Coastal areas and midway between two intersections are almost safe to drink in term of most of the drinking water quality parameters. Concentration of color of samples collected from Bahadharhat intersection and Kalurghat industrial area exceed the limit of BD standards and WHO Guideline values as shown in Fig.1. From Fig.2, it is observed that concentration of turbidity of some sample cross the limit of WHO Guideline values and few samples cross the limit of BD standards. This is due to interaction between rainwater and gaseous effluents released from industries, as high level air pollution, vehicular emission and refuse burning are exist in this area. From Fig.3, it is observed that concentration of total suspended solid in almost all sample of rain water except Hathajari village area, midway between Muradpur & 2 no. gate, Kalurghat & Baizid industrial area and Potenga sea beach exceed the limit of BD standard.

Table 2: Results of rain water collected from Urban area with standard values

	Crowded intersection			Industrial area			**Standard value**	
Water quality parameter	GEC	Bahadhar hat	Anderkill a	Kalurgha t	Sitakund	Baizid	BD	WHO
Arsenic(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	0.05	0.01
Alkalinity as C_aCO_3(mg/l)	20	20	25	30	25	32	-	30-50
Acidity as C_aCO_3(mg/l)	8.5	7.9	5.68	5.68	6.36	7.18	-	47-146
Color(Pt.Co.Unit)	10	20	15	25	15	10	15	15
CO_2(mg/l)	7.5	7	5	5	5.6	6.32	-	6-60
Chloride(mg/l)	5	9	7	12	14	10	150-600	250
Hardness as C_aCO_3(mg/l)	160	150	90	10	12	8	200-500	-
Iron(mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	0.3-1.0	0.3
Nitrate(mg/l)	<10	<10	<10	<10	<10	<10	<1	3
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	-
P^H	7	7.2	6.69	6.7	7	6.5	6.5-8.5	-
Salinity(mg/l)	8.24	14.9	11.54	19.7	23.07	16.47	-	-
Sulfate(mg/l)	92	95	93	90	93	97	400	250
Turbidity(NTU)	9.4	19.6	6.27	13	10	8	10	5
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	-	-
Total Solid(mg/l)	60	630	250	150	160	158	-	-
Total Suspended Solid(mg/l)	15	18	25	10	12	8	10	-
Total Dissolve Solid(mg/l)	45	612	225	140	148	150	1000	1000
Total Organic Carbon(mg/l)	7.692	-	-	7.334	-	-	-	-
Total Coliform(N/100ml)	0	0	0	0	0	0	0	0
F. C. (N/100ml)	0	0	0	0	0	0	0	0

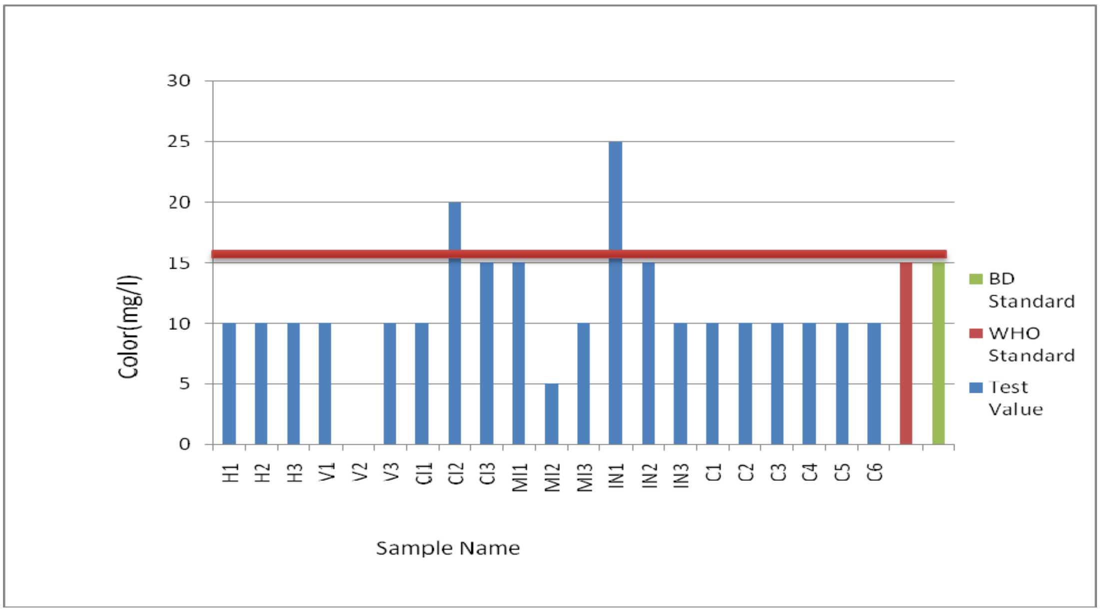

Fig.1: Color value of different samples with standard values

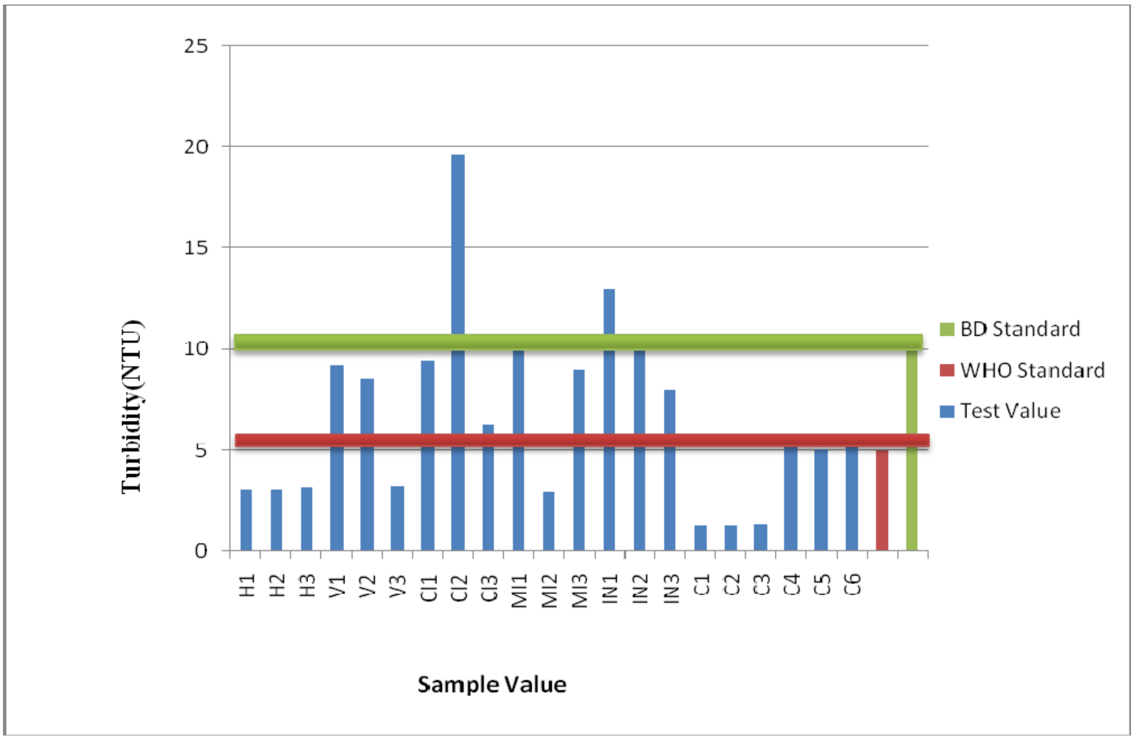

Fig.2: Turbidity value of different samples with standard values

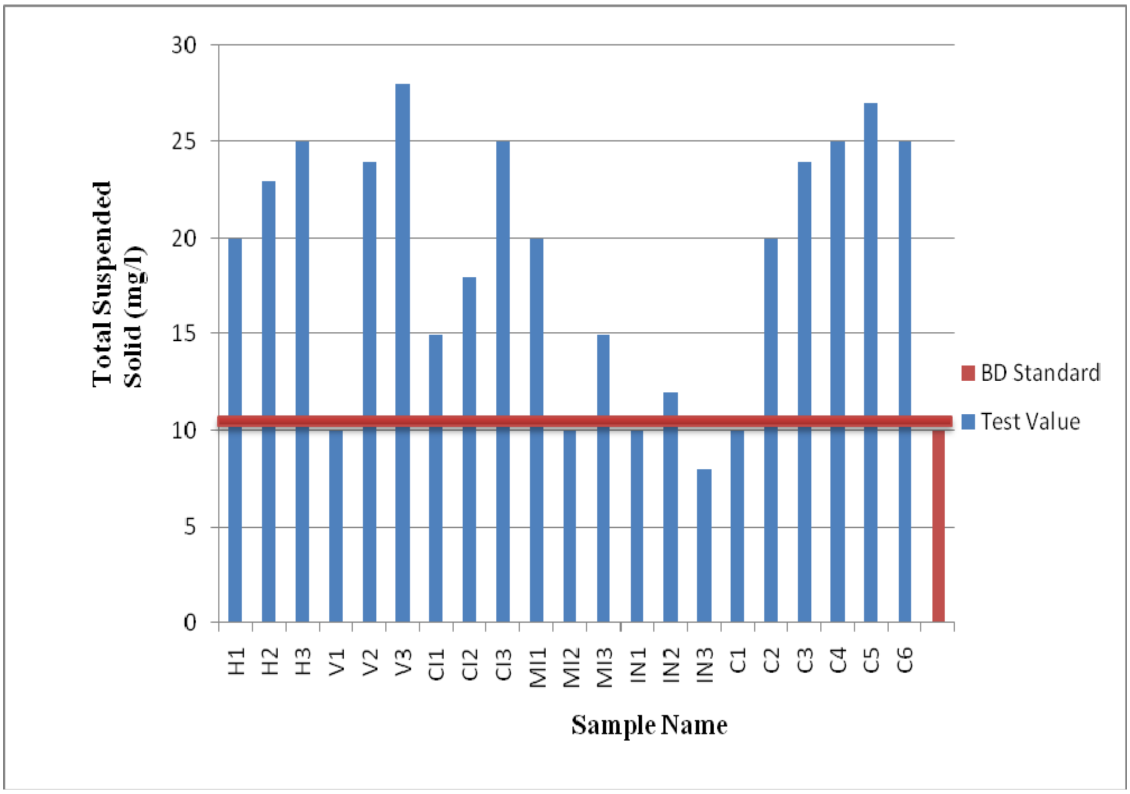

Fig.3: Total suspended solid value of different samples with standard values

CONCLUSION AND RECOMMENDATION

It has been observed that rainwater collected from rural areas, Coastal areas and midway between intersections satisfies all the standard values of water quality parameters of Bangladesh standards and WHO Guideline values except the value of total suspended solids. Thus this rain water could be used directly for washing without preservation and for irrigation purposes. For drinking, it should be required to filtrate the sample in order to remove total suspended solid. As a high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water. For more than 7 days after collection it should required to be preserved. Rainwater collected from Bahadharhat intersection and Kalurghat industrial area should be treated before drink. As color is not acceptable in drinking water from aesthetic view so it should be required to remove color. Color can be removed by Filtration and Aeration method. It has been observed that few sample of rain water are turbid. Turbidity must have to remove before using water as drinking water. Turbidity can be removed by Plain Sedimentation, Sedimentation with coagulation, Filtration.
For the severe scarcity of safe drinking water in rural, coastal and hilly areas of the country people could use rainwater for drinking purposes in dry season by adopting rain water harvesting system. Sustainable and ecologically designed RWH systems could be the solution to the present water crisis. A sustainable management of rainwater could be helpful to make an ecologically balanced environment. Groundwater recharge through the infiltration facilities provides a potential storage of water resource which can be withdrawn in the future if necessary. Further research on rainwater management system is imperative that could be helpful to reduce the pressure of groundwater during rainy season, and to reduce flooding and water logging as well.

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ARSENIC CONTAMINATION OF TUBE WELL WATER IN CHITTAGONG CITY- A CASE STUDY

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ABSTRACT

Arsenic, a semi-metal colourless, tasteless and odourless toxic element is known as the "King of Poison" at present. Arsenicosis is a well known chronic disease which occurs due to drinking of arsenic contaminated tube-well water having arsenic level exceeding the normal level for a prolonged period. It is likely to create a significant health impact ranging from skin lesions to cancer culminating in death. In 2008, Chittagong University of Engineering and Technology (CUET) and the Institution of Engineers Bangladesh, Chittagong Centre (IEBC) are jointly conducted a sample survey in 41 Wards, administrative sub-divisions, of the Chittagong city. From the research, Arsenic was found in shallow tube-well water in 13 city wards which exceeding WHO guides line value of 0.01mg/l. In the present paper, South Bakalia-a city ward is taken as the study area for detailed investigation where arsenic concentration was found 0.3mg/l to 0.4 mg/l in sample survey.
All the tube-wells of the ward are tested for measuring arsenic concentration in the field by collecting water sample from tube-wells using Wagtech Arsenic Field Test Kit (UK). Arsenic contaminated tube-wells are marked with red colour paint for future reference and to create public awareness. A total no of 45 Deep tube-wells water are also tested randomly throughout the ward and found free from Arsenic. Arsenic contamination is found only in shallow tube-wells and clustered in particular areas. Considering the result, Arsenic contaminated prone areas within the ward have been identified so that people of the area can take their drinking water from alternate sources.

Keyword: Chittagong city, Arsenic contamination, shallow tube-well, Arsenic prone area.

INTRODUCTION

Background
Bangladesh is facing perhaps the largest mass poisoning regarding Arsenic in history. Though the shallow tube-wells are free from pathogens but most of the shallow tube-wells 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 now are expected to experience a slow and painful death from Arsenic [1].

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 and found alarming amount of arsenic contamination in ground water of Bangladesh. Considering the Bangladesh standard limiting value (0.05 mg/l), about 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 0.01 mg/l and 0.05 mg/l respectively. It is widely believed that the contamination of people occurred only recently because of the extensive use of groundwater for drinking and irrigation purposes in the rural areas since the 1960s[2]. Major cities in Bangladesh like Dhaka and Chittagong were not covered by the survey, though ground water is extensively used in these two cities. In 2008, Chittagong University of Engineering & Technology (CUET) & the Institution of Engineers Bangladesh, Chittagong Centre (IEBC) are jointly conducted a samples survey in all 41 wards, administrative sub-divisions of Chittagong City Corporation (CCC).

Findings of the CUET- IEBC study 2008

In 2008, Chittagong University of Engineering & Technology (CUET) and institution of Engineers Bangladesh (IEB) [3], Chittagong centre conduct a joint research project for arsenic screening in Chittagong city. In that work, 10 samples from each ward collected and instantly tested on the spot by them. Total 410 samples have been collected from the whole city. Among the ten samples 7 of them obtained from shallow tube wells and rest of them from deep tube wells. The water samples obtained from the deep tube wells investigated did not contain traceable Arsenic. Water samples from nearly 32% of city wards were found to contain Arsenic above the WHO guideline value. Seven wards, out of total contaminated with Arsenic above Bangladesh standards. Arsenic was not found above 45m depth and 10.99% tube wells of all the shallow tube wells (282 tube wells) investigated was found to be contaminated with Arsenic. Hence screening of tube wells water for Arsenic as well as other drinking parameters is an immediate necessity for Chittagong city. Summary of that research have been shown Fig. 1 and Table 1. Wards coloured red in Fig 1, are the worst affected areas where Arsenic concentration exceeds Bangladesh standard limiting value of 0.05 mg/l [4].

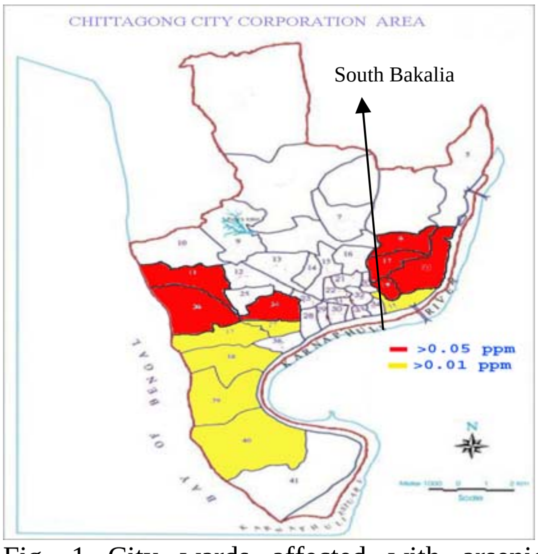

Fig. 1 City wards affected with arsenic contamination [C]

Table 1 wards exceeding WHO guide line value 0.01mg/l

Ward no	Ward name	Concentration (ppm)
6	East Sholashahar	0.50
11	South Kattali	0.20
17	West Bakalia	0.40
18	East Bakalia	0.08
19	South Bakalia	0.40
24	North Agrabad	0.08
26	North Halishahar	0.50
27	South Agrabad	0.05
35	Boxir Hat	0.05
37	North Middle Halishahar	0.04
38	South Middle Halishahar	0.04
39	South Halishahar	0.04
40	North patenga	0.04

Objective of the present study

As mentioned in article 1.2, ward 19, South Bakalia is one of the worst Arsenic contaminated ward in the range of thirty to forty times of the WHO limiting value of 0.01 mg/l, so the present study aims to fulfil the following objectives for screening Arsenic concentration within the ward 19. Location of the ward comprising the study area illustrated in Fig. 1.

- To determine arsenic concentration in all shallow tube wells water for the ward.
- To compare the result with WHO guide line value and Bangladesh standard
- To identify the arsenic contaminated area of the ward.

- To take measure for creating public awareness among the people in the ward.
- To check the safe distance of tube wells from latrine.
- Painting of arsenic detected tube wells by red colour.

Study area

The Study area comprises of ward-19:South Bakalia. South Bakalia (Ward No.19) is one of the As affected wards among 41 wards. It is surrounded by East Bakalia (No.18), West Bakalia(No.17), Boxir Hat(No.35), and Dewanbazar (No.20). It is located besides Raja Khali Khal. The area of this ward is 2.28 square kilometers (.88 square miles). It has population about 89 thousand and literacy rate about 63%. Location of the ward comprising the study area illustrated in Fig. 1.Considering a huge number of people using water from shallow tube well, assessing quality of water become very important.

METHODOLOGY

Shallow & Deep tube wells Defined

Local people in general consider a tube-well as shallow, when the well diameter is 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 38 mm, depth greater than the average tube-well and when motorized pumps are used for extracting water, the tube-wells are termed as deep tulle-well. In Chittagong, generally shallow tube-wells find water within a maximum depth of 200 ft. (about 60 meters). Deep tube-wells sunk in deep aquifer, on the other hand, having depth above 200 feet (above 60m).

Safe distance between tube well and latrine

Tube well, should be provided a minimum distance in order to allow for sufficient residence time for the pathogens to be eliminated. In absence of information on ground water flow in horizontal direction, a distance of at least 10m should be provided.

Field testing of tube-well water

Though testing of water samples from all the tube-wells in the Ward South Bakalia were aimed at, it is possible that some of the tube wells might have been left out of this survey. From 110 shallow tube-wells, about 33% were found contaminated with Arsenic *i.e.* 1/3rd of shallow tube-wells water of the ward have Arsenic. 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 samples. As the tube well owners without approval, generally avoids disclosing their identity for fear of retaliation by CWASA. Moreover, a few locations of shallow tube-wells may have gone unnoticed during the field survey. Like earlier CUET-IEBC study, Wagtech Arsenic field Test Kit has been shown in Fig. 2, was also used for field-testing of water samples from the tube-wells.

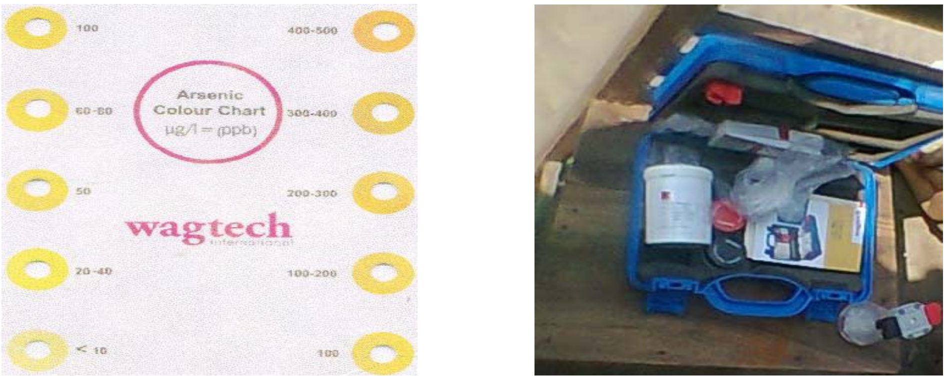

Fig. 2 Wagtech Arsenic kit box with colour chart

While using the test kit, procedures and instructions given by the manufacturers were followed. Field test in spot & Painting of arsenic detected tube wells by red color have been shown in Fig 3

Fig. 3 Field test in spot & Painting of arsenic detected tube wells by red color

The result of the field investigations of the contaminated tube-wells are given in Table2.

Table 2: Results of Arsenic screening of all the tube wells in ward-19

No of tube wells tested	No of tube wells As >0.05 mg/l (Bangladesh standard)		No of tube wells As>0.01 mg/l (WHO guide line value)		Remark
	No. of tube wells	%	No. of tube wells	%	
110	20	18.18	36	32.73	The tube wells were claimed to have been sunk to a depth varying between 15m to 60m

Source: Field investigation done in March & April 2012

RESULTS

The survey team tried to locate all the tube wells, both shallow and deep, in the area. A total of 110 tube wells were located in which more than 32% tube wells in this Ward are contaminated with Arsenic. Of the Arsenic contaminated tube-wells 18.18% are having contamination above the Bangladesh standard value of 0.05 mg/I.

Quite a number of tube wells are found to be having contamination in the range of six to eight times the Bangladesh limiting value. Affected areas of the ward are illustrated in Fig. 4 Mia khan Lane, Moidar Mill, Belagazir Bari and Abdul Karim Road, surrounding areas of Abujafor Road etc. are the worst affected areas in the ward. Deep tube-well in this report, were not found contaminated with Arsenic above the allowable limit.

Not every area of the Ward is densely populated. There are pockets of uninhabited low lying areas in the Ward. The areas found to be contaminated with Arsenic remains submerged under water for a few days for several times in every year. The Ward is partially covered by CWASA water supply network.

DISCUSSION ON RESULTS

Arsenic contamination of tube wells in the Ward, South Bakalia were found to be more severe than it was thought of after the CUET-IEBC sample survey in the year 2008. 32% of all the tube-wells in the ward is found to be contaminated with Arsenic compared to the earlier finding of 20%

in the CUET-IEB sample survey done in the year 2008. Three Arsenic contaminated prone areas are identified which are shown in Fig. 4 by red colour.

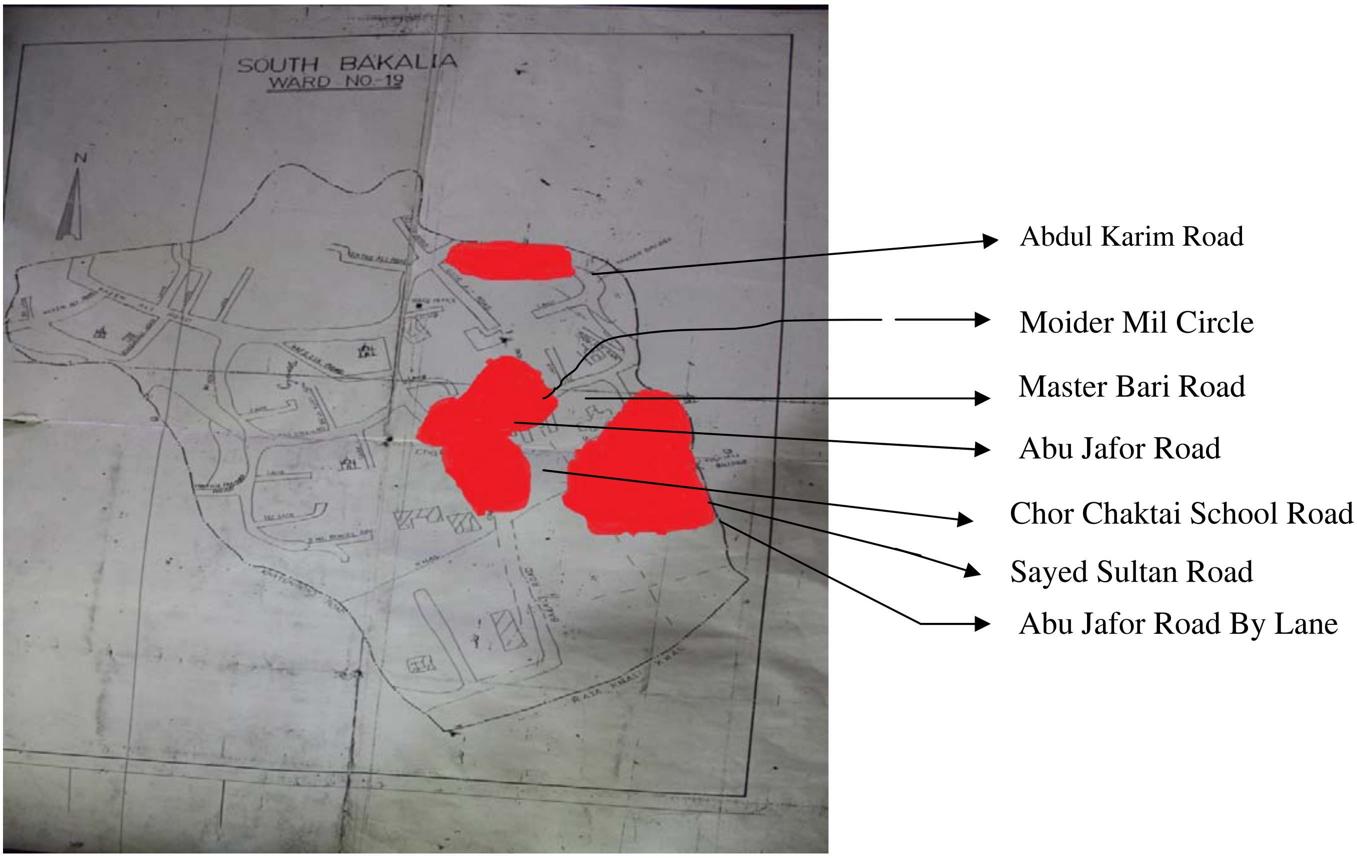

Fig. 4 Arsenic contaminated area of ward-19: South Bakalia

Awareness Programme

Awareness campaigns about arsenic can reduce the risk of many arsenic-related problems. Different types of awareness campaign have been conducted in Bangladesh since 1995. A variety of materials developed by different organizations have been used in awareness campaigns. The IEC materials included posters, banners, leaflets, stickers, flip charts, and TV and Radio messages and serials performed in different media. In addition awareness programme can also be done by village meetings, Courtyard meetings, orientation by Imam, school awareness programmes. It has been conducted a awareness programme at the councillor office of South Bakalia (Ward-19) at the initial stage of field survey for the local people of the area. Awareness campaign & raising public awareness by electronic media have also been conducted and it has been shown in Fig. 5. Arsenic contaminated tube-wells are marked with red colour paint for future reference and to create public awareness has been shown in Fig. 3.

Fig.5 Awareness campaign & raising public awareness by electronic media

CONCLUSION AND RECOMMENDATION

During field investigation high level of arsenic has been detected in 20 out of 110 shallow tube wells exceed Bangladesh standard (0.05ppm). If the WHO provisional guideline value of 0.01 ppm is considered, 36 tube wells exceed the limit within 110 shallow tube wells. Most of the affected tube-wells are having depth within 15-30 m. The arsenic affected areas are Mia khan Lane, Moidar mill, Belagazir bari and Abdul karim road are low laying area near the Rajakhali khal are often flooded during monsoon period. During flood the water remain stagnant for two to three days in those areas which may contains arsenic sediments. The reducing environment in organic matters. The deposition of recent sediments occurs each year in the flooded area like South Bakalia. The reducing soil environment in the deeply flooded areas appears to be conductive to the release of arsenic in groundwater. That may be one of the possible reasons of arsenic contamination in South Bakalia. Rajakhali khal, located in Bakalia, may have an additional reason of Arsenic contamination because of various industrial wastes containing arsenic compounds carried by it and deposited. During field investigation the distance between the tube well and latrine also measured. Most of the tube-wells are situated beside the latrine which may be contaminated by pathogens. . From the investigation it is clear that people of the affected area are not fully aware about arsenic related health hazards and safe distance between tube well and latrine.

Considering the gravity of the problem, all the tube wells in the remaining wards, identified as Arsenic affected in the CUET-IEBC study 2008, are to be screened for Arsenic content. Chittagong City Corporation (CCC), Chittagong Water & Sewerage Authority and NGOs working in the environmental sector can arrange the necessary finance for the proposed detailed study of the remaining Arsenic affected Wards. Users of the tube-wells which are in use for five years or more may have visible signs of arsenicosis. These people are to be identified and their medical needs assessed. Moreover, most of the tube-wells in South Bakalia 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 tube well waters may be screened for bacteria and faecal content.

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ECOSAN: AN ALTERNATIVE OF RESOURCE RECOVERY IN RURAL AGRICULTURE

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ABSTRACT

By emphasising the strong link between ecological sanitation (EcoSan) and agriculture, main objective is to improve food production in rural areas via the promotion of sanitized urine and faeces as an organic fertilizer. Sanitation refers to the principles and practices relating to the collection, treatment or disposal of human excreta, household wastewater and refuse as they impact on people and environment is to protect and promote human health by providing a good management of human excreta. A sustainable sanitation system has to be not only economically viable, socially acceptable and technically/institutionally appropriate, but also should protect the environment and natural resources. Ecological sanitation is benefited through reduction of using water to function; protection of the environment and providing the nutrients in human faeces and urine to be returned to the soil as fertilizer. EcoSan, increasingly recognized as a realistic and resources-oriented technology can provide an alternative source for fertilizer from human urine and faeces. It has been found that it not only protects water resources and enhances soil fertility but also optimizes resource management. This study aims at investigating the resource recovery through EcoSan toilets with regards to fertilize the soil in rural agriculture of Bangladesh.

Keywords: Ecological Sanitation (EcoSan), Agriculture, Fertilizer, Human Excreta, Sustainable

INTRODUCTION

Ecological sanitation is an approach to avoid the disadvantages of conventional wastewater system which is based on water as transport medium for collection and transport of human excreta via a sewer system. It includes wastewater treatment and disposal, vector control and other disease prevention activities that mean proper management of human excreta and urine ((Mashauri and Senzia, 2000). Nevertheless, EcoSan is a cycle or a system or a closed-loop system which treats human excreta as a resource where excreta are processed on site until they are free from pathogen and sanitized excreta are recycled by using them for agriculture purposes. EcoSan is the appropriate method of human excreta management, where this might be used as both organic matter and fertilizer. The EcoSan toilet uses a special pedestal or squat plate in which urine enters the front part of pedestal and then diverted through the pipe and thus separated from the faeces which fall directly downwards into a vault or container. Some wood ash is added to cover the faeces after every visit. This covers the deposit and helps to dry out the surface of the faeces and makes them easier to handle and transfer. The distinct advantage of this method is that the urine can be collected separately, making it available as a liquid fertilizer. Also the solid component, being in semi dry state, is much easier to handle and safer from the beginning, even if it does initially contain pathogens. Being semi dry, it does not smell so much and its potential as a fly breeding medium is much reduced compared to the mixes of urine and faeces. Eventually, the faeces become completely composted (Morgan, 2007).

Bangladesh is predominantly based on agriculture that is highly intensive and also subsistence of people to meet up demand of food security. Due to intensive cultivation, soil is losing organic content day by day for excessive use of chemical fertilizer and pesticides without application of organic matter. The low organic content is considered as one of the main reasons for low productivity of soils (Rahman, 2003). The crucial need for proper content of organic matter in soil should be top emphasized in view of the low organic matter content. Alternatively, to meet up demand of food, more inputs are used in form of fertilizer, pesticides, insecticides and irrigation, therefore a tremendous pressure in put on natural balance. A time has come now to look into overall problem of the indiscriminate use of pesticides and chemical fertilizer. Now agriculturist, policy planner and farmer also feel a great demand of organic farming for productivity, stability and sustainability of agriculture in rural Bangladesh. Organic farming is currently termed as ecological farming based solely on organic inputs, which have the potentials to reduce some of the negative impacts on conventional agriculture on the environment. Due to realize the crucial need of organic matter in soil and lack of alternative source of organic matter, human excreta should be used as fertilizer for its high nutrient content in Bangladesh agriculture. Conventional pit latrines have certain limitations especially in densely populated areas with risks of contamination of groundwater in rural areas are short of water and subject to critical environmental degradation (Niemezynowicz, 1996). A pit is usually filled to capacity within months or a year depending on its size and number of user. When it is fulfilled, the pit is broken and environment gets pollute. In contrast of ecological sanitation includes such as flush free urinals, urine diverting toilets, dry and composting toilets, dehydration devises for composting of faeces, uses faeces or excreta for generation organic fertilizer (Annam, 2004). EcoSan toilet insists on maximum possible reuse of nutrients from human excreta. Urine uncontaminated by faeces requires minimal processing and can easily be re-used in gardening as fertilizer. On the other hand, human faeces in a separate composting module of dry toilet are being dehydrated with solar energy and used as fertilizer.

In this study, it has been focused at investigating the resource recovery by organic fertilizer which is produced from EcoSan toilets with regards to fertilize the soil in rural agriculture of Bangladesh.

MATERIALS AND METHODS

The perception towards the resource recovery through sustainability of EcoSan toilets in rural areas of Keshabpur upazila under Jessore district was studied using household interview and observation. The survey was carried out in the village of South Banshbaria named EcoSan village in Sagardari Union. The village is low lying area and located in the bank of river “Kobadak” showing in Fig. 1. The survey was based on a sample of 40 out of 125 respondents. Most of residents in the villages are deprived and occupied with poor agriculture which was main source of income. However, EcoSan toilets are most appropriate for agriculture based families. The field survey was carried out in April, 2012. As a study area, the village was selected due to implementing pilot project on EcoSan toilets for duration of three years by an international agency, JADE that was funded by Toto limited, Japan; Mitsui Limited, Japan and Australian High Commission. The project was intended to improve a concept of ecological sanitation among villagers who lives in this area. The toilets were given out on first come first serve basis to residents who requested for the toilet through the project coordinator. The beneficiaries paid a small fee because the toilets were subsidized by the project.

Household interviews were conducted among 40 families in the village with support of a guide to locate household respondents' homes. In cases where the household head or landlord was not present, any adult in the sampled household was interviewed. Data was collected using a structured questionnaire comprising both open-ended and close-ended questions. For open ended questions, the respondent was at liberty to give multiple answers and also to bring to discussion other issues he/she thought are relevant to the questions. While close ended questions necessitated the respondents to rank, accept by indicating either yes or no answers. The questions were prepared in English language but translated into Bengali language in case the respondents felt more comfortable than speaking in English. However, some respondents were not willing to give information or be interviewed because they were busy at their work place while others were simply not interested because they have been interviewed several times by other researchers and that they have not seen any changes as a result. This necessitated a lot of convincing explanations by the interviewer to let those respondents accept to be interviewed.

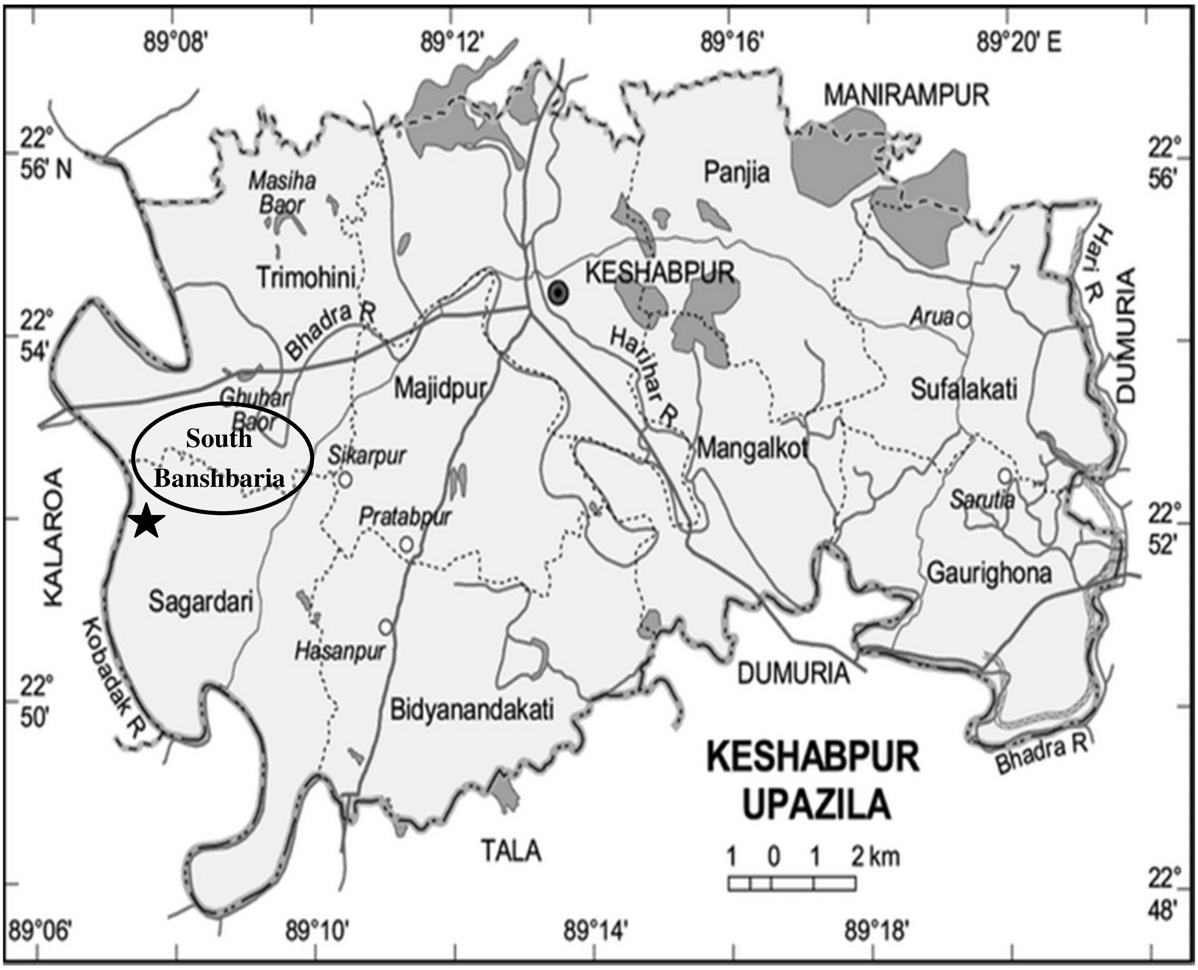

Fig. 1 Location of study area under Keshabpur Upazila of Jessore District
(Source: http://bdmaps.blogspot.com/2011/12/keshabpur-upazila.html)

RESULTS AND DISCUSSIONS

Progress of ecological sanitation

Households remain steady in no. of 125 in the village of South Banshbaria from year 2009 to 2011. Census data on the prevalence of toilets in the area shows an improved percentage of household sanitation with the EcoSan toilets in Fig. 2. Result of pre-survey showed 58 out of 125 no. of households (46.40%) had no fixed toilet for defecation and 56 out of 125 no. of households (44.80%)

used pit toilets with 2 (1.60%) no. of EcoSan toilet. So it is concluded that sanitation facilities was very poor in 2009. Lack of awareness about good sanitation, superior health protection and well hygienic environment is main reason for this problem. In one word, they were unknown to ecological sanitation. In 2011, rate of open defecation has been significantly reduced from 46.40% to 12% with ecological concept through providing EcoSan toilets. After passing two years (in 2011), sanitation facilities have been improved than previous situation in 2009. Recently, 61 families (49% of total families) are using EcoSan toilets when rate of using pit latrines and open defecation is 35% and 12% respectively. They are well known to use the toilet and its benefits. The toilet has achieved good response in the area and surrounding the village. Most of them have constructed the toilet very closed to their houses. They are well practiced to keep the toilet neat and clean. They are also capable to motivate others about the sanitation concept through benefit analysis of the toilets. However, the families who have not EcoSan toilet are not feasible due to economic and land scarcity.

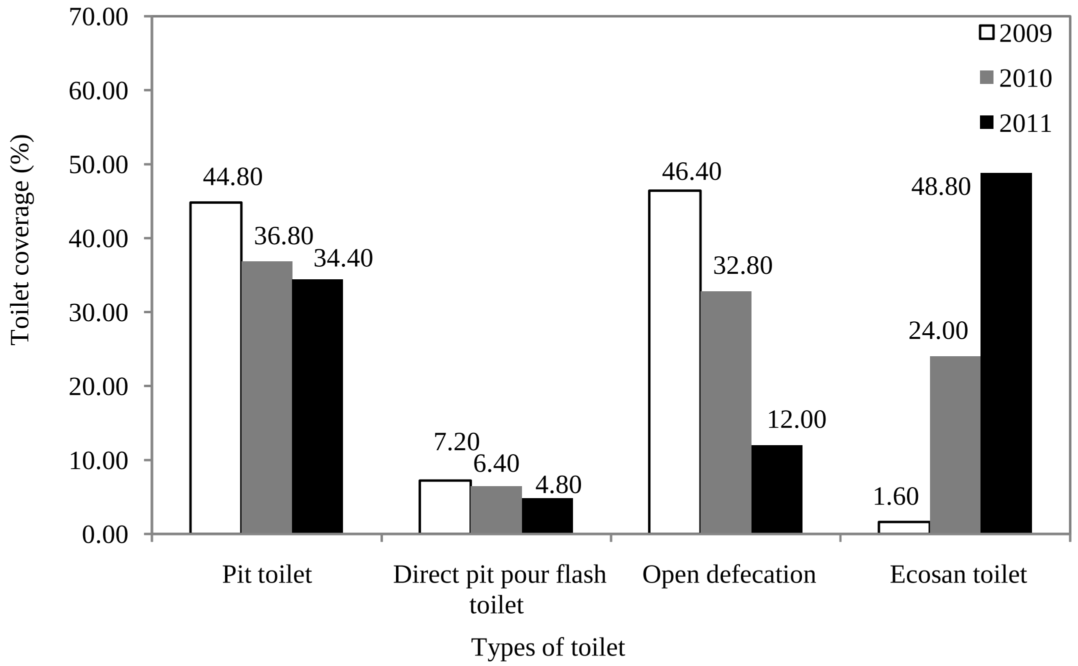

Fig. 2 Improvement of household sanitation in South Banshbaria from 2009 to 2011

Improvement of EcoSan family with organic fertilizer

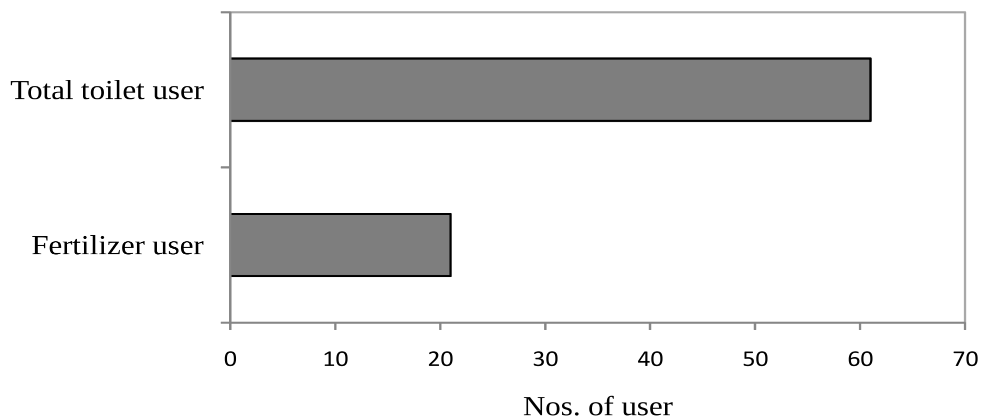

Fig. 3 Progress on practice of using organic fertilizer

Fig. 3 shows that 35% of EcoSan toilet user (21 out of 61 families) was improved with resource recovery using organic fertilizer in agricultural field. It is mentioned that the organic fertilizer was treated as result of recycling human excreta. The recycling process was occurred in faeces vault of EcoSan toilet. It is proved that people who have EcoSan toilet are being well practiced with using the fertilizer day by day. They are being interested getting benefits of organic fertilizer.

Potentiality of nutrient content

Potentiality of nutrient content in human excreta are N (3-3.4%), P_2O_5 (2.7-5.4%), K_2O (2.1-3.5%) and organic matter (Rose, 1999). Strauss (1985a) and Rose (1999) noted the nutrient content is outlined below:

Table 1: Potentiality of nutrient content

Nutrient	Human faeces (% dry weight)	Human Urine	Fresh night soil
N	4-5	15-19	10.4-13.4
P_2O_5	3-5.4	2.5-5	2.7-5.4
K_2O	1.25	3-4.5	2.1-3.5

So excreta are not only fertilizer but also soil conditioner due to its organic matter content which minimize the purchase of chemical fertilizer. As a consequence, treatment strategies and technological option for human excreta, and waste water will have to be developed which allow the optimum recycling of nutrients and organic matter to rural agriculture, while being adapted to the local situation and demands.

Urine and faeces content

Human excreta not only contain the nutrients; nitrogen, phosphorus and potassium which are valuable for agriculture but also many pathogens which are harmful to human body. The contents of excreta composed of urine and faeces are shown in table 2.

Table 2: The contents of urine and faeces

	Urine (500L/person/year)		Faeces (50L/person/year)	
	gm/person/day	% in excreta	gm/person/day	% in excreta
Nitrogen	11.0	88	1.50	12
Phosphorus	1.0	67	0.50	33
Potassium	2.50	71	1.0	29
Pathogens	Little		Much	

Harada, 2006

a) In case of urine

Total amount of nitrogen $= \frac{11*365}{500} = 8.03$ gm/Lit in form of ammonia (NH_3) that is source of urea fertilizer

Total amount of phosphorus $= \frac{1.0*365}{500} = 0.73$ gm/Lit

Total amount of potassium $= \frac{2.50*365}{500} = 1.83$ gm/Lit

b) In case of faeces

Total amount of nitrogen $= \frac{1.50*365}{500} = 1.10$ gm/Lit

Total amount of phosphorus $= \frac{0.50*365}{500} = 0.37$ gm/Lit

Total amount of potassium $= \frac{1.0*365}{500} = 0.73$ gm/Lit

Form above calculation, it is found that both urine and faeces contain nitrogen, phosphorus and potassium but urine is rich in quantity for which urine is more effective than faeces. Depending on the result, it is understood that both urine and faeces act as a replacement of chemical fertilizer. Thus, EcoSan was made an alternative source of chemical fertilizer. Nonetheless, EcoSan acts as an alternative of resource recovery.

CONCLUSION

EcoSan toilet is an approach to both improved sanitation and promoted nutrient recovery from human excreta. In addition, EcoSan can provide comfortable toilets for people in rural areas of Bangladesh. EcoSan toilet is not only compulsory but also ecological concept with resource recovery that is most imperative for\ rural people to lead themselves diplomatic life. It is an appropriate technology to improve the rural sanitation and agriculture. Acceptance of EcoSan technology in this area is good. EcoSan technology is considered as most expectable alternative for resource recovery through producing organic fertilizer with regards to fertilize the soil in rural agriculture of Bangladesh.

ACKNOWLEDGMENT

The authors would like to express deep gratitude to non-profitable international organization named Japan Association of Drainage and Environment (JADE) that implemented the EcoSan project, funded by Toto limited, Japan; Mitsui limited, Japan and Australian high commission for the study. Many thanks go in particular to the rural people who helped them to complete the research successfully. Finally, we express our gratefulness to the god.

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CHARACTERIZATION AND OPTIMIZATION OF COAGULATION OF TEXTILE EFFLUENT COLLECTED FROM GAZIPUR AREA

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ABSTRACT
Serious environmental pollution has been happened in Bangladesh. Among all the pollution problems, the water pollution has become alarming in our country. The river water of different rivers of Dhaka, Narayangonj and Chittagong is highly polluted because of direct discharge of untreated industrial effluent to different rivers, Burigonga, Shitalakkhya, Turag, Balu and Kornofuly. The water pollution contributed by Textiles created a bad impact to the environment. The source of water pollution contributed by textiles is wet processing. Characterization of Textile effluent is necessary for environmental protection in our country. The analytical results of the physicochemical parameters, pH, TDS, DO, COD and BOD_5 showed that most of the values were larger than acceptable limits. In the present work, we have collected 30 Textile effluent samples from Gazipur area and temperature, color, odor, pH, TDS, DO, COD and BOD_5 were measured. We obtained high pH (11.3), TDS (3012 mg/L), COD (323 mg/L), BOD_5 (126 mg/L) and low DO (1.92 mg/L). It should be noted that national discharge limits of Textile effluent are pH (6-9), TDS (2100 mg/L), DO (4.5-8 mg/L), COD (200 mg/L) and BOD_5 (50 mg/L). On the other hand some samples were collected for optimization for coagulation. Three coagulants were used for coagulation experiments. Those were potash alum, ferrous sulphate and ferric chloride. Potash alum was the best coagulant as per experimental results.

Keywords: Textile Effluent, pH, COD, BOD_5, Coagulation.

INTRODUCTION

Serious environmental pollution has been happened in Bangladesh. Among all the pollution problems, the water pollution has become alarming in our country. The river water of different rivers of Dhaka, Narayangonj and Chittagong is highly polluted because of direct discharge of untreated industrial effluent to different rivers, Burigonga, Shitalakkhya, Turag, Balu and Kornofuly (Guha 2010 and Islam et al., 2011). The water pollution contributed by Textiles created a bad impact to the environment. Though the ready made garments (RMG) sector of Bangladesh exported 3971.52 Million US$ in the fiscal year 2010-11 which was 78.97% to total export of Bangladesh (BGMEA website). To support ready made garments various Textile industries are needed, such as, spinning, knitting, weaving, dyeing, printing and finishing. The source of water pollution contributed by Textiles is wet processing. We know that huge water is used in wet processing. So characterization of Textile effluent is necessary for environmental protection in our country. Area based characterization of textile wastewater was done recently (Guha 2011 and Guha 2010). Guha and coworkers reported (Guha 2011 and Guha 2010) high pH and TDS values in Textile effluent samples of Chittagong, Narayangonj, Savar, Ashulia, Dhamrai and Gazipur areas. For example they found pH (14) and TDS (3304 mg/L) in effluent samples of Narshindi and Gazipur areas respectively. But the parameters such as DO, COD, BOD_5, and TSS were not measured in effluent samples of above areas. Roy and coworkers (Roy et al., 2010) reported high pH (11.2), TDS (4356 mg/L), TSS (336 mg/L), COD (800 mg/L) and BOD (299.1 mg/L) values in Textile effluent samples of H.R. Textiles of Savar, Dhaka. Textile effluent analysis was also done by other workers (Rahman 2008, Ahmed 2007, Saha 2007 and Kabir 2002). It requires more studies for complete characterization of Textile effluent samples collected from various situations of different Textile industrial zones of Bangladesh. From this view point we collected Textile effluent samples from various situations of Gazipur area and analyzed physicochemical parameters (color, odor, temperature, pH, TDS, DO, COD and BOD_5). In addition we also carried out jar tests for coagulation optimization of different effluent samples. Because it is well known that coagulation is an important treatment method for chemical treatment of effluent which is defined as "Coagulation is the clumping together of very fine particles into larger particles caused by the use of chemicals (coagulants)" (Kerri 1998). We varied coagulants to find out optimum condition for textile effluent coagulation of Gazipur area.

MATERIALS AND METHODS

The samples were collected from different regions of Gazipur area. Different sampling situations are shown in [Fig. 1]. Clean and dry plastic bottles were used for sampling and immediately measured the temperature, color, and odor for accurate results. The samples were stored in an ice box and sent to four laboratories (BUET, DoE lab, Reedisha Knitex Lab and Department of Textile Engineering, Southeast University) because all instrumental facilities were unavailable in the laboratory of Southeast University and those samples were analyzed within six hours of sampling. In BUET and DoE. USEPA standard methods of analysis were followed. The COD method of analysis was USEPA 410.4; SM 5220D, on the other hand the BOD_5 method of analysis was USEPA 410.1; SM 5210B; SM 5210D and the DO method of analysis was USEPA 360.3; 360.2; SM 4500-OB,G. In Reedisha Knitex Lab pH, TDS and DO were measured by using pocket-sized pH meter (Hanna Instrument, Model No: HI98108, Country of Origin: USA), TDS meter (Hanna Instrument, Model No: HI98301 , Country of Origin: USA) and digital DO meter (LTLtorn, Model No: DO5509 , Country of Origin: Taiwan) respectively. The pH, TDS and DO were measured in the Southeast University lab by using pocket-sized pH meter (Hanna Instrument, model no. HI96107, Country of Origin: China) and TDS meter (Hanna Instrument, model no. HI98301, Country of Origin: China) and digital DO meter (LTLtorn, Model No: DO5509 , Country of Origin: Taiwan) respectively. All the meters were calibrated as per instructions of the operation manuals of the manufacturing companies. For example the pH meter was calibrated by using a standard buffer solution, pH=7.01. The optimization of coagulation was done by jar test in this work in the laboratory of Southeast University. Three types of coagulants were used, potash alum [$K_2SO_4.Al_2(SO_4)_3.24H_2O$], ferrous sulphate ($FeSO_4$) and ferric chloride ($FeCl_3$). The coagulation was done by mixing 100 mL of sample effluent with 100 mL of coagulant solution (100 mL deionized water + 30g coagulant). The resultant solution was kept 2 hours and observed changes at three stages, just after addition of coagulant, after 1 hour and 2 hours.

Fig. 1. Photographs of sampling places.

RESULTS

The textile effluent samples of Gazipur area collected from different discharge points of industries, ponds, canals, open areas and paddy fields. The obtained analytical results have been listed in [Table 1].

Table 1: Analytical Results of Textile Effluents of Different Regions of Gazipur Area.

Sl. no	Sampling Date	Regions	Sampling Situation	Color	Odor	Temp. (^{0}C)	pH	TDS (mg/L)	DO (mg/L)	COD (mg/L)	BOD_5 (mg/L)	Remark
1	25.02.12	Donua	Discharge	Black	Odor less	32	7.8	2360	5.81	140	10	Done by DoE
2	10.03.12	Donua	Discharge	Black	Odor less	27.5	7.2	2218	2.8	41	28	BUET
3	13.03.12	Donua	Pond	Black	Foul	35	10.2	2713	4.6	308	108	DoE
4	13.03.12	Donua	Canal	Black	Foul	33	10.1	2699	3.2	301	98	DoE
5	22.03.12	Joina	Canal	Reddish	Foul	36	10.4	2909	2.13	323	126	DoE
6	23.03.12	Nayanpur	Open area	Bluish	Pungent	28.5	8.9	2308	4.3	-	-	Southeast University
7	23.03.12	Chokpara	Pond	Bluish	Foul	27	10.2	2709	5.4	-	-	Southeast University
8	23.03.12	Maona	Canal	Black	Pungent	27	10.3	2603	3.27	-	-	Southeast University
9	23.03.12	Masterbari	Pond	Greenish	Pungent	30	9.2	2631	2.15	-	-	Southeast University
10	23.03.12	Masterbari	Canal	Greenish	Foul	28.5	10.6	2703	4.32	-	-	Southeast University

11	25.03.12	Mouchak	Open area	Greenish	Pungent	29	9.6	2821	5.41	-	-	Southeast University
12	25.03.12	Razendrapur	Canal	Black	Foul	29.5	9.8	2938	2.73	-	-	Southeast University
13	25.03.12	Rongilabazar	Pond	Bluish	Pungent	30	10.5	2818	2.1	-	-	Southeast University
14	25.03.12	Anserroad	Canal	Bluish	Pungent	28.5	9.5	2796	3.42	-	-	Reedisha Knitex
15	25.03.12	Maona	Canal	Black	Foul	29.5	10.1	2609	2.03	-	-	Reedisha Knitex
16	26.03.12	Maona	Pond	Black	Pungent	28	9.6	2594	3.91	-	-	Reedisha Knitex
17	26.03.12	Razendrapur	Pond	Bluish	Pungent	29	10.3	2545	2.82	-	-	Reedisha Knitex
18	26.03.12	Tongi	Canal	Black	Pungent	31.5	11.3	3012	1.95	-	-	Reedisha Knitex
19	26.03.12	Razendrapur	Paddy field	Greenish	Foul	28.5	10.8	2503	2.03	-	-	Reedisha Knitex
20	26.03.12	Boardbazar	Open area	Greenish	Pungent	31	10.7	2370	3.27	-	-	Reedisha Knitex
21	27.03.12	Boardbazar	Canal	Blusih	Pungent	30.5	10.6	2874	2.51	-	-	Reedisha Knitex
22	27.03.12	Joydebpur	Open area	Black	Foul	29	10.5	2983	4.16	-	-	Reedisha Knitex
23	27.03.12	Mouchak	Pond	Black	Pungent	29.5	10.9	2509	3.86	-	-	Reedisha Knitex
24	28.03.12	Konabari	Canal	Bluish	Foul	30	10.3	2456	3.14	-	-	Reedisha Knitex
25	28.03.12	Shalna	Open area	Black	Foul	30	9.8	2708	4.11	-	-	Reedisha Knitex
26	28.03.12	Bagerbazar	Canal	Greenish	Foul	31	10.2	2615	2.03	-	-	Reedisha Knitex
27	30.03.12	Shalna	Canal	Greenish	Pungent	31.5	9.6	2374	2.12	-	-	Reedisha Knitex
28	30.0312	Chondra	Open area	Black	Foul	33.5	10.6	2874	3.24	-	-	Reedisha Knitex
29	30.0312	Kaliakoir	Canal	Black	Foul	32.5	10.4	2914	2.58	-	-	Reedisha Knitex
30	30.0312	Kaliakoir	Open area	Black	Foul	32	9.8	2598	3.78	-	-	Reedisha Knitex

The jar tests were carried out to optimize coagulation process. Effluent samples were collected from five sampling points varying situations, raw effluent, oxidation tank, pond effluent, canal effluent and paddy field.

DISCUSSIONS

The samples collected from the discharge points were odor less but samples collected from pond, canal, and open areas had foul and pungent odors. The colors of samples were black, reddish, bluish and greenish in different situations. All the recorded temperatures were within discharge limit. The discharge limit of temperature of Textile effluent guided by Department of Environment (DoE) is 40 ^{o}C (DoE website). We obtained pH (7.2-11.3) in 30 samples of effluents of Gazipur area. Most of the pH values were above 10 which were above the acceptable limit (6-9). The high pH values were indicative of strong alkaline nature of effluent. As a result fishes of water bodies of Gazipur were died remarkably. Only 25 ppm NaOH is deadly for fish (Pandey 2005). Similar pH values in Textile effluent samples were found in previously reported papers (Guha 2010, pH = 7.1-9.8, Roy et al., 2010, pH = 9.6-11.2). The total dissolved solids (TDS) of this work were larger than its limit. The obtained values of TDS were (2308-3012 mg/L), the discharge limit of TDS is 2100 mg/L. The reported TDS values were 2380 mg/L (Rahman 2008), 2808 (Guha 2010), 3392 mg/L (Roy et al., 2010). The dissolved oxygen were found ranging from 1.95 mg/L to 5.81 mg/L. The dissolved oxygen (DO) content should be 4.5-8 mg/L according to DoE standard. Most of the obtained DO levels of the present work were below 4.0 mg/L [Table 1]. The reported DO values of Textile effluent were 2.15-5.9 mg/L (Ahmed 2007) which were very close to obtained values in the present work. As we know that Textile effluent consists of huge oxygen demanding organic wastes. So it is necessary to check BOD_5 values of collected Textile effluent samples. In the present work we analysed 5 samples to check BOD_5. The obtained BOD_5 values were 10-126 mg/L. Among 5 samples 2 BOD_5 values (10 and 28 mg/L) were within limit. The other three values (98, 108 and 126 mg/L) were 2-2.5 times larger than national discharge limit (50 mg/L). The previously reported BOD_5 values were 94.33-141.66 mg/L (Ahmed 2007) and 151.24 mg/L (Roy et al., 2010). The COD values 41-323 mg/L were found in 5 samples in the present work. Among 5 samples the COD values of 2 samples (41 and 140 mg/L) were within the limit and remaining 3 samples (301, 308 and 323 mg/L) were 1.5-1.6 times larger than its corresponding standard guided by DoE (200 mg/L). The reported COD values were 170.88-854.4 mg/L (Ahmed 2007). The fig. 2 shows COD and corresponding BOD_5 values of five effluent samples.

The jar tests for optimization of coagulation of Textile effluent of Gazipur area were done. Three types of coagulants were used in this work. Those were potash alum, ferrous sulphate and ferric chloride. The best results were achieved in case of potash alum understood by observing three stages changes of color and turbidity. The change in color and turbidity after two hours was remarkable in case of potash alum [Fig. 3]. The color and turbidity were reduced more in potash alum than other coagulants. In a previous report (Amokrane et al., 1997), it was concluded that among three coagulants, potash alum, ferrous sulphate and ferric chloride, high efficiency was found during the reaction of potash alum for the treatment of stabilized leachates.

The findings of this paper need to de discussed at a glance. After experimental works we were able to achieve analytical results of physicochemical parameters such as color, odor, temperature, pH, TDS, DO, COD and BOD_5 of samples of Textile effluent collected from Gazipur District of Bangladesh. We got various colors, such as black, greenish, bluish etc., foul and pungent odors, Temperature (27-36 ^{o}C), pH (7.2-10.9, most of the values were above 10), TDS (2218-3012 mg/L), DO (1.95-5.81 mg/L) COD (41-323 mg/L) and BOD_5 (10-126 mg/L). The obtained temperatures were within acceptable limit. Most of the values of the other parameters (pH, TDS, COD and BOD_5) were above the acceptable limits. The most of the obtained DO values were less than 4 mg/L which were also much lower than acceptable limit. The acceptable limits are pH (6-9), TDS (2100 mg/L), DO (4.5-8 mg/L), COD (200 mg/L) and BOD_5 (50 mg/L) guided by the Department of Environment of the Govt. of Bangladesh.

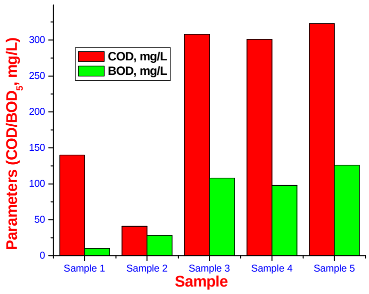

Fig. 2 .The column diagram of parameters (COD/BOD_5 mg/L) vs. sample.

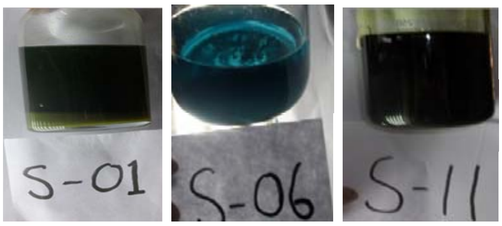

Fig. 3. Photographs of jar test experiments. S-01: ferrous sulphate, S-06: potash alum and S-11: ferric chloride.

From the above findings it could be easily understood that many Textile wet processing industries in Gazipur area discharge huge effluent containing excess toxic substances with larger values of physicochemical parameters than DoE standards. Another important point should be noted. Literature survey showed that most of the reported effluent characterizations were done in some particular industries. But in our country the existing scenario is very critical. Commonly the industrial effluent samples show excellent test results but remarkable quantity of untreated effluents have been discharged by using bypass pipe lines to the canal, paddy field, open areas, river even in front of residential areas. By physical inspection we verified this information at Gazipur area. In this paper we reported our experimental results of effluent samples collected from various situations like canal, pond, paddy field, open areas etc. to find out real pollution level. So these effluents are detrimental for our Environment. This effluent is also a public threat at the locality.

In this paper, we also reported the most suitable coagulant for chemical treatment of the effluent. The Jar test results showed that the best coagulant was potash alum. Because of excellent separation of sludge and color removal were observed by potash alum. We also done Jar tests for coagulation by ferrous sulphate and ferric chloride to compare results between three coagulants used in this work.

CONCLUSION

The analytical results of physicochemical parameters of Textile effluents of Gazipur area indicate alarming situation of pollution in many cases. For Environmental protection, quantitative determination of physicochemical parameters of Textile effluent is necessary. Literature survey showed that there are some reports related to Textile effluent characterization. But it needs more studies regarding Textile effluent characterization in our country. Effluent characterization and treatment are essential in our country as per Environment Conservation Rule (ECR) as well as for buyer’s demand. By monitoring of key parameters of Textile effluent such as pH, TDS, DO, COD and BOD, ETP managers and workers will be able to run ETP perfectly so that the Environment will be protected. Due to lack of appropriate pH and insufficient oxygen faulty treatment in biological plants has been observed. Different types of chemicals and auxiliaries such as alkalis, salts, dye stuff; enzymes etc. are dumped with effluent from Textile industries. Effluents also contain heavy metals and surfactants. In this paper we reported the obtained values of physiochemical parameters of Textile effluent samples. Most of the obtained values were above the acceptable limits. We obtained Temperature (27-36 ^{o}C), pH (7.2-10.9, most of the values were above 10), TDS (2218-3012 mg/L), DO (1.95-5.81 mg/L), COD (41-323 mg/L) and BOD_5 (10-126 mg/L). The standards are pH (6-9), TDS (2100 mg/L), DO (4.5-8 mg/L), COD (200 mg/L) and BOD_5 (50 mg/L). Proper effluent treatment is necessary before discharging the effluent. The optimization of coagulation varying coagulants concludes that potash alum was the best coagulant for coagulation of effluent. In our country some common coagulants such as ferrous sulphate, potash alumn and lime are used in Textiles ETP. But it needs proper R & D studies before selection of appropriate coagulants in ETPs. Due to lack of enough technical knowledge this is not practiced in our Textile sector. Our findings would be helpful for designing, treatment and monitoring of ETP in Textile sector in Gazipur as well as other areas.

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AUTOMATIC SORTER MACHINE FOR SMART WASTE MANAGEMENT SYSTEM

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ABSTRACT

Waste management is one of the most challenging tasks in a modern world. If the wastes are not properly handled, it may become a great concern for the authority. But, by managing wastes effectively and recycle efficiently, it may be found as a resource of the country. In this work, an automatic sorter machine is developed which can sort out the wastes in various categories to make waste management easier and efficient. It can be possible to sort out metal, paper, plastics and glass by developing an electromechanical system using microcontroller and operational amplifier. For sorting metal and glass conventional sensors are used and for sorting paper and plastics a sensor using LASER and LDR is developed. A weight sensor and counter is used to find out the amount of sorted materials. By using the proper recycling system, the curse of waste will turn into blessings for the civilization. The sorting procedure will make recycling more efficient. By means of this waste sorter, the conventional waste management system will be transformed into SMART system. This SMART system will help to make our environment more suitable for living, reducing global warming and making the world healthier.

Keywords: *A*utomatic Sorter Machine; Smart waste management; Microcontroller; Operational amplifier.

INTRODUCTION

From the beginning of the human civilization, people used various methods of waste disposal to get rid of unwanted material. Sometimes it was buried in the land, thrown in the sea, fed to the animal or burnt. Getting rid of unwanted material is always a major concern for the modern society. Trash has played a tremendous role in history. The Bubonic Plague, cholera and typhoid fever, to mention a few, were diseases that altered the populations of Europe and influenced monarchies. They were perpetuated by filth that harboured rats, and contaminated water supply [1]. When wastes are not properly managed then it may cause serious hazard, as seen in 1350. "Black plague" erupted and more than 25 million people from all over Europe fall victim to it in just five years [2]. There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47,064 tonnes per day by 2025. The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6 in 2025. A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement [3]. The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the people of Bangladesh [4]. This is not the only problem of Dhaka city but also for other big cities around the world [5]. With so much concern recently about being greener and economically friendly, waste management has become a very important topic. People and companies are starting to realize that the things they use and the way they dispose of them can make a big impact on our world. Proper management of waste plays a vital role in global environment. That is why a waste sorting system is designed which can be used in houses, offices, industries as a part of smart waste management system.

PRESENT STATUS OF SOLID WASTE GENERATION

Present condition of the solid waste generation can be described in different point of views. The generation and management of solid wastes are described in World and Bangladesh perspective.

World Scenario

Confederation of European Waste to Energy Plants (CEWEP) [6] and European Environment Agency (EEA) [7] provides sound, independent information on the environment.

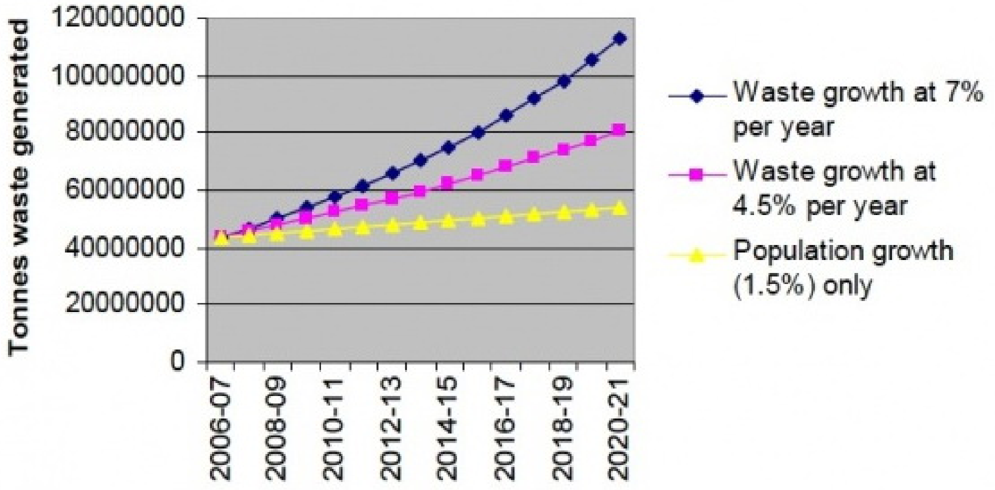

Fig. 1 Comparative waste generation 2006-07 to 2020-21.

Fig. 1 has been generated from the corresponding data from CEWEP and EEA [6,7]. Considering present condition, waste growth at 7% per year is plotted. Considering future waste reduction, waste growth at 4.5% per year is plotted. Fig. 1 illustrates the fact about the total generation of wastes around the word. The total amount is increasing day by day and hence the waste management is becoming a challenge for both the developed and developing countries. Hence, recycling is becoming very important [5]. Recycling is a resource recovery practice that refers to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items are made can be reprocessed into new products. For recycling the waste is required to separate into various different bins. As it enables us to convert waste into a valuable resource, gradually this practise is gaining popularity.

Bangladesh Scenario

The waste generation amount by Zone (shown in Fig. 2a) [8] at Dhaka metropolitan city, Bangladesh is shown in Fig. 2b. The zonal average of waste generation is estimated at 320 t/d (tonnes per day) with the maximum at approximately 460 t/d in Zone 8 and the minimum at 43 t/d in Zone 10. The zonal waste generation reflects the population size and business activities in each zone [8].

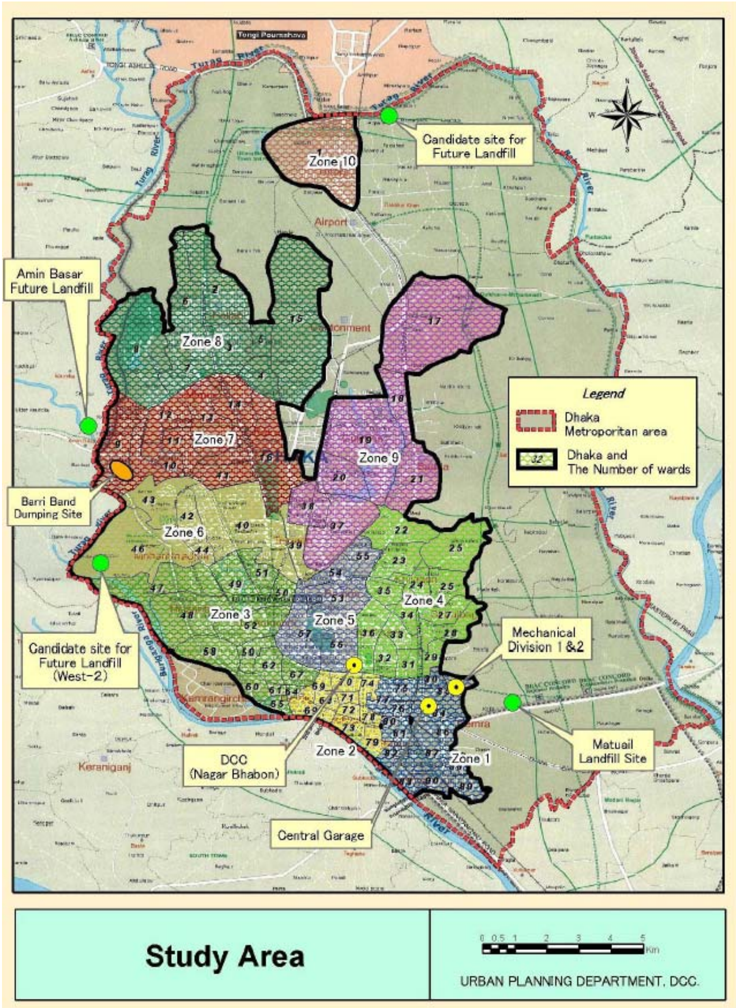

Fig. 2a Different zones of Dhaka metropolitan city, Bangladesh

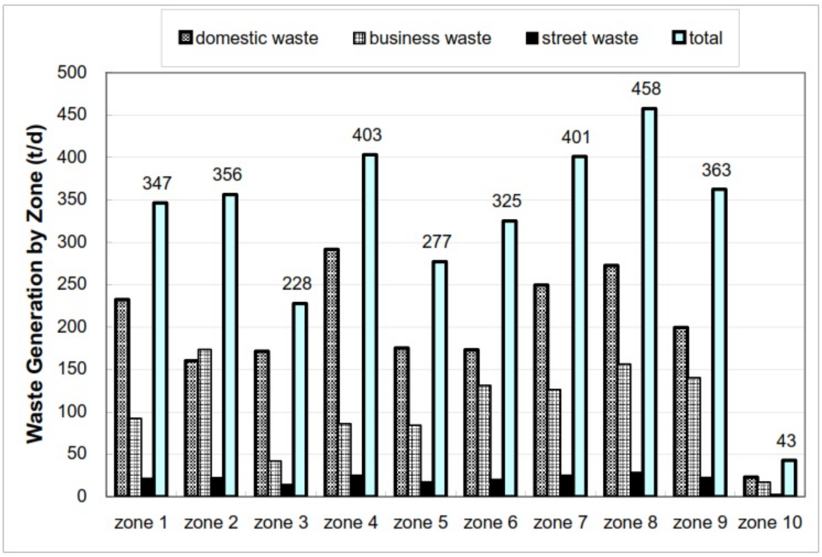

Fig. 2b Waste generation amount by zone at Dhaka metropolitan city, Bangladesh.

Estimated Volume of paper, glass, metal and plastic waste generation in Dhaka City is shown in Table 1 [8].

Table 1. Estimated generation for paper, glass, metal and plastic waste in Dhaka city

Materials	Estimated Generation (t/d)
Plastic	124
Paper	260
Glass	46
Metal	27
Total	457

OPERATIONAL METHOD

The system activates when the IR detects some sorts of material is being put on the system tray. Then at first the weight sensor activates and find out the weight of the trash, then the metal sensor and glass sensor starts their actions. If metal sensor detects the material as metal, then a servo motor will put that trash in the bin 1 (which is dedicated for metals). If the glass sensor detects glass then it will perform same action and put the trash in bin 2. If both sensors fail to detect then the LASER and LDR activates. If the LASER passes through the trash then it is decided as a transparent and moves to bin 3. If the LASER fails to pass then the material is decided as Paper and move to bin 4.

SORTING SYSTEM DETAILS

The sorting system consists of Light Dependent Resister (LDR), LASER, Infrared (IR) transmitter and receiver, Metal Sensor (Capacitive proximity sensor *E2K-C*) [9], glass sensor (Omron E3SCR67C), Weight Sensor (MLC900 micro weight sensor) [10] and a Liquid Crystal Display (Alpha-numeric 16*4 LCD). The whole program is run by a microcontroller (PIC 16f877A) [11].

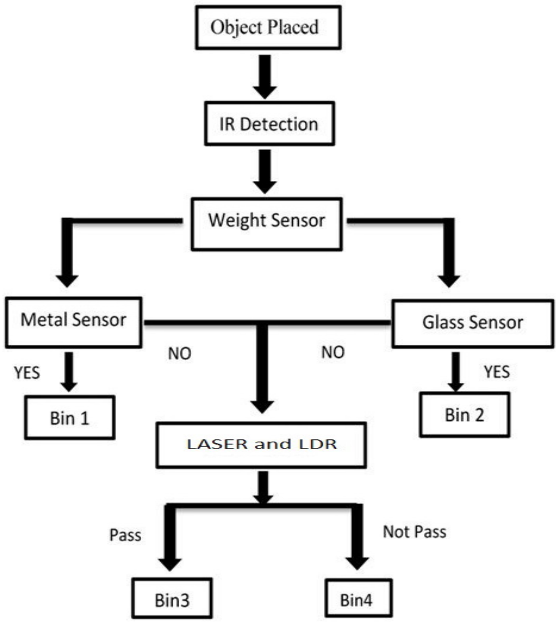

Fig. 3 Sequential Logic Flow Chart.

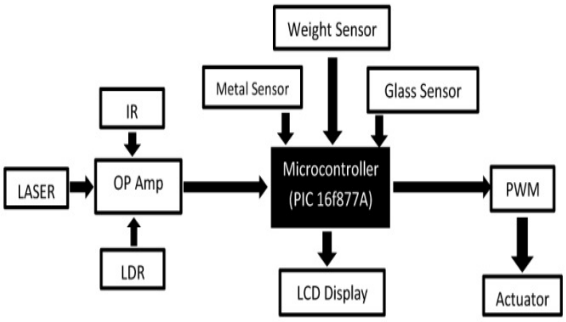

Fig. 4 Block diagram of the sorting system.

A servomotor (HS-65MG, Mighty Metal Gear Feather Servo) [12] based electro-mechanical system works as an actuator which puts trash in the desired bin. The microcontroller will count the trash sequence number and also the total weight of definite type of wastes.

ELECTROMECHANICAL SETUP

In this system there are four bins. Each bin contains unlike materials. Bin 1 is for metallic elements, bin 2 is for glass particle, bin 3 is for plastic bottles and bin 4 is for paper. First the object is placed at the detection zone. The sensor detects the material and a signal comes out from microcontroller that run the servo motor to a definite direction depending on the material that is being sensed.

A servo motor is a motor which forms part of a servomechanism. The servo motor is paired with some type of encoder to provide position/speed feedback. This feedback loop is used to provide precise control of the mechanical degree of freedom driven by the motor. A servomechanism may or may not use a servomotor. For example, a household furnace controlled by a thermostat is a servomechanism, because of the feedback and resulting error signal, yet there is no motor being controlled directly by the servomechanism. Servo motors have a range of 0°-180° [13].

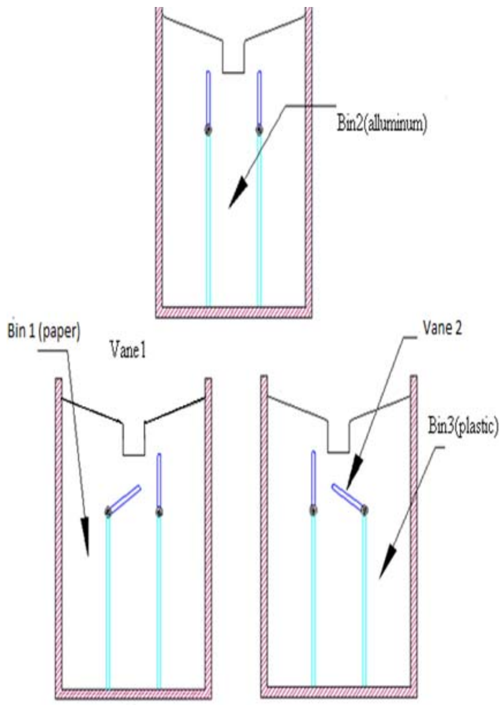

Fig. 5 Sorting mechanism

The Servo motor is controlled by sending a pulse of variable width by the microcontroller. The control wire is used to send this pulse. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and a repetition rate. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the clockwise direction as it does in the counter clockwise direction. It is important to note that different servos will have different constraints on their rotation but they all have a neutral position, and that position is always around 1.5 milliseconds (ms). The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse width Modulation [13].

The servo expects to see a pulse every 20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 90 degree position (neutral position). When these servos are commanded to move they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position [14].

Fig. 6 Servo Motor (HS-65MG)

COMPARATIVE STUDIES

Comparison between the existing waste sorting bin and Automatic Sorter Machine for Smart Waste Management System is discussed below.

Automation

Most of the waste sorters available presently are manual, which are less user friendly. Automatic Sorter Machine for Smart Waste Management System is fully automated, which have made the whole sorting procedure very easy and effective.

Fig. 7 Manual Waste Sorting Bin

Cost Comparison

Many local and international companies manufacture trash can. Among them Carron Phoenix Disposal Products are worldwide famous. But at present the price of the trash cans, by Carron Phoenix, ranges from $120 to $250 [15]. The Automatic Sorter Machine for Smart Waste Management System will cost around $90. It is cheaper than other because a unique algorithm to sort paper and plastic is developed and the mechanical structure is very simple.

Bin Number

Presently available trash bins can sort out only two or three types of trash materials [16]. But Automatic Sorter Machine for Smart Waste Management System can automatically sort out minimum four types of trash materials very easily and efficiently.

Unique Sensor Designing

Special type of sensor by using LDR and LASER is used in Automatic Sorter Machine for Smart Waste Management System. These have replaced the conventional sensors available in the market for sorting out paper and plastic.

Power Consumption

The power supply of Automatic Sorter Machine for Smart Waste Management System is driven by 9 V (DC). It can be driven by 220 V (AC) like the other available automatic trash bins.

FUTURE SCOPE

Automatic Sorter Machine for Smart Waste Management System can be deployed to solve our existing problem as well as can bring about a change in our daily life meeting our own demand.

Sorting More Types of Materials

The developed Automatic Sorter Machine for Smart Waste Management System can sort only four types of waste materials. If more sensors are used then it will be possible to sort more types of materials (Such as: Transparent and nontransparent plastics, Thick and thin papers, Semi-conductor and Conductors, Rubber materials, Organic etc.).

Reduction of Cost

Companies those are manufacturing and distributing trash bin throughout the world, currently producing manual trash bins. If a large scale production of Automatic Sorter Machine for Smart Waste Management System is possible then the price of this product will be cheaper than present manufacturing cost. It will be cheaper because the mechanical structure is very simple and the sensors will be industrial grade.

Increasing Response Time

The response time of electromechanical system is relatively fast. But it can be made faster by using industrial grade servo motor. The microcontroller and servo motor used in presently developed Automatic Sorter Machine for Smart Waste Management System are properly synchronized. When the industrial grade servo motor will be used, then the system should be synchronized to perform smoothly and faster.

Health Service

Special type of sensor could be used to sort out the organic parts of the wastes. When the organic parts of the wastes are sorted out then they may be tested automatically to find out the food habit of the user and analyze it for the improvement of the user’s diet. Another application of sorting out the organic parts of the wastes is, the organic parts may help to diagnosis several disease of the user. Thus the health issues of the user of Automatic Sorter Machine for Smart Waste Management System will be insured at some extent.

Primary Recycling and Reusing Unit

A primary recycling and reusing plant may be installed with the automatic sorter machine. This will ensure that a home user will practice recycling and reusing. The primary plant may consist of only paper or plastic recycling unit. This will ensure a healthier life style and guarantee cost minimization for the home or industrial users.

CONCLUSIONS

In communities where appropriate sites are available, sanitary landfills usually provide the most economical option for disposal of solid waste. However, it is becoming increasingly difficult to find sites that offer adequate capacity, accessibility and environmental conditions. The amount of waste, which is been recycled or reused, stands for the reduction of waste to be managed by the authority. Proper management of waste plays a vital role to control global warming [1]. Automatic Sorter Machine for Smart Waste Management System is an excellent example of proper waste management. It will also ensure effective recycling system. Hence, the improvement of waste sorter will ensure economic and ecological development.

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COMPERATIVE STUDY OF BIODIESEL PREPARATION FROM WASTE COOK OIL AND BAKUL OIL

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ABSTRACT

In this paper, production of biodiesel from Waste Cook Oil (WCO) and Bakul Oil (*Mimusops Elengi*) by three-step method and optimization of the process were studied. The raw oils, WCO containing 1.9 wt% and Bakul Oil (BO) containing 11.1 wt% Free Fatty Acid (FFA). The viscosity of WCO was 47.6 mm^2/s and for BO it was 76.62 mm^2/s. The WCO were collected from local restaurants and BO collected from local source of Sylhet city. Comparison between two raw oil properties, preparation methods and final biodiesel properties were studied. Since the WCO contains lower percentage and BO higher percentage of FFA but the three-step methods yields the better result than transesterification methods. In the three-step method, the first step is saponification of the oil followed by acidification to produce FFA and finally esterification of FFA to produce biodiesel. The reaction yield was found 79% for WCO and 80% for BO. Finally various properties of biodiesel such as FFA, viscosity, specific gravity, cetane index, pour point, flash point etc. were measured and compared with biodiesel and petro-diesel standard. The properties of produced biodiesel from WCO and BO almost similar. So, BO and WCO blend can be used for biodiesel production.

Keywords: Waste cook oil, Bakul oil, Esterification, Biodiesel, Comparison.

INTRODUCTION

Biodiesel is a clean burning fuel produced from renewable domestic sources such as vegetable oils and animal fat. It is biodegradable, non-inflammable, non-toxic and has a favourable combustion–emission profile (Encinar et al., 2005). The interest in the use of renewable raw materials for fuel production started during the early 1990's and one significant research has been the utilization of fatty acids esters derived from vegetable oils for biofuel production (Sharma et al., 2008). The most common oil sources are used for biodiesel production worldwide are WCO, sunflower oil, corn oil, canola oil, soybean oil, castor oil, rapeseed oil, soybean soap stock, koroch seed oil, Sclerocarya birrea oil (SCO), melon bug oil (MBO), sorghum bug oil (SBO), cardoon (Cynara cardunculus L.), Gum copal (kauri resin), frying oil (a mixture of olive oil and sunflower oil), Karanja (Pongamia pinnata), Jatropha (Jatropha Curcas), Neem (Azadirachta indica), Mahua (Madhuca indica), Simarouba (Simarouba indica), Jojoba (Simmondsia chinensis Link Schneider) etc (Sharma et al., 2008). Some of these sources are now used for the commercial production of biodiesel.

Four major techniques (dilution, microemulsion, pyrolysis, and transesterification modification techniques) are used for biodiesel production, among them transesterification process has been widely used to reduce the high viscosity of the oil. Transesterification reaction can be catalyzed by both homogeneous (alkalies and acids) and heterogeneous catalysts. The most commonly used alkali catalysts are NaOH, CH_3ONa, and KOH (Kaniz et. al., 2011). It has been found that the alkaline-catalyzed transesterification process is not suitable to produce esters from unrefined oils (Ramadhas et. al., 2005) where the FFA content is higher. In order to prevent saponification during the reaction, FFA and water content of the feed must be below 0.5 wt.% and 0.05 wt.%, respectively. Because of these limitations, only pure vegetable oil feeds are appropriate for alkali-catalyzed Transesterification without extensive pre-treatment (Freedman et. al., 1984). Homogeneous acid catalyzed reaction is about 4000 times slower than the homogeneous base-catalyzed reaction and hence is not popular for industrial production of biodiesel. A three-step method was developed for the biodiesel production from oil (Morshed et al., 2011), where in the first step is saponification of the oil followed by acidification to produce FFA and finally esterification of FFA to produce biodiesel. In the present paper biodiesel was prepared from non-edible oils, such as waste cook oil and Bakul oil by different methods. The difficulties of each process are discussed and the biodiesel properties are measured and compared.

MATERIALS AND METHODS

CHEMICALS

Methanol (99-100%), ethanol (99-100%), sodium hydroxide pellets (96%), potassium hydroxide pellets (>84%), phenolphthalein (P^H 8.2-9.8), acetone (99%), diethyl ether , hydrochloric acid (37%), sulfuric acid (98%), iodine , sodium iodide, bromine, carbon tetrachloride, glacial acetic acid, potassium dichromate etc. All the chemicals were used as analytical reagent grade.

RAW MATERIAL

Waste cook oil (palm oil and soybean oil) was collected from local restaurants located in Sylhet city in Bangladesh. The oil was filtered and its properties were measured. Bakul seeds were collected from gardens and road side of Sylhet region. Oil from the seeds was extracted by mechanical press and soxhlet extraction method. The oil content of Bakul seed was found 20% (v/w) by press method and 30% by soxhlet extraction method. The oil was stored at room temperature.

BIODIESEL PREPARATION FROM OIL

Transesterification methods
Biodiesel can be prepared from WCO by base and acid catalyzed transesterification reaction (Meher et al., 2006; De and Bhattacharyya, 1999). Transesterification methods weren’t effective for biodiesel preparation from BO due to higher FFA content of raw oil. Base and acid catalyzed transesterification reaction was carried out as described by Meher et al. (2006).

Biodiesel preparation by three- step method
For saponification process required amount of WCO and BO were taken in a three necked flask and mixed with different stoichiometric amount of aqueous sodium hydroxide solution (Morshed et al., 2011). The mixture was heated under reflux with vigorous stirring at temperature of 100 ^{0}C for different time. After saponification, produced sodium soap solution was treated with different stoichiometric amount of concentrated hydrochloric acid at a temperature of 65 -70 ^{0}C. After dissolving the soap, the fatty acid contents were separated in separatory funnel. Produced FFA was reacted with different stoichiometric amount of methanol at different temperature. After preparing the

biodiesel from WCO and BO various physico-chemical properties were measured and compared with the standard biodiesel.

ANALYTICAL METHODS FOR OIL AND BIODIESEL

FFA and saponification value was measured by standard method described by Jeffery et al. (1991). The iodine value (IV) was determined by titrating the sample with 0.01 N sodium thiosulphate and chemical reagents until the disappearance of blue color described by Jeffery et al. (1991). Iodine value was calculated by following Eq. (1):

$$IV = (V_1-V_2) * S * 0.1269 * 100 / W \quad (1)$$

V_1 and V_2 are the volume of sodium thiosulphate (mL) required for titration with sample and blank titration, S is the concentration of $Na_2S_2O_3$ in Normality, W is the weight of oil sample in gm. Physical properties color, moisture content and density of the sample were by the following ASTM D 1500, ASTM D 1744 (Karl fisher method), ASTM D 1480/81 and ASTM D 240. Viscosity, cloud point, pour point were determined by standards ASTM D445 respectively.

RESULTS AND DISCUSSION

CHARACTERIZATION OF WCO AND BO

The properties of WCO and BO such as viscosity, specific gravity, moisture content, saponification value, pour point, cloud point were measured and presented in Table 1.

Table 1: properties of WCO and BO

Properties	Experimental value	
	WCO	BO
Physical state	Liquid	Liquid
Color	Deep oily	Dark Brown
Specific gravity at 25^0C	0.902	0.89
Kinematic viscosity, mm^2/s at 40 ^0C	47.6	76.62
FFA content (wt% of oil)	1.9	11.1
Average molecular weight of FFA (gm/mol)	275.5	281.5
Molecular weight of oil (gm/mol)	864.5	882.5
Saponification value (mg of KOH/gm of oil)	238	228
Cloud point (^oC)	12	15
Pour point (^oC)	6	6

PREPARATION OF BIODIESEL FROM WCO AND BO

Biodiesel Preparation by transesterification method

For the biodiesel preparation and optimization by single step method, NaOH and H_2SO_4 used as base and acid catalyst. The effects of oil to methanol molar ratio, catalyst concentration and temperature on transesterification reaction were investigated. The reaction was carried out at different conditions. Viscosity reduction and reaction yield increases with increase in molar ratio of oil to methanol, catalyst concentration and temperature. The results are represented in the Fig. 1,2,3.

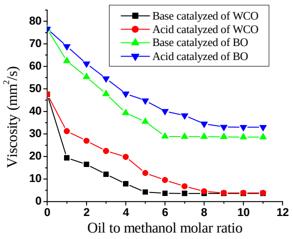

Fig. 1: Effect of oil to methanol molar ratio on transesterification reaction[For base catalyzed, temperature 60 °C, catalyst (NaOH) 1 wt% of oil and time 2 h and for acid catalyzed, temperature 70 °C, catalyst (H_2SO_4) 2 wt% oil and time 16 h under reflux with vigorous stirring].

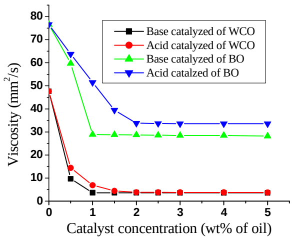

Fig. 2: Effect of catalyst concentration on transesterification reaction[For base catalyzed, temperature 60 °C, molar ratio of oil to methanol was 1:6 and time 2 h and for acid catalyzed, temperature 70 °C, molar ratio oil to methanol was 1:9 and time 16 h under reflux with vigorous stirring].

Table 2: Properties of produced biodiesel by transesterification methods .

Properties	Measured value [Base catalyst]		Measured value [Acid catalyst]	
	WCO	BO	WCO	BO
Specific gravity, at 25 °C	0.79	0.86	0.801	0.86
Kinematic viscosity (mm^2/s), at 40°C	3.51	28.1	3.61	32.8
Free fatty acid content (%FFA)	0.28	3.67	0.85	5.22
Saponification value	183	202	191	205
Yield (%)	58	45	63.5	49

The properties of produced biodiesel were match with the standard value but the yield was low, that is why three-step method was conducted.

Biodiesel prepared by three-step method

FFA preparation

FFA was prepared from WCO and BO by saponification followed by acidification. Saponification was done by the method described above. Saponification was done with different stoichiometric amount of NaOH. After saponification and acidification FFA was produced. The results are present in Fig. 4.

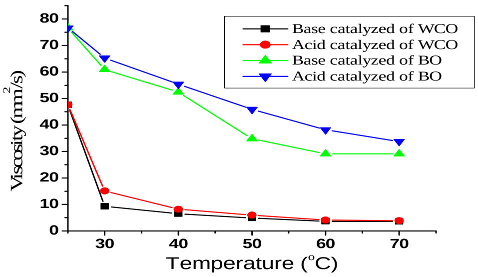

Fig. 3: Effect of temperature on transesterification reaction [For base catalyzed method, catalyst concentration 1 wt%, molar ratio of oil to methanol 1:6 and time 2 h and for acid catalyzed method, catalyst concentration 2 wt %, molar ratio 1:9 wt% of oil and time 16 h under reflux with vigorous stirring].

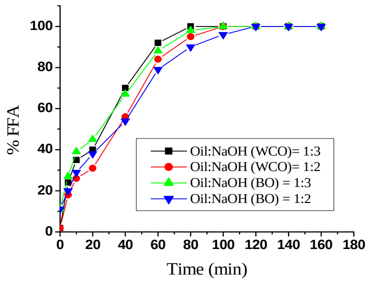

Fig. 4: Preparation of FFA from WCO and BO through saponification and acidification by different stoichiometric molar ratio of oil to NaOH in aqueous solution [Reaction temperature = 100 °C under reflux with vigorous stirring].

Biodiesel Preparation from FFA

The methanol to FFA molar ratio, catalyst concentration and temperature are the important parameters that affecting the FFA conversion to biodiesel. The effect of methanol to FFA molar ratio, catalyst concentration, temperature and silica gel on conversion of FFA was investigated. The results are shown in Fig. 5,6,7,8. From the Fig. 5, 6 ,7, it was found that the FFA conversion to biodiesel was 99% at 6:1 molar ratio of methanol to FFA, 5 wt% catalyst (HCl) concentration, 60 ^{o}C temperature. From the Fig. 8, it can be seen that 99% conversion was achieved within 80 minutes for WCO, BO in presence of silica gel and reaction rate was increased.

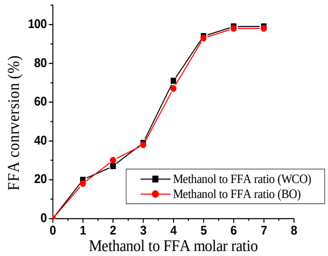

Fig. 5: Effect of Methanol to FFA molar ratio on FFA conversion [temperature 60 ^{o}C, catalyst (HCl) 5 wt% of FFA, time 120 min under reflux with vigorous stirring].

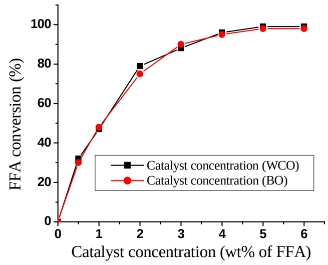

Fig. 6: Effect of catalyst (HCl) concentration on esterification reaction [Reaction temperature = 60 ^{0}C, methanol to FFA ratio 6:1, Reaction time 120 min, under reflux with vigorous stirring].

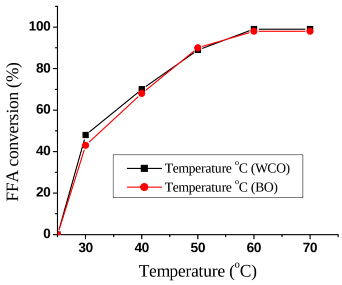

Fig. 7: Effect of Temperature on esterification reaction [Catalyst (HCl) concentration 5 wt% of FFA, methanol to FFA ratio 6:1, Reaction time 120 min, under reflux with vigorous stirring].

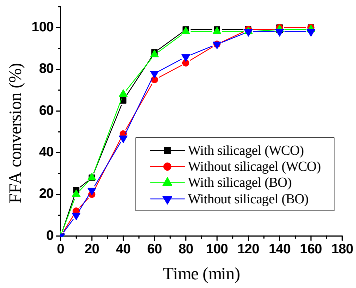

Fig. 8: Conversion of FFA to biodiesel at different methanol to FFA molar ratio in absence and presence of silica gel [Reaction temp. 60 ^{0}C, Catalyst (HCl) concentration 5.0% wt of FFA and Reaction time 2 h under reflux with vigorous stirring].

PROPERTIES OF BIODIESEL

The properties of produced biodiesel from WCO and BO such as viscosity, FFA content, moisture content, pour point, cloud point, saponification value, iodine value, specific gravity were presented in Table 3 and compared with standard values. The reaction yield was 79 and 80% for WCO and BO.

CONCLUSION

Biodiesel was prepared from WCO and BO by three-step method, in three-step method aqueous sodium hydroxide solution was used for saponification, the molar ratio of oil to NaOH and reaction time were optimized. At optimum conditions 99% conversion of the FFA to FAME was obtained and the viscosity, yield were 3.29 mm^2/s and 79% wt/wt of WCO; 3.87 mm^2/s and 80% wt/wt of BO. The properties of produced biodiesel such as viscosity, specific gravity, cloud point, pour point, flash point, cetane number are nearest to the petro-diesel. The present experimental results support that produced biodiesel from WCO and BO by this method can be successfully used as diesel. The properties of produced biodiesel from WCO and BO almost similar. So, BO and WCO blend can be used for biodiesel production.

Table 3: Properties of biodiesel produced from WCO and BO by three-step method and comparison with standard biodiesel and diesel values.

Properties	Produced biodiesel value		Biodiesel Standard (Morshed et al, 2011; Joshi & Pegg, 2007)	Diesel standard (Joshi & Pegg, 2007)
	WCO	BO		
Specific gravity, at 25 ^oC	0.79	0.81	0.88 (at 15.5^0 C)	0.85(at 15.5^0 C)
Kinematic viscosity (mm^2/s), at 40^{o}C	3.29	3.87	1.9–6.0	1.3 – 4.1
FFA content (wt%)	0.94	0.97	-	-
Moisture content (%)	0.12	0.10	0.05% max.	0.161
Saponification value	194	192	-	-
Flash point (^{0}C)	150	155	100 to 170	60 to 80
Iodine value	88	85	-	-
Cloud point (^{o}C)	0	3	-3 to 12	-15 to 5
Pour point (^{o}C)	-3	-3	-15 to 10	-35 to -15
Cetane Index	54	53	-	-
Yield (%)	79	80	-	-

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REMOVAL OF MANGANESE AND ARSENIC FROM GROUNDWATER USING MANGANESE OXIDE COATED SAND

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ABSTRACT
The present study focuses on removal of Mn and As from groundwater using different types of Mn-coated sand. Laboratory filter columns have been prepared in glass burettes and acrylic glass tubes using locally available natural sand, synthetic Mn-coated sand and green sand. It has been found that under favorable conditions (pH, initial Mn concentration, and contact time), Mn-oxide coatings form on natural sand particles, which promote Mn removal from influent water. The effectiveness of the prepared Mn-oxide coated sand thus formed (average Mn content 1480 mg/kg), synthetic Mn-oxide coated sand (Mn content 25,250 mg/kg), and green sand (Mn content 14,400 mg/kg) in removing Mn and As(III) from groundwater has been assessed. All three media have been found to be very effective in removing Mn under a wide range of conditions. Flow rate/ contact time has been found to be the most important parameter governing Mn removal; a contact time of about 3 minutes has been found to be sufficient for removal of Mn in all filter media. None of the filter media have been found to be effective in removing As(III). In addition, As(III) removal has been found to reduce significantly in the presence of bicarbonate and phosphate ions. Results of the study suggest that Mn-oxide coated sand could be used for developing treatment systems for simultaneous removal of Mn, As(III) and Fe.

Key words: Manganese, Treatment, Synthetic, Arsenic, Removal, Mn-oxide, Coated

INTRODUCTION

Two major national level surveys, the National Hydro-geochemical Survey (BGS and DPHE, 2001) and the National Drinking Water Quality Survey (NDWQS) (BBS and Unicef, 2009), showed that in Bangladesh, large numbers of shallow and deep tubewells exceed permissible limits for arsenic (As), iron (Fe) and manganese (Mn). The National Hydro-chemical Survey found that about 25% of wells exceed the national drinking water standard for As (0.05 mg/l); half of the 3,534 wells surveyed exceeded Bangladesh drinking water standard (1 mg/l) for Fe, and three quarters exceeded the permissible limit (0.1 mg/l) for Mn. The WHO recommends a guideline value of 0.4 mg/l for Mn (WHO, 2004) to protect against neurological damage; about 40 percent of wells in the BGS-DPHE survey exceeded this limit (Hasan and Ali, 2010). The NDWQS found that 61 percent of the samples exceeded the Bangladesh standard for Mn, while 35 percent exceeded the WHO guideline value (BBS-Unicef, 2009). The NDWQS also found that although 93 percent of deep tubewells meet the Bangladesh standard for As, only 60 percent meet the standards for As, Mn and Fe. Groundwater from a deeper aquifer (190-240m) in Munshiganj district has been found to contain low As (< 10 μg/l), but very high (2 to 5 mg/l) Mn (Hug et al., 2011). It should be noted that the WHO (2011) eliminated the health-based guideline value for Mn, noting that concentration as high as 0.4 mg/l are rare; obviously this logic is not valid for Bangladesh. Therefore it is reasonable to assume that the WHO (2004) health-based guideline value of 0.4 mg/l still applies in the context of Bangladesh.

A number of technologies were developed for Fe removal at municipal/ community/ household levels in the 1980s (Ahmed, 1981; Ahmed and Smith, 1987, Azim, 1991), but these iron removal plants (IRPs) did not enjoy wide public acceptance, primarily because of problems in operation and maintenance. Since many As-affected areas also suffer from high Fe concentration, many NGOs are now installing different types of such IRPs for arsenic mitigation purposes. However, some recent studies (BRTC-Unicef, 2006; Hoque, 2006; ITN-BUET, 2011) showed variable performance of existing community As and As-Fe removal plants in removing Fe, As and Mn.

Manganese can be removed using the same processes of oxidation, precipitation and filtration as in Fe removal (Fair et al., 1968; Hartmann, 2002). A number of studies (Kan et al., 2012; Buamah, 2009; Afsana, 2004) showed that Mn is removed effectively from groundwater by oxidation and adsorption processes. Manganese oxide coatings formed on filter media in filtration beds have been found to act as good adsorbent for Mn and also plays a role in its oxidation (Eley and Nicholson, 1993; Tasneem, 2010; ITN-BUET, 2011). Media coated with synthetic Mn oxides have also been found to have good Mn removal efficiency (Merkle et al., 1997; 1999; Dhiman and Chaudhuri, 2007; Maliyekkal et al., 2009). This study presents a detailed evaluation of Mn and As removal using Mn oxide coated filter media, and an assessment of the potential of such media for simultaneous removal of Mn and As.

MATERIALS AND METHODS

Preparation of Manganese Oxide Coated Sand Bed

For assessment of formation on Mn-oxide coatings, filter beds were prepared with Sylhet sand using glass burettes (filter depth 43 cm) with cross sectional area of 1 cm^2. The Sylhet sand used consisted of size fraction passing #20 sieve and retaining on #30 sieve, and fraction passing #30 sieve and retaining on #40 sieve in the ratio of 1:2. The Fineness Modulus (F.M.) and unit weight of the Sylhet sand used were 3.67 and 1.31 g/cm^3, respectively; initial Mn-content was 5 mg Mn/ kg. In all cases, the Mn content of sand media was determined after selective leaching with hydroxylamine hydrochloride (Eley and Nicholson, 1993). Groundwater, collected from a deep tubewell pump station at BUET with Mn concentration of 0.022 mg/L was used in all laboratory experiments. The pH of influent water was 7± 0.1. Influent water with known concentrations of Mn (0.5 to 5.0 mg/l) was passed through the filter columns and residual Mn concentration was measured at different time intervals. The flow rate was varied from 1 to 5 ml per minute. Additional experimental details have been reported in ITN-BUET (2011). The average Mn content of the "prepared Mn-oxide oxide coated sand media" was about 1480 mg Mn/ kg of media.

Preparation of Synthetic Mn-Oxide Coated Sand Media using $MnNO_3$

Manganese oxide coated sand was synthesized following the methods of Tilak (undated) and Merkle et al. (1997). For preparation of Mn-oxide coated media, 100 gm of the selected sand was taken in a glass tray. Then 100 ml of $Mn(NO_3)_2.4H_2O$ (Loba, India) solution, with Mn concentration of 10.5 g/l, was added to the tray and mixed thoroughly. Then 0.1N NaOH solution and 1:1 30% H_2O_2 solution were added to the tray until the pH of the mixture was increased to about 9.0. As the pH of the solution gradually decreased, 0.1N NaOH solution was added to the mixture to raise the pH to about 9.0. During the next two days 0.1N NaOH was added to the tray once every day to raise the pH to about 9.0. The above process was then repeated twice. The sand was then washed with groundwater (adjusted to pH 9.0), groundwater, and finally with deionized water; and then air dried.

Manganese and Arsenic Removal Using Mn Coated Sand Media

Removal of Mn and As using the "prepared Mn-oxide coated sand, synthetic Mn-oxide coated sand and green sand" were evaluated by passing groundwater with known concentrations of Mn and/or As(III) thorough a filter bed and measuring the residual concentrations. The filter columns were made of transparent acrylic glass column with a x-sectional area of 28.2 cm^2 (for green sand column 26.5 cm^2), fitted with flow control arrangements. The total depth of filter media in the column was 40 cm, consisting of Mn-coated sand media (6 cm) and selected Sylhet sand. The initial average Mn content of the "prepared Mn-oxide coated media" was 1480 mg/ kg of media; however, Mn content of the top portion (about top 1 cm) of the media was much higher, about 7550 mg Mn/ kg. Mn content of the "synthetic Mn-oxide coated media" and green sand were 25,250 and 14,400 mg Mn/ kg, respectively.

For assessment of removal efficiency, Manganese concentration in the influent water was varied from 0.022 to 5.0 mg/l; while As(III) concentration was varied from 100 to 500 µg/l. The surface overflow rate through the filter media was varied from 0.5 to 8.0 ml/min/cm^2 to assess its impact on removal of Mn. Effects of Alkalinity on removal of (i) Mn (initial concentration 2 mg/l); (ii) As(III) (initial concentration 300 µg/l); and (iii) Mn (2 mg/l) and As(III) (300 µg/l) present simultaneously, were evaluated. In these experiments, flow rate was maintained at 1 ml/cm^2/min and Alkalinity of influent water was varied from 50 to 500 mg/l (as $CaCO_3$). Natural groundwater with an Alkalinity of 216 mg/l (as $CaCO_3$) was either diluted with deionized water, or amended with $NaHCO_3$ solution to attain the desired Alkalinity. Effect of Phosphate on removal of Mn (initial concentration 2 mg/l) and As(III) (initial concentration 300 µg/l) present simultaneously was evaluated by varying Phosphate concentration from 1 to 10 mg/l.

Chemicals and Reagents

All chemicals used in this research work were of reagent grade. Mn(II) and Fe(II) stock solutions were prepared by dissolving $MnCl_2.4H_2O$ and ferrous sulphate ($FeSO_4.7H_2O$), respectively in deionized water. As (III) stock solution was prepared by dissolving arsenic trioxide (As_2O_3) in deionized water containing sodium hydroxide (NaOH). Bicarbonate and phosphate stock solutions were prepared using $NaHCO_3$ and NaH_2PO_4, respectively. Manganese and iron concentrations were measured using Flame-AAS, while As concentration was measured using GF-AAS. All other water quality parameters are being measured following the Standard Methods (AWWA, APHA)

RESULTS AND DISCUSSIONS

The overall objective of this study was to evaluate removal of Mn and As from groundwater using different Mn-coated media. This Section presents results of the laboratory experiments carried out for assessment of removal of Mn and As in three types of Mn-coated media. Formation of Mn-oxide coatings on sand in a filter bed through which Mn-bearing water is passing was evaluated (ITN-BUET, 2011).

Manganese removal: Effect of flow rate/ contact time

Figure 1 shows average Mn removal in "prepared Mn-coated media" and "synthetic Mn-coted media" as a function of flow rate and contact time. It should be noted that in the column experiments, Mn concentration in the effluent water was measured after 90, 120 and 150 minutes; and it was found that Mn removal did not vary with filter run time. Figure 1 shows that flow rate/ contact time has a significant effect on Mn-removal; removal increased as flow rate decreased or contact time increased. For example, at a flow rate of 8.0 ml/min/cm^2 (corresponding to a contact time of about 11 seconds, considering a media porosity of 0.25), Mn removal was only about 10% in for "prepared Mn-coated media"; while removal approached 100% at flow rates less than or equal to about 1 ml/min/cm^2 (i.e., contact time of about 1.5 minutes). Similar results were obtained for the "green sand" media (ITN-BUET, 2011). Under the same experimental conditions, the "synthetic Mn-coated media" (with highest Mn content of 25,250 mg/ kg) performed best in removing Mn, especially at higher flow rates. However, at slower flow rates, other media also performed well. The test results suggest that Mn removal improves with increasing filter run time, as Mn-oxide coatings form on the filter media.

Manganese removal: Effect of initial Mn concentration

In order to assess the effect of initial Mn concentration on Mn removal, Mn concentration in influent water was varied from 0.022 mg/l (natural groundwater) to 5.0 mg/l; flow rate was maintained at 1 ml/min/cm^2. Almost 100% removal of Mn was achieved for all initial Mn concentration; filter run time (varying from 90 to 150 minutes) did not have any effect on Mn removal. Thus, it appears that the Mn-coated media would be able to remove Mn from water having a wide range of initial Mn concentration to levels satisfying the national standard and WHO guideline value. Tasneem (2010) reported almost complete removal of Mn for different initial Mn concentration, even for short filter run times (about 10 minutes), and that the removal efficiency improved with time.

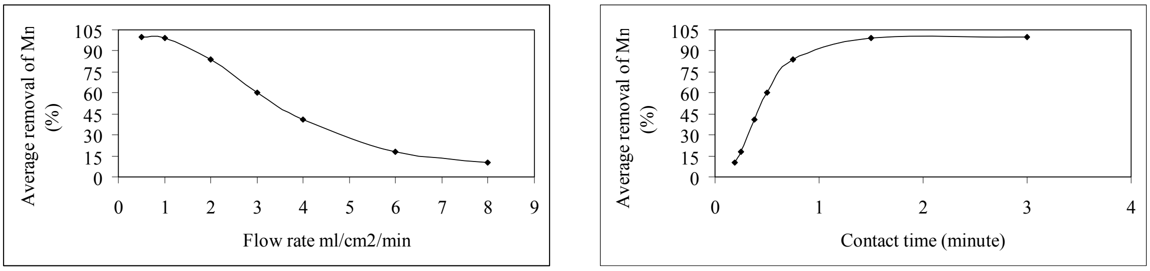

Fig. 1(a): Effect of flow rate or contact time on Mn removal in "prepared Mn-coated media"

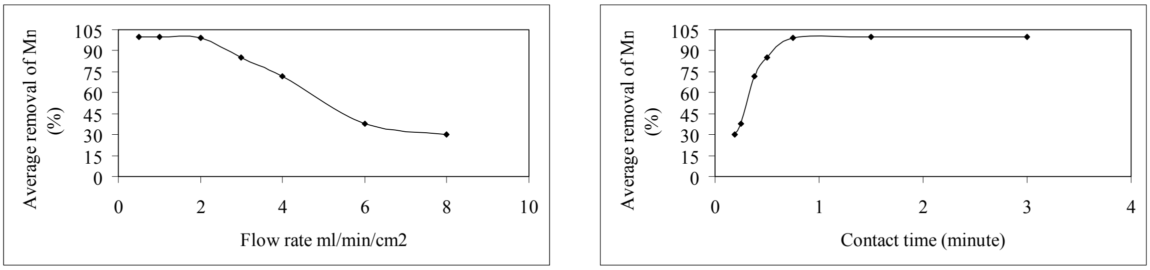

Fig. 1(b): Effect of flow rate or contact time on Mn removal in "synthetic Mn-coated media"

Arsenic removal: Effect of filter run time and initial As concentration

Experimental results (ITN-BUET, 2011) showed that As removal in the Mn-coated media did not vary significantly with initial As concentration. Figure 2 shows removal of As(III) (initial concentration of 300 µg/l), in the "prepared Mn-coated media" as a function of filter run time. Arsenic removal decreased from about 75% after 30 minutes to less than 10% after 330 minutes of filter run time. Tasneem (2010) also reported decreased As removal with increasing filter run time.

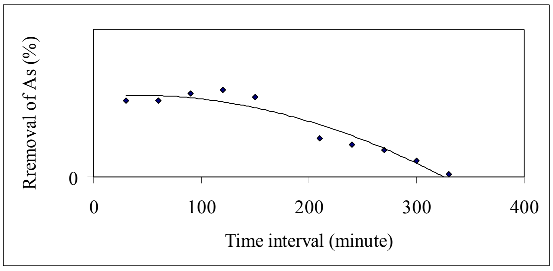

Fig. 2: Removal of As(III) in Mn-oxide coated media as a function of time

Simultaneous removal of Mn and As

Two sets of experiments were carried out to assess simultaneous removal of Mn and As in the "prepared Mn-coated media". In one experiment, As in the influent water was fixed at 300 µg/l, while Mn was varied from 0 to 5 mg/l; in another experiment Mn of influent water was fixed at 2 mg/l, while As was varied from 100 to 500 µg/l. Removal of Mn did not vary significantly with filter run time (which varied from 90 to 150 minutes). In both experiments, almost 100% removal of Mn was achieved, irrespective of the concentration of As in influent water. Similarly, As removal was also found to be largely unaffected by the presence of Mn under the experimental conditions.

Arsenic and Manganese Removal: Effect of Alkalinity

Figure 3 shows average removal of Mn (initial concentration 2 mg/l) and As (initial concentration 300 µg/l) in the "synthetic Mn-coated media" as a function of Alkalinity in the influent water. Since the influent water had a pH of about 7.0, Alkalinity was contributed mainly by bicarbonate (HCO_3^-) ion. It shows that while Alkalinity (or bicarbonate ion) did not have any effect on Mn removal, it has significant effect on As removal. Arsenic removal decreased significantly as Alkalinity (bicarbonate) increased. Thus, the poor performance of the Mn-oxide coated media in removing As from natural groundwater appears to be related to the possible competitive adsorption of bicarbonate ions.

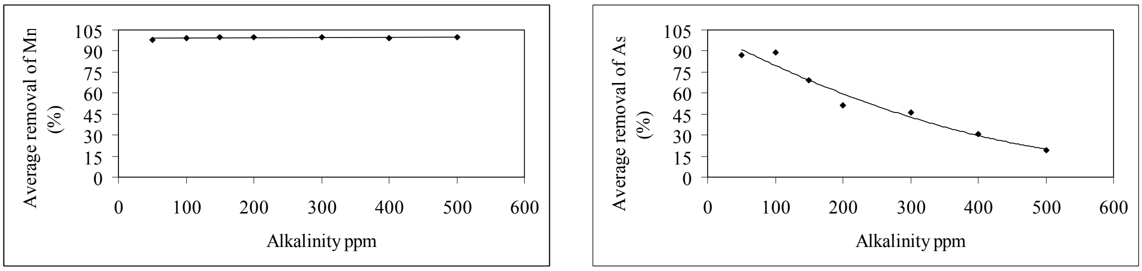

Fig. 3: Effect of Alkalinity on Mn and As removal in "synthetic Mn-coated media"

Arsenic(III) and Manganese Removal: Effect of Phosphate

Figure 4 shows average removal of Mn (initial concentration 2 mg/l) and As (initial concentration 300 μg/l) in the "prepared Mn-coated media" as a function of Alkalinity in the influent water. Removal of Mn did not vary significantly in the presence of phosphate. In the "prepared Mn-coated media", As(III) removal (in the presence of 2 mg/l Mn) came down from about 59% in the absence of phosphate to about 2.3% at 10 mg/l phosphate.

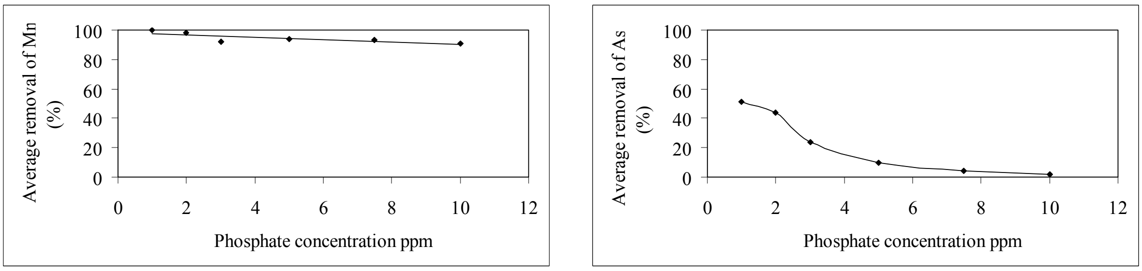

Fig. 4: Effect of Phosphate on Mn and As removal in "prepared Mn-coated media"

CONCLUSION

Three different types of Mn-oxide coated media showed very good performance in removing Mn from groundwater. Removal of As was however poor and decreased significantly with increasing filter run time, and in the presence of Alkalinity (bicarbonate) and phosphate. Flow rate/ contact time has a significant effect on Mn removal; removal increased as flow rate decreased or contact time increased. It appears that it would be possible to design community treatment plants for effective simultaneous removal of Fe, As and Mn from groundwater utilizing Mn-coated filter media. Based on the results of this study, criteria are currently being developed for the design and operation of such treatment plants.

ACKNOWLEDGMENTS

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BIOLOGICAL PRETREATMENT OF THE SITALAKHYA RIVER WATER AT DHAKA: A PILOT STUDY FOR AMMONIA REMOVAL.

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ABSTRACT

The water quality of the Sitalakhya River, the raw water source of Saidabad Surface Water Treatment Plant at Dhaka, the largest treatment plant of Bangladesh, is deteriorated so much that its treatment by conventional water treatment plant has become impossible. In the dry season there are complaints of water with bad smell and aesthetic problem. There is an underlying assumption that the problems observed during 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.

In order to improve water quality of the said source before entering into main treatment chain, a pilot study was conducted to pre-treat the raw water. The objective of the present pilot study is to investigate the reduction of ammonia using the meteor pilot, a biological pretreatment system, which is a laboratory scale moving bed bioreactor (MBBR) with a nominal volume of hundred liters, filled with 50 liters of meteor 660 media. Reduction of ammonia & COD and raw water oxygen demands were evaluated in detail.The reduction of ammonia was quit significant on average 73%, while the reduction of COD was in a range from 20 to 60% and the oxygen demands was highest 99 mg/l. The meteor pilot was effectively able to treat and nitrify the Sitalakhya raw water during the dry season and produce an effluent that respect the guarantee of ammonia <4.0 mgNH3-N/l, when the raw water ammonia concentration was <15 mg NH3-N/l.

Key words: Moving bed bioreactor (MBBR), Sitalakhya river raw water, ammonia removal, drinking water treatment, biological nitrification.

INTRODUCTION

Dhaka, the capital of Bangladesh and a premature megacity of today, with a population of 15 million, is almost 87% dependent on ground water for its potable water. 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.
In this context, Saidabad Water Treatment Plant (SWTP) was constructed with a capacity of 225 mld having conventional treatment process chain and put into operation on July 27, 2002. The Sitalakhya River at the eastern periphery of Dhaka city is the source of raw water for the SWTP (Figure.1).

The tap water quality of the water supply system, which abstract water from Sitalakya river, cannot meet increasingly stringer drinking water quality criteria due to limitation of conventional drinking water treatment.

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.

Figure1. Raw water source and its transmission network from Lakhya River through DND canal to SWTP.

Looking at the available data and the rather complex situation of water quality 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 many cause effect relations. One of which is:

- High ammonia concentration → difficult to disinfect → not possible to control algae fully nor to ensure hygienic quality of water.

During formulation of the project of Saidabad Water Treatment Plant Phase-II a specific feasibility study was conducted for the probable options for pretreatment of the raw water of Saidabad Water Treatment Plant Phase-II.

The TOR for the feasibility study includes three main options for pretreatment to be investigated:

- Nitrification and de-nitrification-if needed
- Stripping of ammonia
- Break point chlorination

All of the above options were selected from the hypothesis that the problems are related mainly to the existence of high ammonia concentrations during the dry season and that a removal of the ammonia will make it possible to operate a normal treatment system to a satisfactory result.

In the feasibility study it was concluded that,

- Nitrifications likely to solve the ammonia problem and partly the sulphides and organic carbon problems but will within near future add a problem of not being able to comply with the Bangladesh Standard for nitrate.

The water which is presently flowing into the Water Treatment Plant during the dry season contains high concentrations of ammonia, TOC and some sulphide, all representing a high oxygen demand. Roughly the oxygen demand can be estimated as follows:

- 10 mg ammonia require around 40 mg oxygen
- 50 mg TOC require around 50 mg oxygen
- 1-20 mg sulphide require around 2-40 mg oxygen

This will during the worst months give a total oxygen demand of around 130 mg O_2/1.

To find out a Pre-treatment solution for ammonia removal before the main treatment chain, is an urgent necessity in order to supply wholesome water to the citizen of Dhaka.

Breakpoint chlorination (also known as super-chlorination) is one of the essential treatment techniques for the removal of ammonia in raw water. Ammonia, when in contact with chlorine will react rapidly to form chloramines. First monochloramine (NH_2Cl), then gradually dichloramine ($NHCl_2$), and then trichloramine (nitrogen trichloride NCl_3), before the breakpoint is achieved. Further dosage of chlorine passing the breakpoint will result in free chlorine residual. Although breakpoint chlorination is considered a cost effective strategy under low ammonia levels, high ammonia levels may greatly increase the chlorine demand. It can be difficult and expensive for water treatment facilities to add enough chlorine to provide satisfactory levels of disinfecting compounds in the water and have reactions proceed at a rapid enough pace. A high amount of chlorine may result in a high concentration of total chloramines that exceeds the MAC level. Trihalomethanes (THMs), halogenated acetic (HAAs), bromides, chlorates and chlorides are other concerns with high dosage of chlorine-based disinfectants.

Under the context a study for a suitable biological Pre-treatment process was mandatory and knows no bound for which this study was taken.

In order to improve water quality of the source of drinking water and mitigate load of drinking water of the Saidabad Surface Water Treatment Plant at Dhaka, a pilot study was conducted with a

laboratory scale moving bed bioreactor (MBBR) to pre-treat the raw water of the Sitalakya River, the source of raw water of the treatment plant.
The objective of the present pilot study is to investigate the reduction of ammonia using the Meteor pilot, as it is named, a biological pretreatment system, which is a laboratory scale moving bed bioreactor (MBBR). Reduction of ammonia & COD and raw water oxygen demands were evaluated in detail, which could be very useful and fundamental data for the design of future water supply project taking Sitalakya River water as raw water source.

MATERIAL AND METHODS

Experimental setup(Meteor pilot unit)
A MBBR bioreactor: (Fig.2) known as Meteor was used to investigate the feasibility of biological pretreatment of Sitalakya River water.

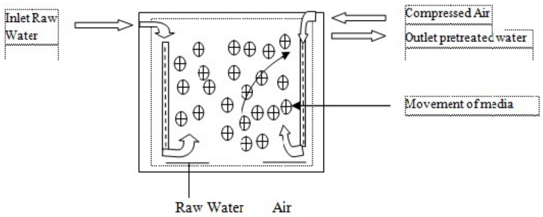

Fig: 2 Experimental setup of Meteor MBBR

The Meteor pilot is a laboratory scale moving bed bioreactor (MBBR) with a nominal volume of 100 liters, filled with 50 liters of the Meteor 660 media. The reactor is equipped with one Flexazur fine bubble aeration tube (length: 35 cm), a raw water inlet pipe and a treated water effluent pipe fitted with a media retention screen. The aeration is located against one side at the bottom of the reactor to create a spiral flow and thus provide good mixing of the media. The raw water coming from the inlet of the water treatment plant is pumped at a controlled rate into the bottom of the reactor, and the effluent leaves the reactor through the media retaining screen and flows by gravity to a drain in the laboratory. The range of flow rate was controlled from 0.5 to 2.0 L/min, with a few excursions to slightly higher flows (3.0 L/min). A flow rate of 2.0 L/min corresponds to the full-scale Meteor design hydraulic retention time of 50 minutes. Compressed air is fed to the diffuser at rates from 6 to 40 L/min, depending on the loading rates and dissolved oxygen measurements.

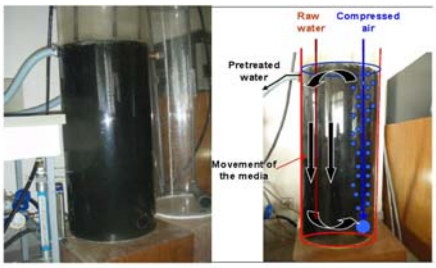

Figure 3: Meteor Pilot Unit & Flow Diagram.

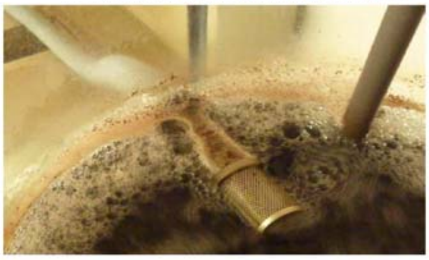

Figure 4: Meteor Pilot Effluent pipe with Media Retaining ScreenUnit & Flow Diagram.

Figure 5: Meteor 360 media

RESULTS AND DISCUSSIONS

START-UP PERIOD

The pilot unit operation started on February 9th, 2011, at a feed flow rate of 0.5 L/min (HRT = 3.3 hours), with a process air flow rate of 6 L/min, which was sufficient to provide good mixing. Progressively the nitrification process began and the effluent ammonia concentration decreased to below 2.0 mg NH3-N/L within 12 days. Thus the nitrification biofilm was developed on the media and the process established within a period of two weeks. By March 6th the pilot was operating consistently at the design flow of 2.0 L/min.

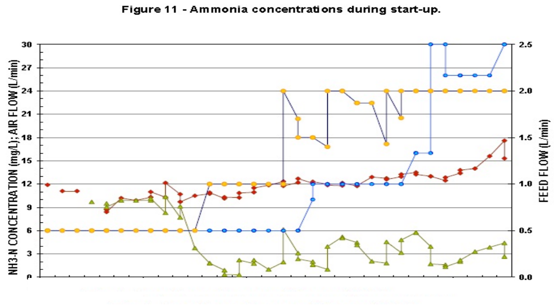

Figure 6: Ammonia concentrations during start-up

The process air was also increased progressively from 6 to 12 and eventually up to 30 L/min. The immediate response to the increased air on March 8th, decrease in the effluent NH_3-N to < 4.0 mg/L, demonstrates that the oxygen was a limiting factor for the prior days when running at the design water flow rate of 2.0 L/min. The design removal of 11 mg NH_3-N/L was achieved within 27 days of operation, once there was sufficient oxygen for the process.

Overall, the required time to achieve the maximum design ammonia removal rates is less than four weeks, and if sufficient air would have been provided sooner the required time would have been less, potentially on the order of three weeks.

Typically the start-up of the Meteor process will coincide with the beginning of the dry-season, which will occur at the beginning of December, and the raw water ammonia concentrations will be in the range of 2 to 4 mg/L and progressively increase to 6 to 8 mg/L during a period of eight weeks. The results from the pilot study show that when starting with virgin media the process will be able to follow this increase in ammonia loading. For a situation where the process needs to start in the middle of the dry-season (high ammonia concentrations > 10 mg/L), the process can be expected to reach design removal rates after a period of approximately three weeks.

NH_3-N REMOVAL

During the first period, after the start-up was achieved, the Meteor was able to remove 11 mg/L at the design flow (see Figure 6).

During period three, from March 29th through May 5th the pilot was run at 2.0 L/min (except for days when there were issues with the feed flow control) and the raw water ammonia concentrations are in the upper range: 10 to 17 mg/L. This period demonstrates well the full capacity of the process, with average removed ammonia of 11 mg/L, and a maximum removed ammonia of 13.5 mg/L. During this period the effluent NH_3-N is maintained below 4.0 mg/L (excluding the days when feed flow rate is > 2.0 L/min), with an average effluent NH_3-N of 1.7 mg/L (excluding days when feed flow rate is not 2.0 L/min).

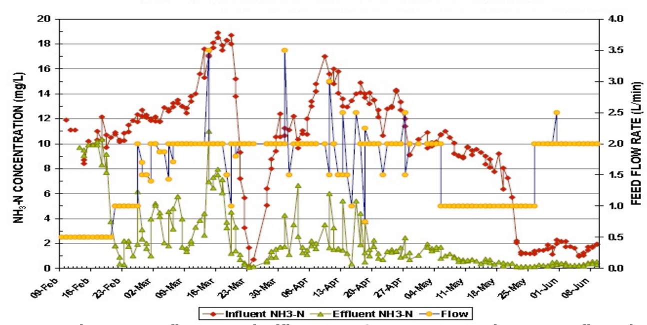

Figure 7: Influent and effluent NH3-N concentration water flow during study.

COD REMOVAL AND RAW WATER OXYGEN DEMAN

The raw water total COD varied significantly during the study, from 10 mg/L to 84 mg/L, with similar general trends in variation of concentration as the ammonia. The average ratio of soluble/total COD in the raw water is 79%, which is higher than typical for municipal wastewaters.

The COD removal based on the influent total COD minus the effluent soluble COD provides a calculation of the maximum amount of carbonaceous pollution removed in the Meteor pilot unit. It also represents the maximum overall oxygen consumed for the oxidation of pollutants in the raw water other than ammonia.Figure7 shows the total raw water COD, effluent soluble COD and a calculated COD removal (the difference between these two values) during the period when these analyses were made. During period 3, from 12/4/11 through 21/5, the COD removal was in a range from 13 to 52 mg/L, with 4 days having COD removal in the range from 30 to 50 mg/L. Thus the biological process was able to remove more carbonaceous pollution than the design values and at the same time remove the required ammonia load. Noted that there still remains 10 to 40 mg/L of soluble COD that is not removed by the biological treatment because this fraction of the COD is non-biodegradable. The very high ratio of COD/BOD in the raw water (5 on average) also attests to the fact that the water is not very biodegradable. Therefore, the results demonstrate that there are forms of dissolved pollution present in the raw water that are not removed by biological treatment.

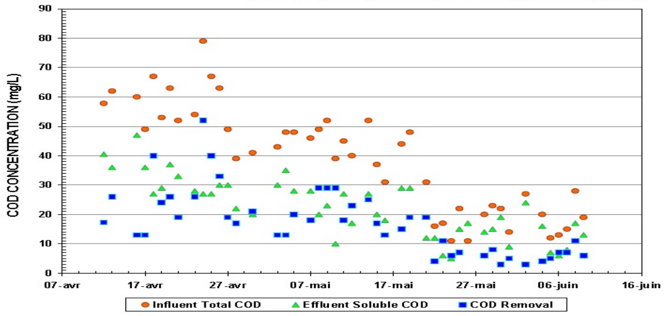

Figure 8: COD removal.

These results show that the oxygen demand of the raw water (not including the ammonia oxygen demand) exceeds the limit of 30 mg/L defined in the feasibility study. Since the measured levels of sulfide in the raw water were insignificant, this means that the level of carbonaceous pollutants is higher than expected. The results show that oxygen demands higher than 30 mg/L will occur during periods of peak pollution coinciding with the peak ammonia concentrations.

A comparison of the actual oxygen consumed in the pilot study (due to both COD and ammonia removal) and the design oxygen demand value for the Meteor process demonstrate that during the peak pollution period in April 2011 the raw water exerted a higher oxygen demand than the full-scale design. Noted that the full-scale design oxygen demand, based on the feasibility study, is 75 mg/L (30 mg/L for carbonaceous pollutants and sulfides + 45 mg/L for ammonia removal). Figure 8 plots both the COD and ammonia removed during the period of April 11th through the end of the study, including the total oxygen consumed values based on: mg/L COD removed + 4.57 x mg NH_3-N/L.

Seven days surpass the maximum design of 75 mg/L, and reach a maximum value of 99 mg/L. No similar COD data is available for the largest pollution peak in March, however clearly during the periods of raw water ammonia concentrations above 15 mg/L, the oxygen demand (to remove the COD and the ammonia down to 4.0 mg/L) will be above the design 75 mg/L. During these periods, the aeration will be a limiting factor and may not allow the removal of more than the design ammonia load.

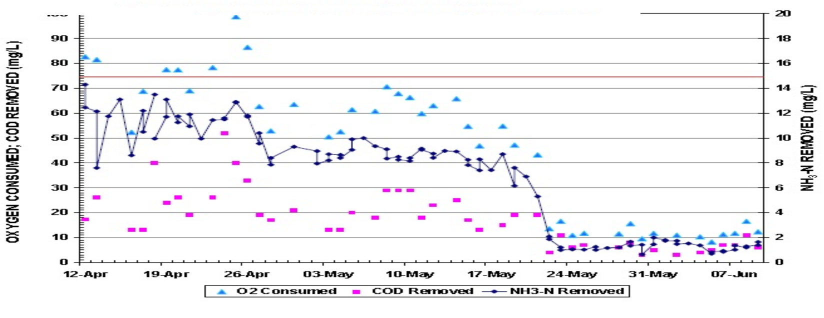

Figure 9: Oxygen Consumption.

CONCLUSIONS

The Meteor pilot was effectively able to treat and nitrify the Saidabad raw water during the dry-season and produce an effluent that respects the guarantees for ammonia < 4.0 mg NH_3-N/L, when the raw water ammonia concentration was < 15 mg NH_3-N/L.
No significant level of sulfides were measured in the raw water or treated water, therefore the guarantee of < 0.1 mg/L S^{2-}/L in the effluent was easily achieved.
The acclimation time required to establish the nitrification process was 2 weeks, and the total time required to achieve the maximum design removal of ammonia (removed SLR of 0.99 g NH_3-N/m2/d, including assimilation) was 27 days. Thus the scheduled time of 3 weeks required for full-scale start-up, at the beginning of the dry season with low ammonia concentrations (thus low loads to remove) remains valid. For the case of full-scale start-up in the middle of the dry-season (high ammonia concentrations > 10 mg/L), the process can be expected to reach design removal rates within a period of 3 to 4 weeks.
The amount of COD removed in the pilot demonstrates an oxygen demand surpassing the design value of 30 mg/L (for carbonaceous and pollution other than ammonia). The periods of high COD removal coincide with periods of high ammonia concentrations and therefore the overall oxygen demand of the raw water during the peak periods surpassed the design total oxygen demand of 75 mg/L.
During the periods when the oxygen supply is a limiting factor, due to excessive pollution in the raw water, the following negative impacts on the biological process performance and WTP are likely to occur:

- The ammonia in the pretreatment effluent will be > 4.0 mg/L, thus overloading the chlorination capacity of the WTP.
- An unstable nitrification process due to ammonia overloading, and lack of oxygen, will produce nitrite NO_2-N, which will exert a chlorine demand and overload the chlorination capacity of the WTP.
- Excessive residual soluble COD pollution will not be removed in the WTP and can interfere with the operation and performance of the WTP.
- As expected, during the periods of peak ammonia concentration in the raw water, the amount of ammonia nitrified and thus nitrate produced was > 10 mg NO_3-N/L, exceeding the nitrate standard for drinking water During the pilot study the influent NH_3-N > 15 mg/L for 20 days, and the amount of NH_3-N removed was > 11 mg/L for 42 days.

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A STUDY ON PLASTIC RECYCLING INDUSTRY OF DHAKA CITY

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ABSTRACT

Plastic recycling industry has registered a mushroom growth in the old parts of the metropolitan city of Dhaka. Basically the non-biodegradable nature of plastics is a matter of concern for municipal solid waste management. The study has been performed in Dhaka city especially on Islambagh area situated at old Dhaka. The main objectives are to determine the basis of sorting and estimate the amount of sorted plastics to be recycled per day, to determine the amount of plastics manufactured and recycled on a weekly quantitative basis, to estimate the amount of loss of plastic, to study the surrounding environment of the factories and finally to recommend some possible suggestions to improve the existing conditions. Basically plastic module and plastic product manufacturing company have been established in the study area. Plastic sorted on the basis of hardness shows that 38% hard, 22% semi hard, 40% soft plastics are collected per day. Seven day long survey reveals that on an average 447 to 611 kg of plastic modules and 631-1032 pcs of various plastic products are manufactured per day in the study area. Around 200 to 256 kg plastic loss takes place while recycling daily. Since production is variable cost also varies. The overall environment of the factories is unhealthy and unhygienic. The workers in the factories are not concerned about their health and safety issues. Management of plastic waste through source separation and proper recycling based on the 4R approach (Reduce, Reuse, Recycle, Recover) should be encouraged to enrich this sector.

Keywords: Plastic, Recycling, Environment, Waste.

INTRODUCTION

Just below the glamorous surface of the benefits and wealth created by the modern technology revolution looms a darker reality. Plastic, appeared in 1950s and considered as a modern, "space age" material seems like a wonder product for its affordability, versatility and durability. Growing huge dependency and usage on plastic product has given rise to a new environmental challenge. Now a day this wonder material becomes a waste due to its improper management. The huge production of plastic releases toxic chemicals into the air and uses up non- renewable energy sources. In the 1950s the worldwide consumption of plastic was approximately five million tonnes which has now reached about hundred million tonnes. The importance of plastic recycling is a burning issue of today. Even the metropolitan city of Dhaka is not far beyond the reach of mushroom growth Plastic recycling industry. Over 250 plastic goods factories have sprung up in Islambagh, Kamalbagh, Siddiqbazar and Mitford areas. These factories make various products like sandals, shoes, buckets, mugs, toys and bowls using waste plastics. The industry generated employments for thousands of workers. In 2005 the total demand for plastic was 540,000 tonnes of which 295,167 tonnes (55 percent) was imported and 244,833 tonnes (45 percent) was recycled (Alom, 2012). The import value of the recycled amount was $350 million. Previous study reveals that management of plastic waste through source separation and proper recycling based on the 4R approach (Reduce, Reuse, Recycle, Recover) should be encouraged at all levels. According to various studies conducted out some years back, Dhaka City Corporation (DCC) collects over 50,000 tonnes of plastic waste annually. The average collection rate is around 137 tonnes per day (Alom, 2012). Roughly around half of this collected waste is recycled. The balance half of the waste needs to be reused for the sake of our environment. Plastic recycling is needed in Bangladesh to save environment, to reduce unemployment and to save millions of dollars of foreign currencies spent for importing virgin plastic.

OBJECTIVES

The main objectives of the study include determining the basis of sorting of plastic and estimating the amount of sorted plastics to be recycled per day in the study area. The study mainly focuses on the manufacturing procedure of plastic goods and modules of two well known companies of Islambagh. The study has also been carried out to determine the amount of plastics manufactured and recycled through a weekly quantitative analysis, to estimate the amount of loss of plastics and to draw a flowchart showing the whole system of plastic recycling. The survey is also concerned with the environmental issues whether the process of production, recycling and management of plastic waste have any harmful effects on the environment or not and finally to recommend some possible suggestions and recommendations.

METHODOLOGY

Survey has been performed in Dhaka city especially on Islambagh area situated at old Dhaka where many plastic manufacturing companies are established. A literature review has been made to find out recycling and management system of plastic. Focus has been given on some plastic manufacturing and recycling industries of Dhaka city in order to fulfil the goal. Data collection is done by field survey which includes amount of plastics manufactured and recycled by a weekly quantitative analysis and the amount of loss of plastics. The information is collected to draw a flowchart showing the whole system of plastic recycling. Practical field observations have been made for collection of necessary photographs, data and information. A questionnaire has been formulated, formal and non- formal interviews have been held with all stakeholders of plastic recycling industry for authentic information. Required data and information have been collected from different sources like Dhaka South City Corporation (DSCC), Department of Environment (DOE) etc. Finally from data analysis and results, conclusions and recommendations are drawn.

FIELD SURVEY AND DATA COLLECTION

There are more than 100 plastic mills and factories situated in Islambagh, Dhaka. The study has been conducted with twelve plastic industries that manufacture plastic modules and plastic goods. The covered industries are - Alam plastic (module manufacturing industry), Image plastic (plastic product manufacturing industry), Shamim plastic, Shojib plastic and some others. The survey has been done for 7 days (January 23, 2011 to January 30, 2011) excluding Friday to estimate the average amount of recycled and manufactured plastic goods.

RESULTS AND DISCUSSIONS

The study reveals that mainly two types of manufacturing industries, plastic module manufacturers and plastic product manufacturers have been established in the study area. Here plastics are sorted on the basis of 'Hardness'. According to the study, plastic collected per day constitute of 38% hard, 22% semi hard and 40% soft plastic [Fig 3]. Plastic modules are classified as crystal, grey and black according to local grading [Fig 4]. About 650 kg to 800 kg of raw plastics are collected daily by a module manufacturer and 500 kg to 550 kg of plastic modules are manufactured there which is shown in Table1. Survey results also show that nearly 850 - 1000 pieces of various plastic products are manufactured per day using 550 – 700 kg of plastic modules which is also shown in Table 1. Depending upon the 7-day long survey it is also revealed that on an average 447 kg to 611 kg of plastic modules and 631 pcs-1032 pcs of various plastic products are manufactured per day in the study area [Fig 1&2]. The percentage loss of plastic during manufacturing of plastic modules is nearly 28% to 32% of the raw materials with correspond to around 200 kg to 256 kg plastic daily. Since the production is variable, the cost also varies. Very poor ventilation system have been observed in most of the industries in the study area. Due to melting of plastic temperature inside the industries are much higher than the normal temperature that make the environment inside and around the factories unpleasant and unhygienic [Fig. 10]. The workers and labors working in the factories are not concerned about their health & safety issues and due to lack of proper knowledge, they are polluting environment in different ways (Khan, 1998). Unhealthy and poor ventilation system has been observed in most of the factories. Use of safety hand gloves and other safety measures are not satisfactory at all [Fig. 11] (Esa et. al., 2011). Child labor is employed in most of the industries. Moreover, discarded plastics are also disfiguring our public areas, littering our waterways, killing marine life and eventually destroying our surrounding environment (Shahriar, 1996). Plastic is such a versatile material that it is incorporated into the production and packaging of almost everything we buy. So recycling efforts throughout the country would help to increase public awareness of the plastic recycling process and to rebuild the flora and fauna of the country to some extent.

Table 1: Production of a plastic module and a plastic product manufacturing industry for consecutive seven days

Days	Alam Plastic Ltd. (Plastic module manufacturing industry)			Image Plastic Ltd. (Plastic product manufacturing industry)	
	Raw materials (Poly Bags, Sheets) used (Kg)	Manufactured modules (kg)	% loss of plastics	Raw materials (Plastic Modules) used (Kg)	Manufactured Products (Pcs.)
January 23, 2011	720	515	28.47	550	850
January 24, 2011	700	500	28.57	620	900
January 25, 2011	750	520	30.67	625	950
January 26, 2011	780	540	30.77	625	920
January 27, 2011	800	550	31.25	650	980
January 29, 2011	650	500	23.08	700	1000
January 30, 2011	680	500	26.47	690	995
Total	5080	3625	28.64	4460	6595

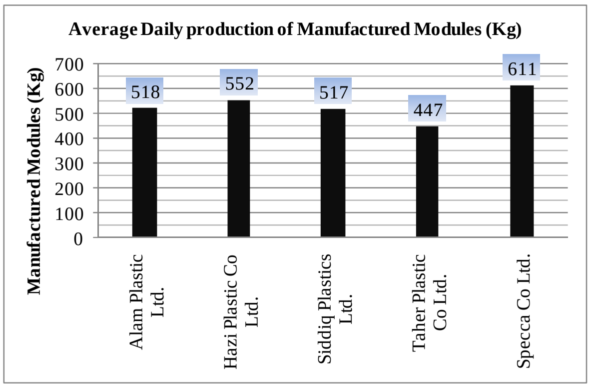

Fig. 1 Average Daily Production of Plastic Modules of Different Industries

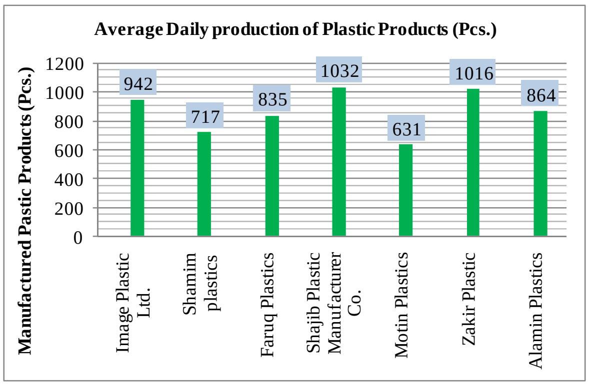

Fig. 2 Average Daily Production of Plastic Products of Different Industries

The collected plastics that are recyclable are sorted locally on the basis of hardness. There are three types of plastics:

1. **Hard plastic** (e.g. bottles, electronic equipment casing/covers, cassettes etc.)
2. **Semi hard plastic** (fibers, ropes, different tubes)
3. **Soft plastic** (poly bags, sheets etc.)

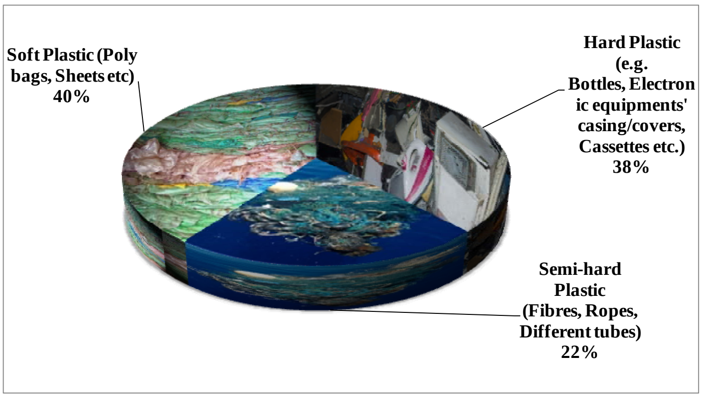

Fig. 3 Types of Sorted Plastic

Table 2 Types of Modules according to the local grading

Name	Grade	Cost per pound	Manufactured products
Transparent / Crystal modules (locally called "crystal pp")	1st class	Tk 22/- to 25/- per pound	Spectacles glass, lenses, Car head light/backlight covers etc.
Grey modules	Moderate	Tk 15/- to 18/- per pound	Household goods e.g – buckets, mug, jug, racks etc.
Black modules (locally called "Kalo pp")	Low class	Tk 10/- to 12/- per pound	Bottle caps, CD/DVD covers etc.

Fig. 4 Sorting of raw materials

Fig. 5 Transparent/Crystal modules

Fig. 6 Grey modules (after color added)


Fig. 7 Condenser is used to cool down plastic goods


Fig. 8 The product has been molded and taken out


Fig. 9 Products are ready to be supplied


Fig.10 Unhealthy environment


Fig.11 Labor without safety hand gloves

After the detail survey of the study area total management of plastic waste collected in Islambagh area is shown in the flow chart [Fig. 12]. The main procedures that are followed are collection, sorting, washing & drying, grinding, melting and molding in plastic good production. And in case of plastic modules production, melted plastics are molded into wires and finally chopped into modules. Some photographs of the total procedures of plastic waste recycling are shown in Fig. 4 to Fig. 9.

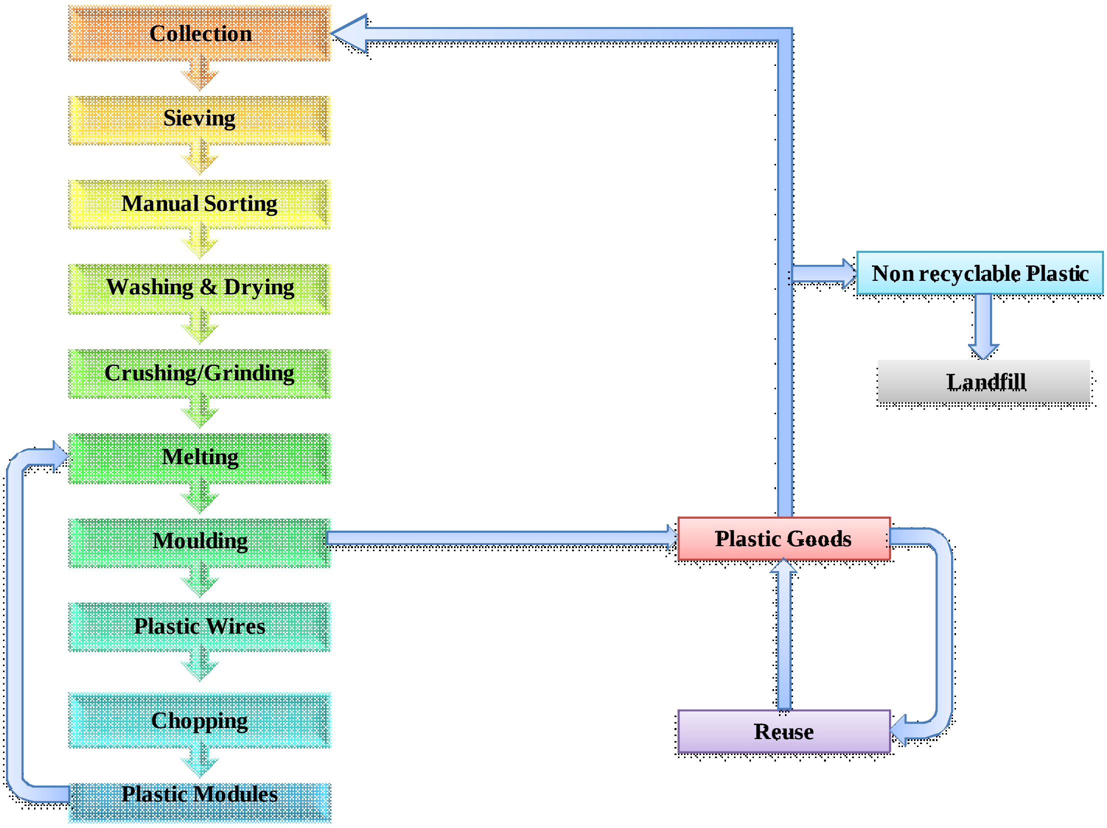

Fig. 12: Flowchart showing plastic recycling procedure of the plastic industries of Islambagh, Dhaka

CONCLUSIONS

The study reveals that two types of manufacturing industries, plastic module manufacturers and plastic product manufacturers have been established in the study area. Here plastics are sorted on the basis of 'Hardness'. Plastic collected per day constitute of 38% hard, 22% semi hard and 40% soft plastic . Plastic modules are classified as crystal (1st class), grey (moderate) and black (third class) according to local grading. On an average,to produce one piece of plastic product (small bucket) about 0.60 -0.70 kg plastic modules are required which is obtained from 0.68 - 0.80 kg of raw plastic. Survey results show that nearly 850 - 1000 pieces of various plastic products are manufactured per day using 550 – 700 kg of plastic modules. Survey also reveals that on an average 447 kg to 611 kg of plastic modules and 631 pcs-1032 pcs of various plastic products are manufactured per day in the study area.The percentage loss of plastic during manufacturing of plastic modules is nearly 28% to 32% of the raw materials with correspond to around 200 kg to 256 kg plastic daily. The main procedures that are followed during plastic recycling are collection, sorting, washing & drying, grinding, melting and molding in plastic good production and finally chopping in case of plastic modules production. The workers and labors working in the factories are not concerned about their health & safety issues due to lack of proper knowledge. Unhealthy and poor ventilation has been observed in most of the factories.

RECOMMENDATIONS

Plastic seems like a wonder product as it is inexpensive, versatile and durable. Popularity of this material would be highly increased if disposal, reuse or recycle would have been done in a environment friendly manner. In our country, due to the lack of proper utilization of resources and equipments the plastic industries are not coming into the limelight and not being established like the other industries. If it would be possible to relocate and replace the plastic industries to another area away from locality to reduce pollution then it could have been much better than the present situation. Besides, proper utilization of resources, fund and recruitment of skilled labors can also accelerate the generosity and reliability of the plastic industries. Legalization of plastic industries and factories, adoption of developed and modern technology to minimize pollution, establishment of effluent treatment plant (ETP) and proper drainage system for disposal of toxic waste generated from factories, employment of skilled and matured labors ensuring their safety can help to flourish this sector. A testing laboratory to maintain the quality of plastic products should be settled in the country for the healthy promotion of this fledgling industry. Bangladesh is capable of producing world class plastic products to capture a sizeable portion of the 500 billion dollars global plastic market.. Management of plastic waste through source separation and proper recycling based on the 4R approach (Reduce, Reuse, Recycle, Recover) should be encouraged to enrich this sector (Khan, 2007).

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POSSIBLE ERRORS INVOLVED IN THE ESTIMATION OF LEACHATE POLLUTION INDEX OF SOLID WASTE DISPOSAL SITE IN BANGLADESH

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ABSTRACT

An important part of maintaining a solid waste landfill is managing the leachate through proper treatment methods designed to prevent pollution into surrounding ground and surface waters. Any assessment of the potential impact of a landfill on groundwater quality requires consideration of the components of the leachate most likely to causze an envionental impact as well as the source of concentration of those components. Leachate pollution index (LPI) is an environmental index used to quantify and compare the leachate contamination potential of solid waste landfill. This index is based on the concentration of 18 pollutants of the leachate and their corresponding significance. That means, for calculating the LPI of a landfill, concentration of these 18 parameters are to be known. However, sometimes the data for all the 18 pollutants included in the LPI may not be available to calculate the LPI. In this studyr, the possible errors involved in calculating the LPI due to the nonavailability of data are reported by the author. The leachate characteristic data for solid waste landfill at Chittagong in Bangladesh have been used to estimate these errors. Based on this study, it can be concluded that the errors may be high if the data for the pollutants having significantly high or low concentration are not available. However, LPI can be reported with a marginal error if the concentrations of the nonavailable pollutants are not completely biased.

Keywords: Landfill, leachate, sub-index, pollutant weight, error analysis, lechate pollution index

INTRODUCTION

Landfill leachate is liquid that moves through or drains from a solid waste landfill. Leachate is the main medium for the contaminants transportation from the landfill to groundwater and surface water (Rowe 1995). Landfill leachate is formed from the infiltration and passage of water through solid waste which results in a combination of physical, chemical and microbial processes that transfers pollutants from waste materials to the water (Jasper et al. 1985).The most common source of landfill leachate is rainwater filtering down through the landfill and aiding bacteria in the process of decomposition (Kelley 1976). Modern landfills are often designed to prevent liquid from leaching out and entering the environment; however, if not properly managed, the leachate is at risk for mixing with groundwater near the site, which can have terrible effects.

A large number of environmental indices have been eveloped in last four daades. Various indices are developed to quantify the pollution or quality of water and air. Usually, the indices are formulated based on studies conducted by the indices developers or on the Delphi technique. In an effort to evelop a method for comparing the leachate pollution potential of various landfill sites in a given geographical area, an index known as Leachate Pollution Index (LPI) was formulated using Rand Corporation Delphi Technique (Kumar and Alappat 2003). The LPI can be used to report leachate pollution changes in a particular landfill over time. The trend analysis so developed for the landfill can be used to assess the post closure monitoring periods. The leachate trend at a given landfill site can facilitate design of leachate treatment facilities for other landfills in the same region. The LPI can also be used to compare leachate contamination potential of different landfills in a given geographical area or around the world. To quantify and compare the leachate contamination potential of municipal landfills 18 characterstics to be known. The other potential applications of LPI include ranking of landfill sites based on leachate contamination potential, resource allocations for landfill remediation, enforcement of leachate standards, scientific research and public information (Kumar and Alappat 2003). The intention of this study was to calculate the error invloved in estimation of LPI due to nonoavailability of data. In this study it is analyzed the possible error associated with estimation of LPI. The study area was pilot scale sanitary landfill at Khulna where daily waste disposal were 450 tons on average.

MATERIALS AND METHODS

To assess the errors involved in calculating LPI due to nonavailability of leachate data, a case study was taken up. Moreover, in the laboratory the required 18 leachate parameters involved in LPI were measured. In contrary, the LPI based on these 18 parameters is considered to be the true LPI. The weighted sum linear aggregation function was found to be the most suitable for the calculation of LPI and when 18 parameters are available Equation (1) is used (Kumar and Alappat 2004).

$$LPI = \sum_{i=1}^{n} w_i p_i \qquad (1)$$

However, when the data for all the leachate pollutant variables included in LPI are not available, the LPI can be calculated using the data set of the available leachate pollutants by the Equation (2):

$$LPI = \frac{\sum_{i=1}^{n} w_i p_i}{\sum w_i} \qquad (2)$$

Where, LPI = weighted additive leachate pollution index; w_i = the weight for the i^{th} pollutant variable; p_i = the sub-index value of the i^{th} leachate pollutant variable; n =18 and $\sum w_i = 1$, m=number of leachate pollutant parameters for which data are available, but in that case, n<18 and $\sum w_i < 1$.

To estimate possible errors involved in calculating LPI, due to the nonavailability of leachate data, two approaches had been considered as: (i) ignoring pollutant data based on weight factor and (ii ignoring pollutant data based on sub-index value. The subindex values of the 18 pollutant in leachate have been derived from the subindex curves reported by Kumar and Alappat (2003; 2004).

Removing Pollutants with Low Weight Factors

i. In the first step, the concentration of the total iron, the parameter having lowest weight, is presumed to be unknown. Hence, by deleting the sub-index value of total iron, the LPI value is derived by using Eq. (1). The derived LPI value is reported in the sixth column, Table 1.
ii. In the next step, chlorides, the parameter having second lowest weight, is also presumed to be unknown in addition to the concentration of total iron. Again using Eq. (1), the LPI of the data set with 16 parameters is calculated and reported in the seventh column, Table 1.
iii. In a similar fashion, it is presumed copper, total dissolved solids, ammonia nitrogen, total coliform bacteria, nickel, total kjeldhal nitrogen, pH, and zinc are also not known one by one in addition to the earlier unknown concentrations of the parameters. The derived LPI values considering concentration of 15, 14, 13, 12, 11, 10, 9,8,7,6,5 and 4 parameters are calculated and reported in columns 8, 9,10, 11, 12, 13, 14,15,16,17,18 and 19 of Table 1, respectively.
iv. The percentage error introduced calculating LPI, with respect to LPI when data are available for all 18 leachate pollutants, is also reported in the last row of respective columns of Table 1.
v. The variation in LPI values with respect to the number of parameters considered in calculating LPI is provided in Figure 1. It also gives the percentage error introduced in calculating LPI values with respect to the number of parameters considered.

RESULTS AND DISCUSSION

Errors Introduced by Ignoring Parameters with High Weight Factors

Based on Table 2 and Figure 2, it can be depicted that the error introduced in calculating LPI is 3.75 %, when concentration of one parameter, i.e., total iron (pollutant with lowest weight factor) is not considered. It depicts that error increases to 3.19 % when concentration of two parameters, total iron and chlorides, is unknown. Then the error decreases to 2.50 % when data for three parameters, total iron, chlorides, and copper, is not known. Result reveals that the error is 4.59 %, when data for one parameter that is chromium (pollutant with highest weight factor) is not considered in calculating LPI. The error is highest, i.e., 53.11 %, when data for the twelve pollutants are ignored. But the percent error drops to 12.15 % when thirteen parameters are not considered in calculating the LPI value. This leads to the conclusion that error involved in calculating LPI does not vary with the number of parameters considered and the variation is erratic.

Errors Introduced by Ignoring Pollutant Data Based on Sub-index Value

The error introduced is highest, i.e., 82.64 %, when data for the fourteen parameters having the highest subindex values are not considered, followed by 79.96 % (Figure 3) when data for the thirteen parameters having the highest subindex values are not considered. Moreover, the errors introduced due to nonconsideration of data of one parameters having the lowest subindex values are 5.56 % are not considered. Here, it is important to note that derived LPI are lower than the true LPI value in the case when pollutants with high sub-index values are ignored. On the contrary, the derived LPI are higher than the true LPI when data for the pollutants with low sub-index values are ignored. Hence, the results obtained by ignoring data for the pollutants with high subindex values produce falsified results, leading to a false sense of security, indicating a relatively more polluted environment as less polluted. But in the case when data for the pollutants with low subindex values are ignored, (Figure 4) distended results are obtained and the results will raise an unnecessary alarm by indicating a comparatively less polluted environmental situation to be more contaminated. Based on this discussion, it is possible to conclude that the errors involved in LPI values are high and dangerous when the data for the pollutants having high subindex values are not available as compared to the scenario when data for the parameters having low subindex values are not available. The error involved in LPI values is low when data for the pollutants having highest and lowest subindex values are not considered simultaneously.

Table 1. Estimating errors involved in calculating LPI values due to nonavailability of data (Parameters with low weight factors ignored)

Pollutant	Pollutant weight, w_i	Pollutant concentration, c_i	Subindex value, p_i	Derived LPI with considered leachate parameters ($w_i p_i$)									
				18	17	16	15	14	13	12	11	10	**9**
Cr	0.064	1.5	6.5	91	5.824	NC	NC	NC	NC	NC	NC	NC	NC
Pb	0.063	1.0	0.45	6	0.378	0.378	NC	NC	NC	NC	NC	NC	NC
COD	0.062	9700	6868	68	4.216	4.216	4.216	NC	NC	NC	NC	NC	NC
Hg	0.062	0.007	0.3	40	2.48	2.48	2.48	2.48	NC	NC	NC	NC	NC
BOD_5	0.061	4800	2890	54	3.294	3.294	3.294	3.294	3.294	NC	NC	NC	NC
As	0.061	0.01	0.01	5	0.305	0.305	0.305	0.305	0.305	0.305	NC	NC	NC
Cn	0.058	0.7	1	14	0.812	0.812	0.812	0.812	0.812	0.812	0.812	NC	NC
Phenol	0.057	3.2	3.5	10	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	NC
Zn	0.056	2.9	0.04	5.1	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856
pH	0.055	8	8.1	8	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
TKN	0.053	718	3200	95	5.035	5.035	5.035	5.035	5.035	5.035	5.035	5.035	5.035
Ni	0.052	0.06	0.04	5.5	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.286
TCB	0.052	6700	9000	87	4.524	4.524	4.524	4.524	4.524	4.524	4.524	4.524	4.524
NH_4-N	0.051	487	450	47	2.397	2.397	2.397	2.397	2.397	2.397	2.397	2.397	2.397
TDS	0.05	11350	1350	20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cu	0.05	3.5	4	37	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Chloride	0.048	3250	1700	9	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432	0.432
Iron	0.045	79	18	7	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.315
Summation	1.000				34.444	28.620	28.242	24.026	21.546	18.252	17.947	17.135	16.565
Total weight					1.000	0.936	0.873	0.811	0.749	0.688	0.627	0.569	0.512
Derived LPI					34.444	30.576	32.350	29.625	28.766	26.528	28.623	30.114	32.353
Percent error					0.000	11.227	6.078	13.991	16.484	22.980	16.899	12.571	6.070

Table 2. Estimating errors involved in calculating LPI values due to nonavailability of data (Parameters with high weight factors ignored)

Pollutant	Pollutant weight, w_i	Pollutant concentration, c_i	Subindex value, p_i	Derived LPI with considered leachate parameters ($w_i p_i$)									
				18	17	16	15	14	13	12	11	10	**9**
Cr	0.064	1.5	5	5.824	5.824	5.824	5.824	5.824	5.824	5.824	5.824	5.824	5.824
Pb	0.063	1.0	6	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378	0.378
COD	0.062	9700	68	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Hg	0.062	0.007	40	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
BOD_5	0.061	4800	54	3.294	3.294	3.294	3.294	3.294	3.294	3.294	3.294	3.294	3.294
As	0.061	0.01	5	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305	0.305
Cn	0.058	0.7	11	0.638	0.638	0.638	0.638	0.638	0.638	0.638	0.638	0.638	0.638
Phenol	0.057	3.2	10	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Zn	0.056	2.9	5.1	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856	0.2856
pH	0.055	8	8	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	
TKN	0.053	718	95	5.035	5.035	5.035	5.035	5.035	5.035	5.035	5.035	-	
Ni	0.052	0.06	5.5	0.286	0.286	0.286	0.286	0.286	0.286	0.286	-	-	
TCB	0.052	6700	87	4.524	4.524	4.524	4.524	4.524	4.524	-	-	-	
NH_4-N	0.051	487	47	2.397	2.397	2.397	2.397	2.397	-	-	-	-	
TDS	0.05	11350	20	1.0	1.0	1.0	1.0	-	-	-	-	-	
Cu	0.05	3.5	37	1.8	1.8	1.8	-	-	-	-	-	-	
Chloride	0.048	3250	9	0.432	0.432	-	-	-	-	-	-	-	
Iron	0.045	79	7	0.315	-	-	-	-	-	-	-	-	
Summation	1.000			34.304	33.989	33.557	31.757	30.757	28.360	23.836	23.550	18.515	18.075
Total weight				1.000	0.955	0.907	0.857	0.807	0.756	0.704	0.652	0.599	0.544
Derived LPI				34.304	35.590	36.997	37.056	38.112	37.513	33.857	36.119	30.909	33.225
Percent error				0.000	3.751	3.197	2.503	2.996	3.922	22.330	18.594	18.665	12.936

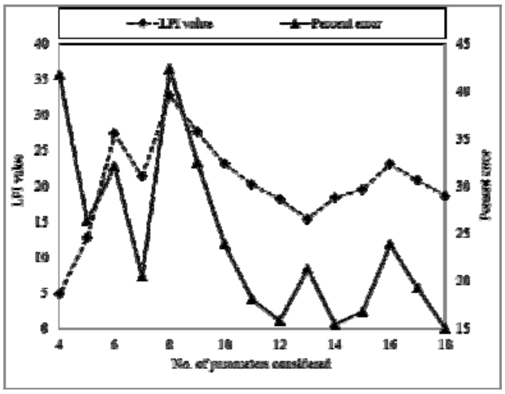

Figure 1: Variation of LPI and percent error when low weight parameters are ignored.

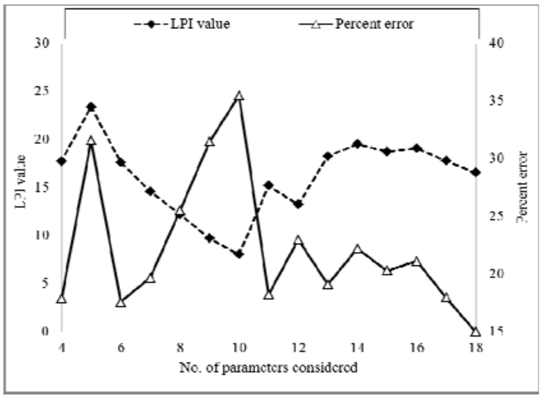

Figure 2: Variation of LPI and percent error when high weight parameters are ignored.

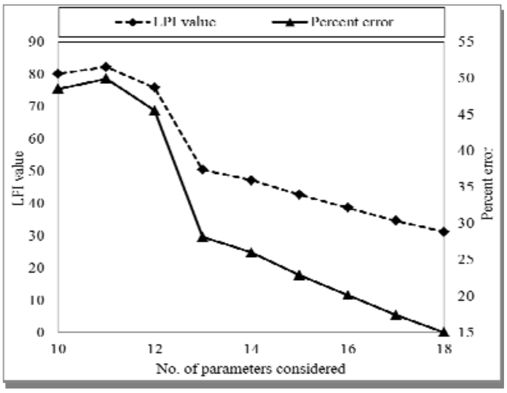

Figure 3: Variation of LPI and percent error when parameters with highest Sub-index.

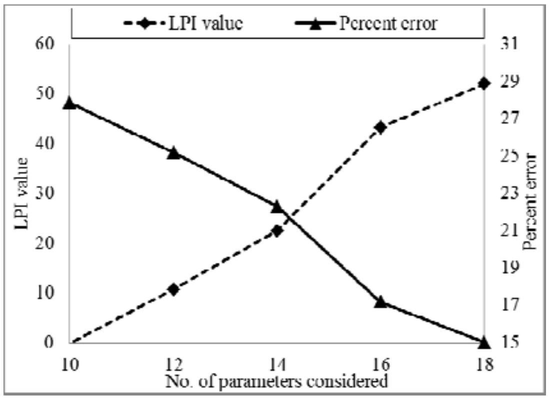

Figure 4: Variation of LPI and percent error when parameters with lowest Sub-index ignored

CONCLUSIONS

Result reveals that maximum error (22.98 %) was introduced in calculating LPI when the data for the five low weight parameters are not considered, but the error was as low as 6.07 % when data for nine parameters are not considered. Similarly the error involved in calculating LPI is maximum (18.65%) when data for eleven high weight parameters were ignored, but the error involved was low (2.99 %) when data for four high weight factors were ignored. Here it can be concluded that the errors introduced in calculating LPI values are not at all related to the number of parameters whose concentrations are not known. From this it can be concluded that LPI is more reliable and accurate as a larger number of parameters are available in its formulation. In contrary, the error introduced in calculating LPI was more sensitive when data for the parameters having high sub-index were not considered. Finally, it can be concluded that errors introduced in calculating LPI are marginal when the data of the parameters having highest and lowest sub-index were not considered simultaneously.

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OPTIMIZATION OF BIODIESEL PRODUCTION FROM WASTE COOK OIL

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ABSTRACT
Synthesis of biodiesel from Waste Cook Oil (WCO) by three-step method and optimization of the process were studied. The raw oil, containing 1.9 wt% Free Fatty Acid (FFA) and viscosity was 47.6 mm^2/s.WCO was collected from local restaurants of Sylhet city. By the transesterification method yield was lower than three-step method, so three-step method were optimized. In the three-step method, the first step is saponification of the oil followed by acidification to produce FFA and finally esterification of FFA to produce biodiesel. In the esterification reaction, the reaction parameters such as methanol to FFA molar ratio, catalyst concentration and reaction temperature were optimized. Silica gel was used during esterification reaction to adsorb water produced in the reaction. Hence the reaction rate was increased and finally the FFA was reduced to 0.94 wt%. A factorial design was studied for esterification reaction and developed to obtain lower viscosity and higher yield of biodiesel. Finally various properties of biodiesel such as FFA, viscosity, specific gravity, cetane index, pour point, flash point etc. were measured and compared with biodiesel and petro-diesel standard. According to diesel properties the produced biodiesel from WCO by this method can be successfully used as diesel.

Keywords: Saponification, Acidification, Esterification, Biodiesel, Factorial design.

INTRODUCTION

The diesel engine is widely used to provide the power source on-land transportation vehicles, marine vessels and power plants. However, a diesel engine also emits various forms of pollutants in gaseous, liquid and solid phases to the environment. These pollutants can endanger human health and damage the ecological environment (Cherng et al., 2006).The concern is increasing worldwide for environmental protection and for the conservation of non-renewable natural resources. Fatty acid methyl esters (FAME) show great potential as diesel substitutes, and they are known to be sources of biodiesel (Xuejun et al., 2007).

Currently, more than 95% of the world biodiesel is produced from edible oil which is easily available on large scale from the agricultural industry. However, continuous and large-scale production of biodiesel from edible oil has recently been a great concern because they compete with food materials the food versus fuel dispute. There are concerns that biodiesel feedstock may compete with food supply in the long-term. Non-edible plant oil has been found to be promising crude oil for the production of biodiesel. The use of non-edible oil for biodiesel production compared with edible oil is very significant in developing countries because of the tremendous demand of edible oil as food and they are far too expensive to be used as fuel at present (Mustafa, 2011; Arjun et al., 2008). In Bangladesh the potentiality of producing oil source is investigated and it is found that the production potential is not too high. As we have a very large population, the edible oil sources cannot be employed for the biodiesel production. Moreover we have extreme limitation of land. So additional land acquiring is also impossible for the production of oil seeds. The oil seed source that can be used for biodiesel production in Bangladesh are WCO, Bakul oil, mustard oil, sesame oil, coconut oil, peanut oil, linseed oil, castor oil, nahor oil etc.(http://www.eoearth.org/article).

There are different methods for biodiesel preparation like base or acid catalyzed transesterification (Meher et al., 2006; B.K, 1999), two-step method (Zullaikah et al., 2005) and three-step method (Morshed et al., 2011). Encinar et. al. (2005) prepared biodiesel from WCO by base catalyzed transesterification but the reaction yield was too low then two-step method was conducted to increase the reaction yield. Zheng et. al. (2006) produced biodiesel from WCO by acid catalyzed transesterification but the molar ratio of oil to methanol was 1:74. In this method huge amount methanol required for reaction and additional cost involved for the separation of biodiesel. In the present study biodiesel was prepared from WCO by three-step method to increase the reaction yield and minimize the methanol molar ratio. Additionally optimization study was done by the application of factorial design based on viscosity to find out the better reaction conditions.

MATERIALS AND METHODS

CHEMICALS

Methanol (99-100%), ethanol (99-100%), sodium hydroxide pellets (96%), potassium hydroxide pellets (>84%), phenolphthalein (P^H 8.2-9.8), acetone (99%), diethyl ether , hydrochloric acid (37%), sulfuric acid (98%), iodine , sodium iodide, bromine, carbon tetrachloride, glacial acetic acid, potassium dichromate etc. All the chemicals were used as analytical reagent grade.

RAW MATERIAL

Waste cook oil (palm oil and soybean oil) was collected from local restaurants located in Sylhet city in Bangladesh. The oil was filtered and its properties were measured.

BIODIESEL PREPARATION BY THREE- STEP METHOD

For saponification process required amount of WCO was taken in a three necked flask and mixed with different stoichiometric amount of aqueous sodium hydroxide solution (Morshed et al., 2011). The mixture was heated under reflux with vigorous stirring at temperature of 100 ^{0}C for different time. After saponification, produced sodium soap solution was treated with different stoichiometric amount of concentrated hydrochloric acid at a temperature of 65 -70 ^{0}C. After dissolving the soap, the fatty acid contents were separated in separatory funnel. Produced FFA was reacted with different stoichiometric amount of methanol at different temperature, catalyst concentration, different molar ratio of methanol to FFA and different time. After preparing the biodiesel from WCO various physico-chemical properties were measured and compared with the standard biodiesel.

ANALYTICAL METHODS FOR OIL AND BIODIESEL

FFA and saponification value was measured by standard method described by Jeffery et al. (1991). The iodine value (IV) was determined by titrating the sample with 0.01 N sodium thiosulphate and chemical reagents until the disappearance of blue color described by Jeffery et al. (1991). Iodine value was calculated by following Eq. (1):

$$IV = (V_1-V_2) *S*0.1269*100/ W \quad (1)$$

V_1 and V_2 are the volume of sodium thiosulphate (mL) required for titration with sample and blank titration, S is the concentration of $Na_2S_2O_3$ in Normality, W is the weight of oil sample in gm. Physical properties color, moisture content and density of the sample were by the following ASTM D 1500, ASTM D 1744 (Karl fisher method), ASTM D 1480/81 and ASTM D 240. Viscosity, cloud point, pour point were determined by standards ASTM D445 respectively.

RESULTS AND DISCUSSION

CHARACTERIZATION OF WCO

The properties of WCO such as viscosity, specific gravity, moisture content, saponification value, pour point, cloud point etc were measured and presented in Table 1.

Table 1: properties of WCO

Properties	Experimental value
Physical state	Liquid
Color	Deep oily
Specific gravity at 25^0C	0.902
Kinematic viscosity, mm^2/s at 40 ^{0}C	54.53
FFA content (wt% of oil)	1.9
Average molecular weight of FFA (gm/mol)	275.5
Molecular weight of oil (gm/mol)	864.5
Saponification value (mg of KOH/gm of oil)	238
Cloud point (^{o}C)	12
Pour point (^{o}C)	6

BIODIESEL PREPARED BY THREE-STEP METHOD

FFA preparation

FFA was prepared from WCO by saponification followed by acidification. Saponification was done by the method described above. Saponification was done with different stoichiometric amount of NaOH. After saponification and acidification FFA was produced. The results are present in Fig. 1.

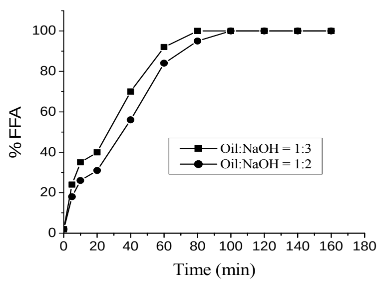

Fig. 1: Preparation of FFA from WCO through saponification and acidification by different stoichiometric molar ratio of oil to NaOH in aqueous solution [Reaction temperature = 100 ^{0}C under reflux with vigorous stirring].

Biodiesel Preparation from FFA

The methanol to FFA molar ratio, catalyst concentration, temperature and silica gel are the important parameters that affecting the FFA conversion to biodiesel. The effect of methanol to FFA molar ratio, catalyst concentration, temperature and silica gel on conversion of FFA was investigated. The results are shown in Fig 2,3,4,5.From the Fig. 2,3,4, it was found that the FFA conversion to biodiesel was 98% at 6:1 molar ratio of methanol to FFA, 5 wt% catalyst (HCl) concentration, 60 ^oC temperature. From the Fig. 5, it can be seen that 98% conversion was achieved within 80 minutes in presence of silica gel and reaction rate was increased.

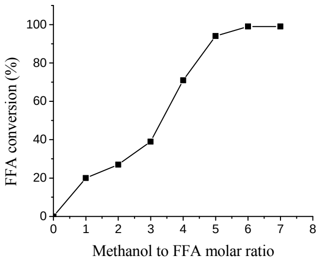

Fig. 2: Effect of Methanol to FFA molar ratio on FFA conversion [temperature 60 ^oC, catalyst (HCl) 5 wt% of FFA, time 120 min under reflux with vigorous stirring].

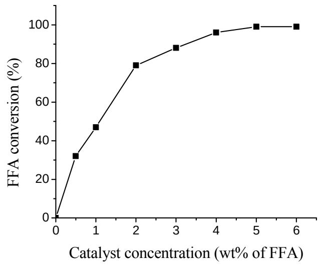

Fig. 3: Effect of catalyst (HCl) concentration on esterification reaction [Reaction temperature = 60 ^0C, methanol to FFA ratio 6:1, Reaction time 120 min, under reflux with vigorous stirring].

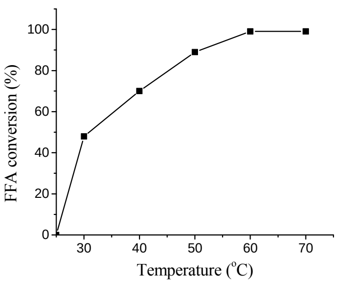

Fig. 4: Effect of Temperature on esterification reaction [Catalyst (HCl) concentration 5 wt% of FFA, methanol to FFA ratio 6:1, Reaction time 120 min, under reflux with vigorous stirring].

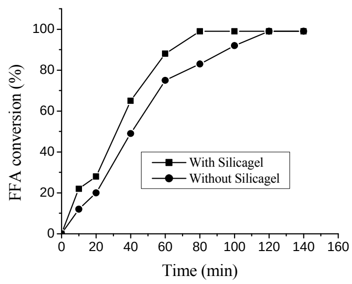

Fig. 5: Conversion of FFA to biodiesel at different methanol to FFA molar ratio in absence and presence of silica gel [Reaction temp. 60 ^0C, Catalyst (HCl) concentration 5.0% wt of FFA and Reaction time 2 h under reflux with vigorous stirring].

OPTIMIZATION STUDY

Four factors (methanol to FFA molar ratio, catalyst concentration, temperature and reaction time) affect the biodiesel production process from waste cook oil. To study the optimization of process, a factorial design was carried out. The experiments were carried out according to half-Replicate of 2^4 full factorial design. Table 2 shows the decoding values for methanol to FFA molar ratio, catalyst concentration, reaction temperature and reaction time. Table 3 presents the values of sample variances. Eight set of experiments were run for the factorial design and the results are shown in Table 4.

Where Y is the viscosity of biodiesel and $\bar{Y}$ is average value of Y. The sample variances were determined and tested for homogeneity on the basis of Cochran's criterion. It was found that the sample variances are homogeneous for the significance level $\alpha = 0.05$ and the number of degrees of freedom $\nu_1 = 4$ and $\nu_2 = 8$ and the error mean square was 2.65.The complete regression Eq.(1)

describes the contributions of the various factors on the outcome (response) of the biodiesel conversion.

Table 2: Decoding values of independent variables used in the experimental design

Factors	Max. (+1)	Min. (-1)
Molar ratio (X_1)	8	3
Catalyst conc. (X_2)	6	2
Temperature, °C (X_3)	60	40
Time (min) (X_4)	90	30

Table 3: Sample Variances

S_1^2	1.48	S_5^2	2.20
S_2^2	3.02	S_6^2	5.72
S_3^2	2.90	S_7^2	2.29
S_4^2	1.53	S_8^2	2.04

Table 4: Design of the experiment using coded value

No. of runs	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	$\bar{Y}$
1	+1	+1	+1	+1	3.93	4.74	5.85	5.92	3.13	4.72
2	+1	+1	-1	-1	11.42	11.91	12.01	14.95	14.9	13.04
3	+1	-1	+1	-1	8.74	10.21	10.02	12.61	12.57	10.83
4	+1	-1	-1	+1	7.55	8.23	10.16	10.09	7.96	8.80
5	-1	+1	+1	-1	9.83	9.69	12.95	12.46	11.17	11.22
6	-1	+1	-1	+1	9.02	12.53	9.26	11.39	14.77	11.40
7	-1	-1	+1	+1	8.73	9.98	12.03	12.41	10.48	10.73
8	-1	-1	-1	-1	20.39	21.56	21.22	23.65	23.42	22.05
										$\sum\bar{Y}$ = 92.80

$$\hat{Y} = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_{12}X_{12} + b_{13}X_{13} + b_{23}X_{23} \quad (2)$$

The coefficients of the regression equation were estimated and the significance of the coefficients was tested using the student T-test. Only two coefficient appeared as insignificant for the significance level α = 0.01. Neglecting the insignificant coefficient the final regression Eq. (2) becomes as:

$$\hat{Y} = 11.6 - 2.25X_1 - 1.50X_2 - 2.22X_3 - 2.68X_4 + 1.03X_{12} \quad (3)$$

Using the Fisher's test the adequacy fitness of the regression equation was determined. With α = 0. 01, $\nu_1 = 2$ and $\nu_2 = 32$ the tabulated value of Fisher's F was 5.4, where as our experimental value was 3.26. Therefore the equation fits in the experiment.

PROPERTIES OF BIODIESEL

Properties	Produced biodiesel value	Biodiesel Standard (Morshed et al, 2011; Joshi & Pegg, 2007)	Diesel standard (Joshi & Pegg, 2007)
Specific gravity, at 25 °C	0.792	0.88 (at 15.5^0 C)	0.85(at 15.5^0 C)
Kinematic viscosity (mm^2/s), at 40°C	3.29	1.9–6.0	1.3 – 4.1
FFA content (wt%)	0.94	-	-
Moisture content (%)	0.12	0.05% max.	0.161
Saponification value	194	-	-
Flash point (^{0}C)	150	100 to 170	60 to 80
Iodine value	88	-	-

Cloud point (°C)	0	-3 to 12	-15 to 5
Pour point (°C)	-3	-15 to 10	-35 to -15
Cetane Index	54	-	-
Yield (%)	79	-	-

The properties of produced biodiesel such as viscosity, FFA content, moisture content, pour point, cloud point, saponification value, iodine value, specific gravity were presented in Table 5 and compared with standard values. The reaction yield was 79%. Table 5: Properties of biodiesel produced from WCO by three step method and comparison with standard biodiesel and diesel values.

CONCLUSION

Biodiesel was prepared from WCO by three-step method, in three-step method aqueous sodium hydroxide solution was used for saponification, the molar ratio of oil to NaOH and reaction time were optimized. A factorial design was applied to find the optimum conditions for esterification reaction. At optimum conditions 98% conversion of the FFA to FAME was obtained and the viscosity, yield were 3.29 mm^2/s and 79% wt/wt. The properties of produced biodiesel such as viscosity, specific gravity, cloud point, pour point, flash point, cetane number are nearest to the petro-diesel. The present experimental results support that produced biodiesel from WCO by this method can be successfully used as diesel.

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GENERATION AND ANALYSIS OF LEACHATE FROM SIMULATED LANDFILL LYSIMETER USING DIFFERENT TYPES OF SOIL COVER

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ABSTRACT
This study illustrates the leachate characteristics influenced by the variation of landfill operational condition at varying top cover and hence to determine the best applicable soil to be used in sanitary landfill as top cover. To this endeavor, one lysimeter was simulated as open dump i.e. filled solely with municipal solid waste (MSW) having no top cover, while, three lysimeter as sanitary landfill having top cover with different types of soil i.e. sandy loam soil, silty loam soil and clay soil. Distilled water with an amount equal to 50 % of the daily-recorded rainfall in 2010 was recirculated into each lysimeter once a week. In addition, leachate generation rate and amount, leachate characteristics as well as waste settlement at varying lysimeter operational mode were monitored. Result reveals that open dump lysimeter produced more quantity of leachate around 24 % in contrast to the sanitary landfills. Moreover, the rate and amount of genertaed leachate from sanitary lysimeter shows no any significant difference among them. Waste settlement was found as maximum in open dump lysimeter due to high generation of leachate. In contrary, maximum quantities of leachate pollutants were found in open dump lysimeter. Result reveals that lysimeter having sandy loam soil had the lowest concentration and load of most of the pollutants, compared with the lysimeters having silty loam and clay soils as the top cover. Finally, it can be concluded that pollutants are significantly deducted in leachate, with a sandy loam soil used as a top cover in MSW landfill.

Keywords: Landfill lysimeter, solid waste, leachate quality, sandy loam soil, silty loam soil, clay soil.

INTRODUCTION

Landfill is a unit operation for final disposal of ‘municipal solid waste’ (MSW) on land (Tubtimthai 2003). Open dump and sanitary landfill are two types of landfill practices all over the world. Though the serious environmental problems associated with abandoned open dump sites, in South and South East Asia more than 90% of MSW is disposed of in open dumps (Rafizul et al. 2012). In open dumping disposed, waste are neither compacted nor covers with soil. In sanitary landfill soil has been used for daily cover and top cover in order to minimize environmental impact. Lysimeter is a simulated from of landfill in the sense of control device. The word lysimeter is a combination of two Greek words “Lusis” means “Solution” and “Metron” means “Measure” (Rafizul et al. 2009). So lysimeter means leachate quantity measure and leachate problem solution. Sanitary landfill leachate is the most complicated and costly wastewater to treat (Bilgili et al. 2007). In contrary, landfill leachate is formed from the infiltration and passage of water through solid waste which results in a combination of physical, chemical and microbial processes that transfers pollutant from waste materials to the water (Jasper et a.,1985; Kjeldsen et al., 2002). Moreover, the variation of leachate quality interms of organic and inorganic compounds as well as metal and heavy metal concentrations can be attributed to many interacting factors such as composition and depth of MSW; decomposition and age; degree of compaction; landfill design and operation; liner design; filling procedures; availability of moisture content and landfill gas (LFG); rate of water movement and temperature (Rafizul et al. 2009). As a result proper treatment of leachate is almost impossible in developing countries like Bangladesh due to cost effect. The top cover used in sanitary landfill operation might be consided as an option to decrease the pollutants' concentrations in the leachate (Karnchanawong et al. 2009). So in order to minimize the environmental impact with low cost sanitary landfill the objectives of this of this study is to determine the best applicable soil in sanitary landfill as cover soil.

MATERIALS AND METHODS

Set-up of landfill lysimeter

Four lysimeters made of PVC pipe were prepared in this study. Among four, one lysimeter simulated as open dump i.e. filled solely with MSW having no cover soil designated as lysimeter-L. lysimeter-L, represents the aerobic condition. In contrary, the other three lysimeters were treated as sanitary landfill having three different types of soil covers i.e. sandy loam soil, silty loam soil and clay soil and hence designated lysimeter-LSDL, lysimeter-LSTL and lysimeter-LC, respectively. These three landfill lysimeter operated as an anaerobic conditions in presence of cover soil. The cross section of reference cell with in detailed for each lysimeter shown in Figure 1. The height and inner diameter of all lysimeters were 1800 mm and 200 mm, respectively. The upper 100 mm free space is for adding rainfall. Gravel layer served as the waste base and allowed the leachate to flow through the collecting pipe. A geo-textile sheet was used to avoid rapid clogging of the under laying pipe. In addition, using the textural classification chart the soils used as top cover were classified shown in Table 1.

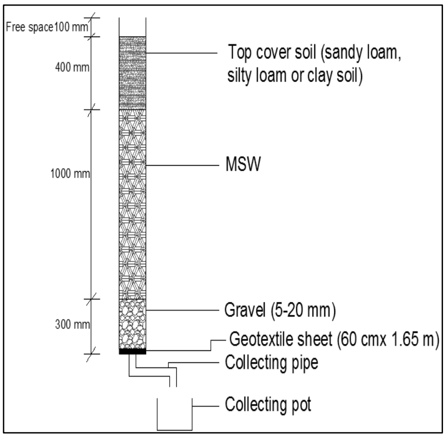

Figure 1: Cross section of reference cell

Physical characterization of deposited MSW

3 Kg of MSW was taken and hence sorting all the composition consists of 60 (w/w) food and vegetables, 7 (w/w) of plastic/polythene, 14 (w/w) of paper/paper products, 0.7 (w/w) of leather/rubber, 2 (w/w) of textile and woods, 3(w/w) of metal and tins, 3.5(w/w) of glass and ceramics, 4(w/w) of stone, 4.5 (w/w) of cloth, 1.3 (w/w) of others. However, the organic and moisture content was found 51 and 56 %, respectively. Moreover, the waste density filled in lysimeter was 700 kg/m^3.

Rainfall addition, leachate sampling and analysis

The duration of rainy season in Bangladesh is from mid June to mid September. The daily precipitation data from June~August 2010 of Khulna city were used to replicate rainfall in this study. The study was conducted for 5-month period. For the first 3-months, June to August daily precipitation data was used and for the next 2-months, July to August precipitation data was used. To work out actual infiltration through the landfill, a runoff coefficient of 0.22 (for compacted top soil with a slope of 3%) and an evaporation level of 28 % of the total rainfall estimated by Jica et al. (1992) were used. The infiltration through the landfill was estimated to be 50 % of daily rainfall. Distilled water with an amount equal to 50 % of the daily-recorded rainfall in 2010 was fed once a week into each lysimeter by adding all the daily rainfall of that week. Leachate quantity, waste settlement rate and leachate characteristics were determined once a week.

Analytical methods for the appraisal of leachate

In the laboratory, pH was determined by pH meter (HACH, Model No. Sens ion 156), EC by conductivity meter (HACH, Model No. Sens ion 5), alkalinity by titration method, COD by closed reflexive method as per the standard methods (APHA, 1998). In addition, TS dried at 103-105 ^{0}C and TKN by macro-kjeldahl method as per the standard methods (APHA, 1998).

Table 1: Classification of soil used as top cover in this study

Parameters	Lysimeter-LSDL	Lysimeter-LSTL	Lysimeter-LC	Analytical method
Moisture content (%)	15	30.9	39.7	ASTM D-2216-90
pH	8.18	8.31	7.63	-
Specific gravity	2.67	2.55	2.51	ASTM D-854
Sand: Silt: Clay	59:36:5	24:55:21	5:7:88	ASTM C-136,D-422
Soil classification	Sandy Loam	Silty Loam	Clay	USDA

RESULTS AND DISCUSSIONS

Leachate generation

Leachate is formed in solid waste landfill when the refuse moisture content exceeds its field capacity (rainfall, initial moisture content, etc.). Amount of rainfall added and leachate generated from different concerned lysimeters are summarized in Figure 2 over time. Cumulative amount of rainfall added into each lysimeter was 16.64 L and cumulative amount of leachate generated from lysimeter-LSDL, LSTL, LC and L were 13.13, 13.66, 13.36 and 17.97 L, respectively. Lysimeter filled solely with MSW produced the highest amount of leachate in contrast to lysimeters having cover soils around 24 % although the same amount of rainfall was added to each lysimeter, due to the top cover that can reduce the percolating of rainwater (Rafizul et al. 2012). Cumulative amounts of leachate from lysimeters having cover soils showed no any significant difference among them it is also supported by Karnchanawong et al. (2009). It can be decided that, sanitary operational mode with a sandy loam soil as a top cover is proved to be most efficient in reduction of leachate quantity.

Settlement of MSW in landfill lysimeter

The waste settlement mechanism in landfill is complex enough. The settlement rate of MSW in lysimeters during the experimental period is summarized in Figure 3. The ultimate settlement amount was recorded 20.6, 22.6, 21.3 and 32.2 % (% of waste thickness) for lysimeter-LSDL, LSTL, LC and L, respectively. The highest amount of settlement occurred in lysimeter-L as the highest amount of leachate was produced from it. Here it is fascinating to note that though the highest amount of settlement occurred in lysimeter-L the initial settlement rate were found higher for lysimeters having cover soils. Due to the additional weight of the soil on the waste, the waste height was compacted at the initial stage and initially settlement rate was found higher for the lysimeters having top cover. But at the latter stage waste settlement rate was increased in lysimeter-L because sanitary lysimeters were compacted due to excessive settlement initially and produced lower amount of leachate finally where no compaction was occurred in open dump lysimeter-L and produced higher amount of leachate finally. In accordance with Visvanathan et al. (2002) and Rafizul et al. (2012) the findings are valid.

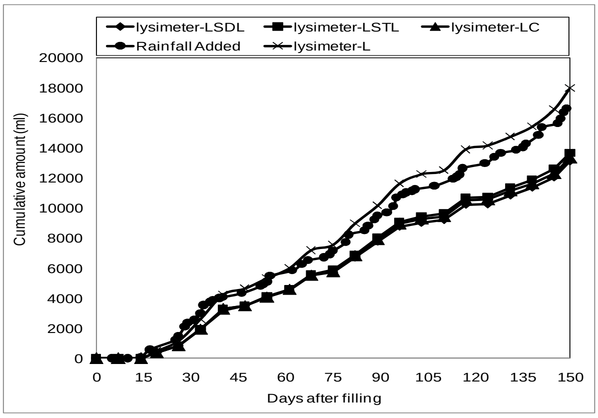

Figure 2: Cumulative amount of rainfall added and leachate generation from simulated lysimeter.

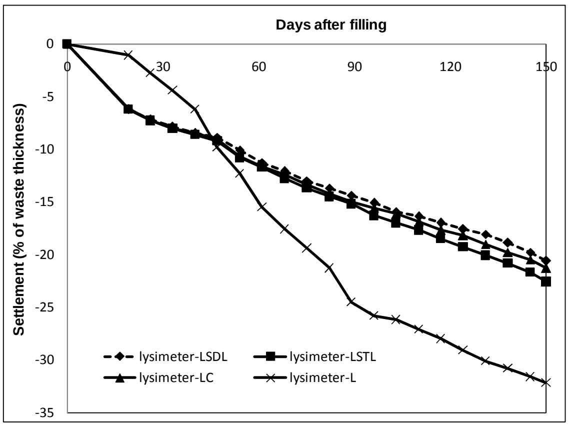

Figure 3: Variation of Settlement of MSW in lysimeter at varying operational condition.

Leachate characteristics

The concentrations and load of leachate pollutants in landfill lysimeter at varying operational condition presents in Tables 2 and 3 and hence discussed in followings.

Table 2: Concentrations of leachate generated from MSW in landfill lysimeter

Parameter	Lysimeter-LSDL	Lysimeter-LSTL	Lysimeter-LC	Lysimeter-L
	Min –Max (Mean)	Min–max (Mean)	Min – Max (Mean)	Min – Max (Mean)
pH	6.41–7.86 (6.82)	6.43-7.72 (6.8)	6.37-7.67 (6.78)	6.56–7.67 (7.06)
EC	13.2–30.2 (20.46)	14.3–33.2 (21.19)	15.1–34.2 (22.97)	15.3–35.2 (23.13)
TS	1527–11500 (4272)	1592-11725 (4408)	1675–11680 (4502)	1243–10960 (3853)
Alkaliniy	358–8045 (3581)	305-7870 (3660)	392–8935 (3965.7)	700–10070 (4464.6)
COD	2065-32305 (11368)	2580-34460 (12268)	2350–36505 (13067)	2800–39725 (14421)
TKN	1057.9-350.5 (576)	975.3-310 (532.5)	978.7-250 (501)	702.3-145.7 (356)

Note: EC=Electric Conductivity; TS=Total Solid; TKN= Total Kjeldahl Nitrogen. COD=Chemical Oxygen Demand. pH has no unit; conductivity is in mS/cm; rests are in mg/L.

Table 3: Pollutant load leached from lysimeters during the study period

Pollutant load (mg/kg dry initial waste)	Lysimeter-LSDL	Lysimeter-LSTL	Lysimeter-LC	Lysimeter-L
TS	2706.8	2888.7	2898.8	3293.4
Alkalinity	2238.56	2275.83	2571.4	3813
COD	6938	7586	8091	11716
TKN	352.7	337.8	314	298.96

pH

pH is considered as the most significant parameter that affects most of the pollutants concentration in leachate (Bilgili et al. 2007). Table 4 exhibits that average value of pH of lysimeter-L is the highest and is in alkaline range and pH of the sanitary lysimeter-LSDL, LSTL and LC is in acidic range. A study by Bilgili et al. (2007) found that pH values were higher in open dump landfill reactor compared to sanitary landfill reactor. Figure 4 illustrates that for all lysimeters pH was sharply increasing in nature for first 47 days from 6.73-7.86, 6.52-7.52, 6.68-7.93 and 6.56-7.67 and then sharply decreased up to 81 days from 7.86-6.83, 7.52-6.8, 7.93-6.75 and 7.67-7.05 for lysimeter-LSDL, LSTL, LC and L, respectively. At last stage pH was leisurely declining in nature and got a more or less unwavering state for all concerned lysimeters.

Conductivity

Figure 5 confirms that for all lysimeters, EC decreased sharply from 30 - 13.2, 32.1 - 14.3, 33.9 - 15.1 and 34.6 - 15.3 mS/cm for lysimeter-LSDL, LSTL, LC and L, respectively, upto 47 days. After that EC values were rising in condition for all concernd lysimeters. So a linear relationship between pH and EC is EC decreases with the increment of pH. With the increase of pH metal dissolution may be decreased and hence EC also decreased due to reduction of free ions. From the Table 2, mean value of EC is the utmost for lysimeter-L and lowest for lysimeter-LSDL. A similar study conducted by Karnchanawong et al. (2009) stated the same results. Hence leachate conductivity is lower through sandy loam soil in sanitary landfill operational mode as top cover.

Total solid

The average value of total solid (TS) in the leachate generated from lysimeter-L was significantly less than lysimeters-LSDL, LSTL and LC. The higher concentrations of TS found from the lysimeters having cover soils might be because of the leaching out of the solids from the soil themselves. The Figure 6 shows that for all lysimeters TS values were found increasing for the first three sampling and then decreased harshly up to 90 days from 11500 - 1527, 11725 - 1674, 11680 - 1778 and 10960 - 1243 mg/L for lysimeters-LSDL, LSTL, LC and L, respectively. TS concentration was decreased due to dilution effects and reduction in availability of loose materials with the increase of landfill. Afterward the graph was gotten a stable state. As TS load was found highest in lysimeter-L and lowest in lysimeter-LSDL (Table-3) sandy loam soil is the best soil as top cover. A study conducted by Karnchanawong et al. (2009) stated the same result.

Alkalinity

The alkalinity of water is due primarily to salts of weak acids and strong bases (Rafizul et al. 2009b). Mean concentration as well as alkalinity load is the maximum for lysimeter-L and minimum for lysimeter-LSDL. Figure 7 indicates that the alkalinity value was increased cruelly over a short time at the initial stage up to 47 days for all lysimeters, from 358-8045, 305-7870, 392-8935 and 700-10070 mg/L for lysimeter-LSDL, LSTL, LC and L, respectively. Soon after that, due to high amount of leachate generation the alkalinity may be watered down. From the above explanations, alkalinity from landfill leachate can be significantly deducted by operating a landfill as sanitary landfill with a sandy loam soil as top cover. Findings are valid according to Karnchanawong et al. (2009).

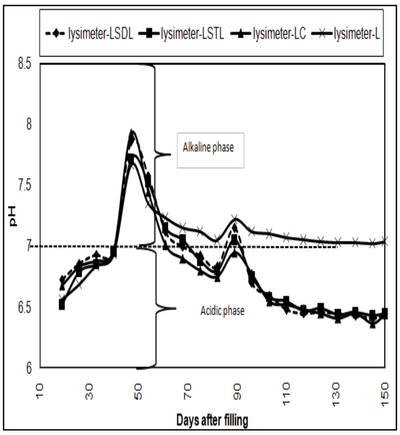

Figure 4: Variation of pH in landfill lysimeter at varying operational condition.

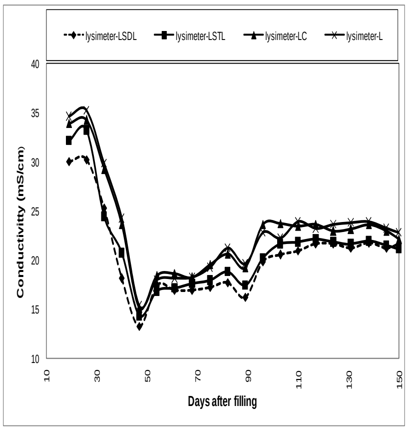

Figure 5: Variation of conductivity in landfill lysimeter at varying operational condition.

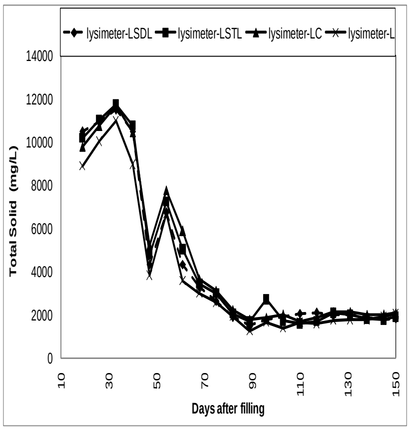

Figure 6: Variation of total solid in landfill lysimeter at varying operational condition

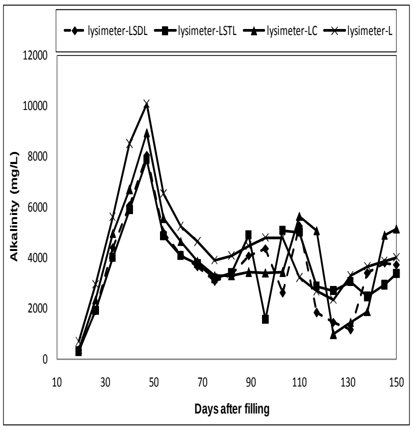

Figure 7: Variation of alkalinity in different lysimeter

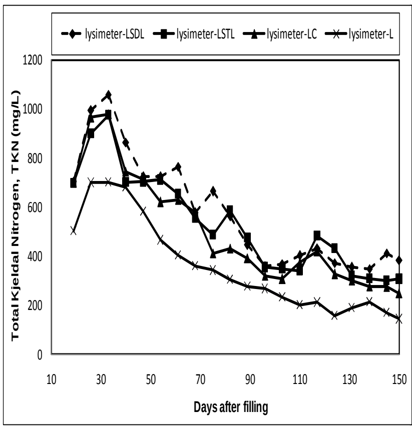

Figure 8: Variation of TKN in different lysimeter

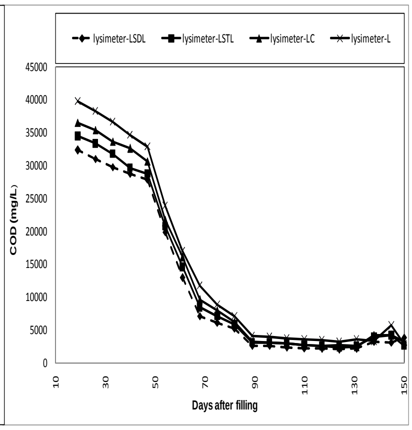

Figure 9: Variation of COD in different lysimeterat

Total kjeldahl nitrogen

Nitrogen which has potential to pollute water and soil is another major constituent in the leachate. Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen (organic-N) and NH_4-N (APHA 1998). Figure 8 depicts that TKN concentration of different landfill lysimeter operational mode varies from 1057.2-355, 975.3-301.7, 978.7-250 and 702.3-145.7 mg/L for lysimeter-LSDL, LSTL, LC and L, respectively. The Concentrations were decreasing in nature with the elapsed period of experimental operation. Tables 2 and 3 illustrate that TKN concentration as well as load during the experimental period was found as highest in lysimeter having sandy loam soil as top cover and lysimeter which was in open dump operational mode produced the least. Hence, it can be concluded that open dumping landfill operation has a great efficiency in reduction of TKN rather than sanitary operational mode.

Chemical oxygen demand

COD is an important test and it gives a quick measurement of pollution load of the leachate. Tables 2 and 3 reflect that the lysimeter-L posses the utmost average concentration and cumulative amount of COD load while lysimeter-LSDL posses the slightest. COD concentration was found highest for the first sampling from all the concerned lysimeters and Subsequently, the graph was declining in nature from 32305-2065, 34460-2580, 36505-2350 and 39725-2800 mg/L for lysimeter-LSDL, LSTL, LC and L, respectively, from the Figure 9. COD decreases sharply between 50-90 days due to comparatively the higher rate of leachate production (Rafizul et al. 2012). Therefore it is proved that an open dump landfill operational mode produced the most tainted leachate where sandy loam soil has a great efficiency to remove COD. The findings are supported by (Rafizul et al. 2012).

CONCLUSIONS

The methodical supervising of physico-chemical characteristics of leachate from MSW deposited in lysimeter has revealed that the comprehensive field level landfill simulation with varying operational condition by using different soil as top cover affected the quality of leachate vastly. Result reveals that open dump lysimeter produced more quantity of leachate around 24 % in contrast to the sanitary landfills. In addition, waste settlement rate in open dump lysimeter is the maximum contrary to the sanitary landfill lysimeters. Though open dump landfill operation has proved to be beneficial for nitrogen removal but rest constituent’s load in leachate were found as highest compared to sanitary landfills. Among all the lysimeters using cover soils, the lysimeter having sandy loam soil as top cover had the lowest concentration and load of most of the leachate constituents and least amount of leachate as well, against the other counterparts i.e the lysimeters having silty loam and clay soil.

In conclusion, it can be concluded that a strategic plan for sustainable landfill with low cost could be achieved by upgrading open dumping practice to engineered landfill in different south Asian countries like Bangladesh, India and so on. In engineered landfill, a sandy loam soil is the most suitable soil to be used as a cover soil due to its significant pollutant reduction capacity from most tainted liquid leachate.

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RESISTANCE OF EPOXY MODIFIED MORTARS TO ACIDIC AND SALINE ENVIRONMENT

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ABSTRACT
The paper presents the resistance to aggressive aqueous media of three different types of external rendering materials (masonry mortar) to concrete structures, namely portland cement mortar (CM), epoxy resin based polymer cement mortar (PCM) and polymer mortar (PM). The resistance of the mortar specimens has been evaluated in terms of the loss in mass and compressive strength after they have been immersed in 10% sulphuric acid and 10% sodium chloride solutions for a given period. CM specimens are found be vulnerable in acid and salt attack, while the addition of epoxy resin to the mortars has favorable effect on the chemical resistance of the materials. The concentrations of epoxy resin in the composition of PCM specimens have a significant role on the improvement of chemical resistance of the mortars. The acid and salt media merely have significant effect on the mortar properties even after exposure to the media for a long period. It is concluded that epoxy based masonry mortars have high potentials to be used as external rendering materials to build-infrastructures, which are supposed to be exposed to aggressive environments.

Keywords: Polymer, mortar, chemical resistance, mass loss, strength loss

INTRODUCTION

The conventional Portland cement mortars are generally used as external rendering materials of the concrete structures such as building and bridges. The mortar as well as the concrete is very vulnerable in aggressive medium. The hydration-products of Portland cement are alkaline in nature and hence if exposed to acidic environment, both the masonry mortar and the concrete structure bound by Portland cement undergo premature deterioration (Steinberg, 1973). In saline zone, ions and molecules of salts are carried to the surface of a structure either by water or by moist/humid-air. The molecules and ions penetrate inside the structure through the connecting pore-network of the mortar, where they are concentrated and form salt-crystals. Gradual increase of the crystals causes an increase in volume, which subsequently results in high-pressure build-up and finally degeneration of the material (Perry and Duffy, 1997). There are several publications in the literature on deterioration of portland cement concrete when exposed to corrosive environment (Hossain et al., 2009; Stooge and Rizkalla, 1988; Hendrik and Orbison, 1987; Fattuhi and Hughes, 1988).
Polymeric materials have got good binding properties and a number of them possess good mechanical strength and chemical resistance. They can be incorporated in conventional concrete and masonry mortar to improve chemical resistance of the concrete and mortars (Muthukumar and Mohan, 2004). In fact, technology for the development of polymer modified mortar/concrete (PM/PC) is in rapidly growing phase, and proper choice of polymer binder would impart tailored properties to the constructional material.
Few reports are available in the literature about the improved chemical resistance of polymer concretes as compared to the Portland cement mortar (or called otherwise conventional mortar (CM)). For

example, Yamamoto (1987) compared the chemical resistance of CM and polyester-based mortar in 10% hydrochloric acid or sulphuric acid. After an immersion period of 28 days in this acidic solutions, it is found that the CM specimens lost about 50% of its initial weight, while no loss was observed in case of polyester resin mortar. Mebarkia and Vipulanandan (1995) analyzed the changes in compressive strength of polyester based concretes in chemical solutions with various pH levels, and found that the strength of PC decreased with increasing pH level of the chemical solutions. Such deterioration is bit unexpected as Yamamoto (1987) observed no mass loss of polyester-based mortar in acid medium. Ohama et al. (1986) investigated the variation in compressive strength of poly(methylmethacrylate)-based concrete in 11 typical chemical reagents. Gorninsky et al (2007) reported degradation in flexural strength of polyester-based concrete in acidic environment and compared with that of Portland cement concrete.

Although cured epoxy resin has high resistances to varieties of aggressive chemical environment, little information is available concerning chemical resistance of epoxy-based polymer concrete (PC) and mortar (PM) in acid and salted solutions. Ribeiro et al. (2012) reported chemical resistance of epoxy and polyester-based polymer concrete to acid and salts. Chemical resistance is evaluated through variation of bending strength and variation of mass, and it is found that epoxy resin-based PC exhibited superior chemical resistance than that of polyester PC. It is found that after an immersion period of 84 days in test solution, the mass changes of epoxy PC and polyester-based concrete was 0.088% and 0.44% respectively, while changes in flexural strength was approximately 8% and 30% respectively.

Chemical resistance of the mortars is more crucial for the durability of the concrete structures as they are used as external rendering material to the concrete structure. But the literature survey shows that the researches on chemical resistance of mortar are quite inadequate. Epoxy-modified mortar is a highly prospective constructional material (Rahman et al, 2012[a], 2012[b]) and the comparison of the chemical resistance between epoxy-based and polyester-based concrete as done by Rebeiro et al (2012) does not cover the full range of investigations, the material deserves. In view of this, chemical resistance of different types of rendering materials (CM, PCM, PM) to acid and salted solutions have been evaluated systematically in this study. The resistance of the rendering materials has been calculated in terms of variation of the compressive strength and the loss of mass of the materials at varying immersion periods. The experimental result of this study shows that the compressive strength of mortar specimens portland cement in composition (CM and PCM) reduces with weight loss after immersion in sulphuric acid solution, while PM specimens shows un affected.

MATERIALS AND METHOD

Materials

The test samples were prepared using local Sylhet sand as fine aggregate, ordinary Portland cement and epoxy resin as a binder, and hardener for epoxy resin.

Binding materials

Epoxy resin and Hardener

Epoxy resin based on Bisphenol A was used in the experiment. It was collected from the local market and used without further treatment/ purification. It has been characterized in the Laboratory of HBRI and found to possess the following characteristics: Viscosity - 3600cp, Specific gravity-1.15 and pH-7.70 at 30^0C.

Triethylene tetramine was used as a hardener for the epoxy resin. It was also collected from the local market. It was in the liquid phase and soluble in the resin. It has the specific gravity of 0.98. The resin to hardener ratio was maintained at 10 on weight basis. At this ratio, the setting time was found to be of 40 min at ambient temperature. The resin-hardener mixture is denoted as RH mixture.

Portland cement

The Portland cement used in the experiment was ASTM type I. The chemical composition and some other characteristics (in weight percent) of the cement as per document are as follows: CaO-63.58,

SiO_2- 20.44, Al_2O_3- 5.34, Fe_2O_3- 4.0, Loss on ignition-1.10, Insoluble residue- 0.07 and Moisture content- 0.5. The standard test-properties of the Portland cement used as binder in the experiment is presented in Table 1

Table 1. The standard test-properties of the used cement

Initial setting time	Final setting time	Fineness	Compressive strength
2 hr.	3 hr.	0.068%	19 MPa

Aggregates

Fine aggregate (Sand) used in the present investigation was collected from the localities 'Sylhet'. The particle size of the fine aggregates is in the range of 0.15-4.75 mm. The physical properties of the fine aggregate are presented in the Table 2.

Table 2. Physical properties of the fine aggregate

Aggregate types	Specific Gravity	Fineness of Modulus	Water Absorption, %
Sand	2.6	2.5	0.9

Mixing, casting and curing procedure

For the conventional mortar (CM), a cement-sand-water ratio was maintained at 1:3:0.4. The components of the CM were mixed by a method and technique as prescribed by ASTM C305. This composition is denoted as CSW mixture.

In case of polymer cement mortar (PCM), a CSW mixture was prepared first. The RH mixture (the resin-hardener composition) is prepared separately. Then the RH mixture is added to the mixture CSW to form the mortar (PCM) composition. The epoxy content was 1, 3 and 5 wt% of combined weight of the sand and cement and the corresponding mortar is denoted by PCM1, PCM3 and PCM5. Epoxy resin being in liquid state contributes additional fluidity to the composition of the mortar. To maintain the desired workability/flowability of the fresh composition, water-cement ratio was maintained at 0.40 in the experiment, and this ratio ensures adequate fluidity and the required amount of water for cement-hydrolysis. To compare the properties of PCM with CM, the same water cement ratio is maintained in the composition of CM

For the PM, the RH mixture (the resin-hardener composition) is prepared. Then a calculated amount of sand was added to the RH mixture and mixed properly with a standard procedure to form the PM composition. The epoxy content was 10, 12 and 14 wt% of the weight of the sand and the corresponding mortar is denoted by PM10, PCM12 and PCM14.

Freshly prepared CM)/PCM/PM composition was put into 50.8 mm cubic molds and compacted with a rod with specific diameter as prescribed by the ASTM. Specimens prepared with portland cement in the composition (CM and PCM) was cured in water for 28 days, and the specimens of PM were air dried at room temperature and demolded after 24 hours.

Method

The cured specimens were tested for chemical resistance at room temperature in accordance with the standard method RILEM PC-12 (RILEM PC-12, 1995). Aqueous solution of sulphuric acid (10%) and sodium chloride (10%) were chosen as the aggressive media. The pre-weighed test specimens were soaked in chemical solutions for a period of 21, 50, 100 and 200 days. After each immersion period, the specimens were cleaned by running tap water and dried in oven at 120^0C temperatures until a constant weight is obtained. The compressive strength of the treated specimen was measured according to ASTM C109. The test results were compared with those of untreated specimens. The relative loss in the mass, Δrm was defined by the following relation:

$$\text{relative mass loss, } \Delta rm = \left(m_i - m_f\right)/ m_i \quad (1)$$

Where m_i is the mass (g) of the specimens before treatment with the reagents, and m_f is the mass (g) after treatment.

Similarly, the relative loss in the compressive strength Δrs was calculated by the following equation:

$\text{relative strength loss}, \Delta rs = (\sigma_i - \sigma_f)/\sigma_i$	(2)

Where σ_i is the compressive strength in MPa of untreated specimens and σ_f is the compressive strength in MPa of the test specimens treated in solutions for a specified period.

RESULTS AND DISCUSSION

Resistance to Acid

The relative loss in compressive strength and mass of epoxy based polymer cement mortar using various epoxy content in 10% sulphuric acid solution, as a function of immersion period are presented in the Fig.1 and Fig. 2.

The relative loss in compressive strength of CM and PCM (with different epoxy contents) under the action of sulphuric acid solution is presented as a function of immersion period in Fig.1. As the Figure shows none of the mortars (independent of type of type, CM or PCM) can withstand the aggressive undergo The Fig.1 shows that the compressive strength of CM was reduced to zero after 100 days of immersion in the acidic solution, while the addition of epoxy resin in the composition (PCM) resists the compressive failure up to 150 days which is clearly indication of increase in chemical resistance. The fig. 1 also shows that the rate of strength loss decreases with resin concentration in the composition of PCM. The magnitude of relative loss in compressive strength 1 in the figure 1 indicates zero compressive strength (compressive failure) of the material.

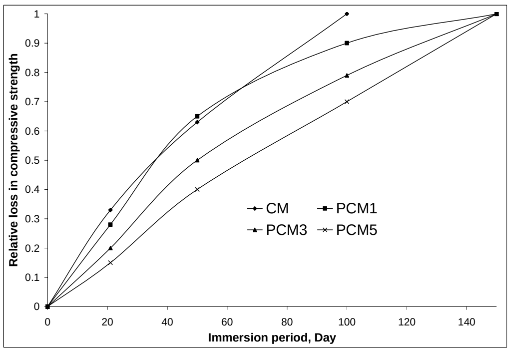

Fig. 1 Relative loss in compressive strength vs. immersion time. CM- Conventional mortar, PCM1, PCM3, PCM5- Polymer cement mortar with 1, 3 and 5 wt% epoxy content

The Fig. 2 shows that the CM specimen was completely disintegrated after 100 days of immersion in the acidic solution, PCM1 (using 1 wt% epoxy of sand and cement) was also disintegrated but it took 150 days to be disintegrated in the solution. It indicates that the addition of 1 wt% epoxy (based on cement and sand) to the CM increases durability 50% in the acidic condition, which is the clear indication of increase in chemical resistance of the material contributed by the epoxy resin. However, PCM specimens using 3 wt% and 5 wt% epoxy (based on the weight of sand and cement) were integrated even after 150 days of immersion in the solution. In fact, the magnitude of mass loss Δrm 1.0 in the figure 2 indicates complete disintegration of the material.

The Fig. 3 shows the effect of sulphuric acid solution on the compressive strength of PM with various epoxy content. The Fig.3 indicates that the compressive strength of 10% PM (prepared using 10 wt% epoxy based on the weight of sand) was slightly affected in the acidic solution, while, strength loss is negligible for the epoxy based 12% PM and 14% PM. The 10 % PM specimen loses 25% and 28% strength after immersion of 150 and 200 days respectively in the acidic solution. The rate of loss in strength of 10% PM is very low compared to CM and PCM, and the loss is probably due to the degradation of the sand interface, as the specimen containing less epoxy compared to other two PM specimens.

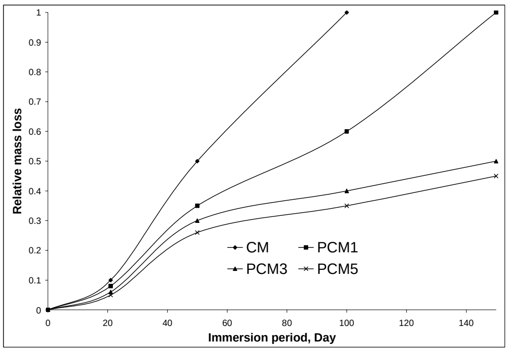

Fig. 2 Relative mass loss vs. immersion time. CM- Conventional mortar, PCM1, PCM3, PCM5- Polymer cement mortar with 1, 3 and 5 wt% epoxy content

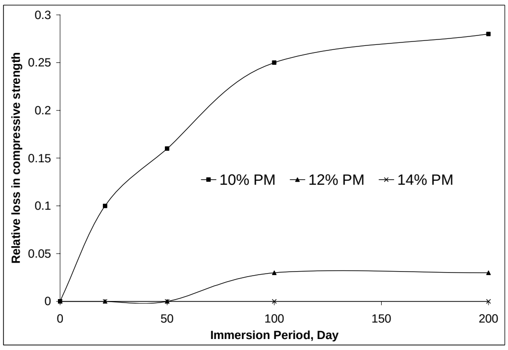

Fig. 3 Relative loss in compressive strength vs. immersion time. PM10, PM12, PM14- Polymer mortar with 10, 12 and 14 wt% epoxy content of sand

The mass loss of PM due to acid attack is presented in the fig.4. About no mass loss was found in case of polymer mortar even after 200 days of immersion in strong acidic solution. This result indicates that there was no reaction or dissolution of epoxy resin based PM in the acidic solution. The reduction in mass loss can be explained by the strong sand-epoxy resin bond.

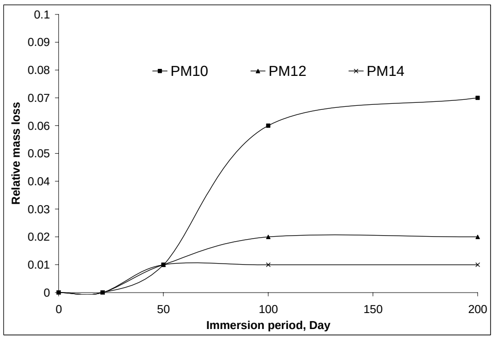

Fig. 4 Relative mass loss vs. immersion time. PM10, PM12, PM14- Polymer mortar with 10, 12 and 14 wt% epoxy content of sand

Effect of Salt Solution

Mass loss and compressive strength variation of different types of mortar specimens due to sodium chloride salt attack are presented in the Table 3. The result shows that the compressive strength of both conventional mortar and polymer cement mortar specimens immersed in the 10% sodium chloride solutions is slightly affected, but mass loss is very insignificant for the specimens. The PM specimen however, shows unaffected by the salt solutions even to longer period (1 year) of immersion.

Table 3. Relative mass loss and relative loss in compressive strength of mortar specimens with different epoxy content after 12 month of immersion in 10% sodium chloride solution

Specimen type	Mass loss, Δrm	Strength loss, Δrs
CM	0.07	0.43
PCM1	0.03	0.30
PCM3	0.02	0.18
PCM5	0.01	0.12
PM10	0.002	0.002
PM12	0.001	0.001
PM14	0	0

CONCLUSION

The effect of epoxy resin as binding material in the composition of masonry mortar on the chemical resistance properties is determined through the mass loss and compressive strength loss after immersion in sulphuric acid and sodium chloride solution. The following conclusions have been drawn from this investigation-

- Unlike what is observed in portland cement mortar, there was less mass loss and compressive strength changes of epoxy based polymer cement mortar after immersion in acidic and salted solutions. The composition of PCM with higher epoxy content showed the higher resistance to the chemical attack. However, the compressive strength and weight of epoxy based polymer mortar is rarely affected by the strong sulphuric acid and sodium chloride solutions, which is the indicator of the good chemical resistance property of the rendering material.
- Choosing epoxy based polymer mortar that can be used as external rendering to concrete structures can minimize the aggressive attack to enhance durability of the structure.

ACKNOWLEDGMENT

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REMOTE SENSING AND GIS APPLICATION IN NODAL WATER DEMAND COMPUTATION FOR PIPE NETWORK MODELING

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ABSTRACT
Nodal water demand is the key component for a water distribution network model. For accurate nodal demand computation, various parameters like land use category, population density, household characteristics etc. are needed to be considered. These information are often complex to extract and integrate into a common database. This study shows application of remote sensing and GIS for nodal demand computation involving satellite image processing, nodal area delineation and load building at individual nodes. A land use map has been produced after satellite image classification. ArcGIS is used for pipe network laying, nodal area delineation and population density mapping. Eventually an integrated GIS based database has been developed for nodal demand computation. Nodal demand of each node is computed and a nodal demand model is prepared for pipe network modelling. Any water distribution network (WDN) modelling tool can utilize this model for simulation setup.

Keywords: Nodal water demand, remote sensing, GIS, image processing, water distribution network modeling.

INTRODUCTION

Water distribution network modeling entirely depends on the input parameters. Hence, a well developed database of input parameters is a matter of prime interest for such type of simulation process. Nodal water demand is the major of the input parameters. But a costly and time consuming survey has to be carried out for accurate nodal water demand determination. Besides, for small towns, such type of survey is sometimes obsolete because of huge cost involvement. Adopting cost effective technology with less sacrifice of accuracy is a must in such situations. Therefore, remote sensing and GIS technology in combined can reduce the effort and cost in nodal water demand computation.

Supervised image classification technique is used in this study to demarcate land classes; since analysis of satellite images is an important technique for assessing physical characteristics of the Earth (Goetz et al.,1983; American Institute of Biological Sciences, 1986; Lo,1986; Lillesand and Kiefer, 1987; Roughgarden et al., 1991). Thereafter, GIS is employed for nodal demand computation. Various methods for nodal demand computation is depicted by various researchers; linear method (Walsky et. al., 1988; Quinary et. al., 1981; Swamee et. al., 1990), non-linear method (Watanada, 1973; Chilpunkar et. al.1986; Gupta et. al. 1993) Lagrangean Multiplier (Lancey & Mays, 1989), dynamic, mixed integer, gradient search, enumeration method etc. to analyze WDN network. We have used Thiessen polygon for nodal area delineation. The prepared database has been created in the form of shape files, therefore can be exported as dbf file and also any of the input parameters can be projected in maps to create visual impact and to enhance the data analyzing capability of the modelers.

STUDY AREA

The study area of this paper is Alamdanga, a small town of Bangladesh. Alamdanga Paurashava is the only municipal area of Alamdanga Upazila of Chuadanga District. It is located in 23°45' N latitude and 88°56' E longitude. The smallest administrative unit of a Paurashava is a ward and presently, Alamdanga Paurashava is divided into 9 wards. The Paurashava has good road connections to Dhaka (capital of Bangladesh) and other neighbour districts and regional centers. Activities related to trade and commerce are increasing day by day and now it is emerged as one of the few A class municipal areas of Bangladesh. Though Alamdanga is a Class A municipality, still there is no piped water supply system.

DATA PREPARATION

Data collection has been done by using both the application of remote sensing and topographic survey in the field. Satellite image of the study area have been extracted from Google Earth. The image is used to classify land use pattern. Demographic information is taken from the Population Census 2011 by Bangladesh Bureau of Statistics. Spatial information like administrative units, road network, water body, spot elevations etc. are taken directly from topographic survey of the study area. Spot elevations are used further to produce the Digital Elevation Model (DEM) of the area under interest.

METHODOLOGY

The methodology adopted in this paper can be shown as the following flow chart [Fig. 1].

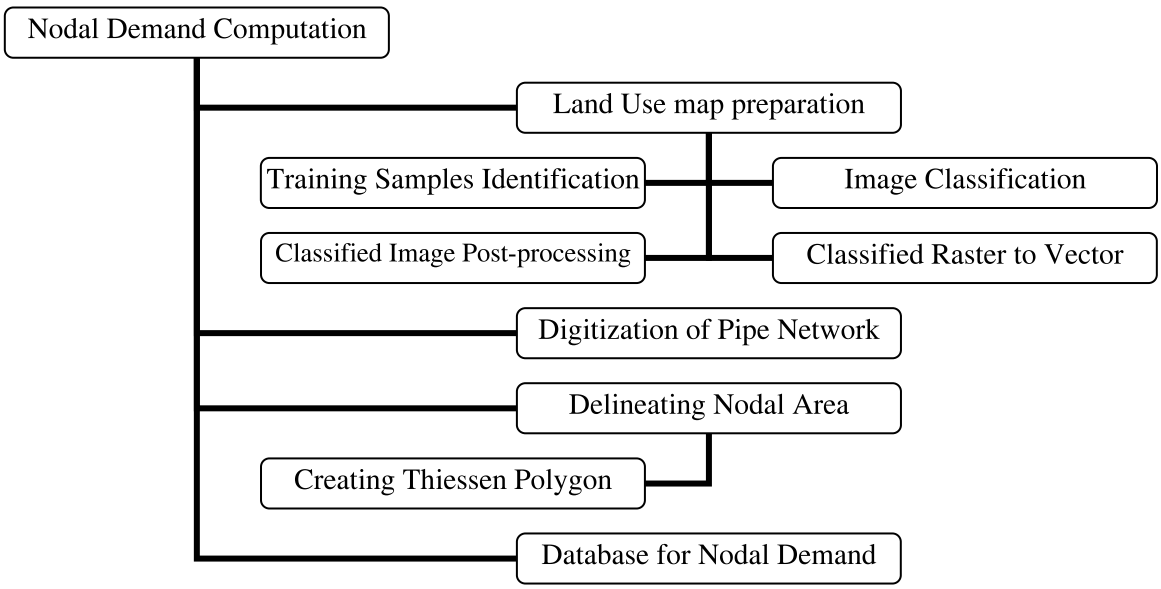

Fig.1: Working steps for nodal water demand computation

Preparation of land use map from satellite image

The satellite image extracted from the Google Earth application has been used for this purpose. The image to the study area is geo-referenced using BTM (Bangladesh Transverse Mercator) projection system. The geo-referenced image has been rectified and exported to save in the disk for further operation. For image processing, Image Classification tool of ArcGIS has been used. Five major classes have been identified for classification- (i) Barren Field, (ii) Green Field, (iii) Settlement, (iv) Tree and (v) Water body.

Training samples for the aforesaid classes are created at first. Using the training samples, Interactive Supervised Classification has been run. The classified image has been ready for post processing. A Boundary Clean operation has been run further to clean the classes; thereafter to isolate smaller segments, a Region Group raster is prepared. The raster is used to create a musk by setting null values defining a threshold number of cells for smaller regions. The resulting raster is used as a musk to nibble the smaller segments into the bigger ones.
Based on the cell counts corresponding to each class, each class's area is computed. The class area is used in water demand computation.

Delineation of nodal area

For nodal area delineation, digitization of the pipe network is the foremost task. In ArcGIS, the pipe network has been digitized along the existing road network of the study area. Each confluence and start of the road network has been digitized as a node. For long pipes, intermediate nodes are also digitized. Total 83 km of pipe network and 852 numbers of junctions have been digitized. Water demand for each node is required to compute for distribution network modeling. To assess water demand inside a node, corresponding commanding area of a node is demarcated using Thiessen Polygon method. Thus total 852 numbers of Thiessen Polygons are created, one for each node [Fig. 2].

Fig. 2: (a) Nodal area demarcation using Thiessen Polygon and (b) Union of shape files for nodal water demand computation database.

Computation of nodal demand

For nodal demand computation, the nodal area, demographic data and land use map has to be integrated into a common database. This operation is done by union of the corresponding shape files. The resulting data represents the contribution of different land use class and population density inside a nodal area [Fig. 2]. Therefore nodal water demand inside a node is determined using Eq. (1).

$$NWD = \sum (PD \times A \times LPCD) \quad ......(1)$$

Where,

NWD = Nodal Water Demand,
PD = Population Density,
A = Area under corresponding land class and
LPCD = Liter per capita demand.

Integration of the nodal water demands eventually constitute the total water demand of an area.

Database for nodal demand computation

The union shape file produced in the previous section is used to create a database for nodal demand computation and storing of information as an input file in any water distribution network simulation. The node's elevations are extracted from DEM of the study area and stored in this shape file. The database is in tabular format, occupies in the attribute table of the node's shape file.

RESULTS AND DISCUSSIONS

While performing classification of satellite image, histograms [Fig. 3] and scatter plots [Fig. 4] of the training samples are checked for assessing the accuracy of classification. Histograms have shown acceptable separations except for tree and green field. Scatter plot also resembles this relationship. However, examining the final output- the classified image carefully, no major accuracy impairment is seen.

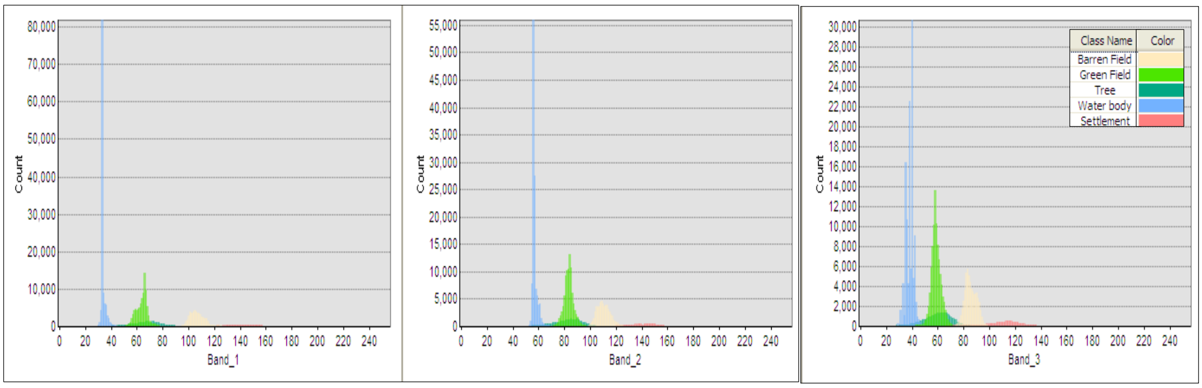

Fig. 3: Histograms of the training samples for the 3- band satellite image.

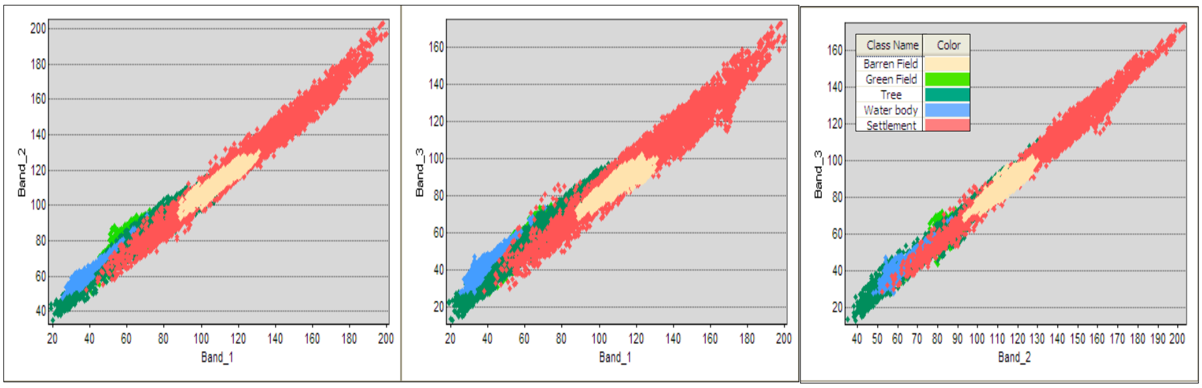

Fig. 4: Scatter plots of the training samples for the 3- band satellite image.

Observing the satellite image and the classified raster, it is evident that some sharpness of the identified land classes has been lost [Fig. 5]. Road alignment and course of the water bodies are acquired from topographic survey and combined into the classified image to increase the accuracy of land classification. Besides, the cell size adopted in the raster operations are the same as the satellite image's cell size; therefore accuracy loss due to coarsening of cell size was not occur.

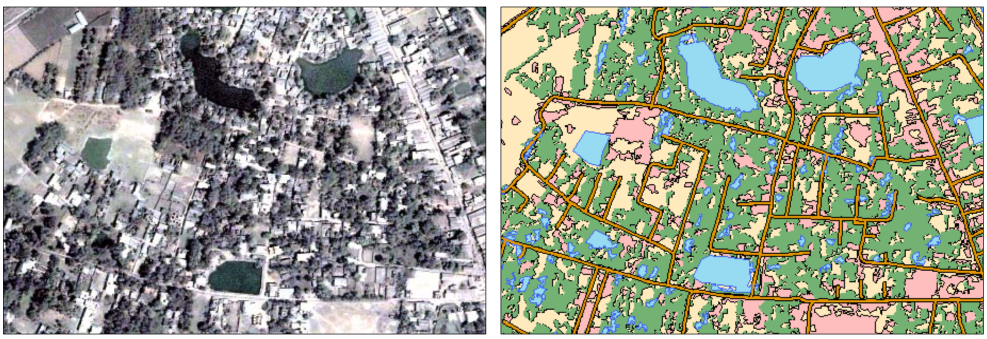

Fig. 5: (a) Extracted satellite image and (b) corresponding land use map produced after image classification and post processing.

Post processing of the image has merged smaller features of land classes into surrounding greater ones by defining a threshold cell number. The threshold number of cells is 200 for this particular task and this value has been achieved by iteration for gaining the smallest cluster without hampering the accuracy of image processing much. Higher resolution image would produce more accurate land class map.

A segment of the prepared WDN modeling input database in shown in Table 1. For avoiding complexity in computation, an idealized LPCD of 100 has been adopted.

Table 1: Database of WDN modeling input.

Label	Elevation	BA[1]	NBA[2]	X_BTM	Y_BTM	PopDen[3]	Population	LPCD[4]	Demand (L/day)
N-1	13.31	0.01689	0.00040	392812	628712	8697	147	100	14700
N-2	14.76	0.00160	0.00000	392858	628652	8697	14	100	1400
N-3	14.60	0.00603	0.00000	392878	628661	8697	52	100	5200
N-4	14.37	0.00618	0.00000	392840	628645	8697	54	100	5400
N-5	14.11	0.00456	0.00000	392915	628588	8697	40	100	4000
N-6	13.13	0.00612	0.00000	392858	628581	8697	53	100	5300
N-7	13.11	0.00232	0.00000	392882	628521	8697	20	100	2000

[1] Built-up area in km^2
[2] Non built-up area in km^2
[3] Population Density in person per km^2
[4] Per capita water demand in liter per day

CONCLUSION

This study reveals the application of remote sensing and GIS in nodal water demand computation of a small town. Satellite image has been used for land class demarcation. Later, GIS tool is used to compute nodal water demand and to produce a database in the form of a shape file. This database can be further employed in any suitable tool for water distribution network modelling. The method is not a precise one; but could be crucial in case of scarce information areas with low funding in utility development works.

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Direct physiological effects on vegetation of increased atmospheric CO2 concentration

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ABSTRACT

An important issue regarding future climate change is that of feedbacks from the biosphere. The future of the terrestrial carbon sink, moderating the atmospheric effects of our fossil fuel emissions, carries major significance in determining future climate. The atmospheric CO2 concentration increase affects plant physiology in complex ways, thus affecting both the terrestrial carbon sink and human food production. The aim of this study is to review current literature on the effects of increased atmospheric CO 2 concentrations on plant physiology, separated on tissue, individual plant and ecosystem scales with special focus on effects on the terrestrial carbon sink. The plant physiological effects were found to be numerous and interacting in complex ways, making projections of the net result hard to determine. From the current level of scientific understanding however, we expect that the terrestrial carbon sink will increase in the near future, and start to decline due to non- beneficial temperature increase around mid century.

KEY WORDS*: Atmospheric CO2, Carbon Sink, Ecosystem, Plant physiology, photosynthesis, FACE, CAM*

1. INTRODUCTION

In climate change research, a widely discussed uncertainty about the future development of the atmospheric carbon dioxide (CO_2) concentration is the size and resilience of the terrestrial carbon sink (Solomon et al., 2007, see Figure 3), that is, the amount of CO_2 withdrawn from the atmosphere by plants to be stored in plant biomass or soil organic matter. The direct physiological effects on vegetation of increasing atmospheric CO_2 concentrations are at the core of the issue, but are still not completely understood. As the photosynthetic response of leaves to increased CO_2 is relatively straightforward, forecasting the response of the biosphere was previously thought to be easier than it's turning out (Körner et al., 2006). With the intricate web of interdependencies in a plant system, including effects such as altered enzyme properties (Reddy et al., 2010, Bader et al., 2010), increased leaf photosynthate concentrations (Bader et al., 2010), reduced stomatal conductance (Long et al., 2004) and, importantly for climate change, enhanced carbon assimilation (Bader et al., 2010), estimating the long term net result on the terrestrial carbon sink becomes very difficult. Even more so considering the importance and spatiotemporal variability of environmental factors such as soil properties (Bonan, 2008, Cavagnaro et al., 2011), temperature (Albert et al., 2011) and water availability (Körner et al., 2006) and also the difficulties posed by different CO_2 enrichment experiment methodologies (Macháčová, 2010).

2. AIM

The aim of this literature study is to give an overview of the current scientific understanding of the effects of increased atmospheric CO_2 concentrations on plant physiology. Processes and effects will, to some degree, be separated on a tissue, individual plant and ecosystem level, with a special focus on ramifications for the terrestrial carbon sink.

3. THE ROLE OF CO_2 FOR THE PHOTOSYNTHESIS IN PLANTS

Green plants obtain all their energy through photosynthesis, which is a chemical process that captures light energy to form photosynthates like sugar, starch, carbohydrates and proteins and release oxygen (O_2) as a byproduct, in the presence of chlorophyll using CO_2 and water (H_2O).

$$6\,CO_2 + 6\,H_2O + e^-\ (light\ energy) \xrightarrow[chlorophyll]{} C_6H_{12}O_6 + 6\,O_2 \qquad \text{Eq. 1}$$

Equation 1 shows the chemical process of photosynthesis; Figure 1 shows a conceptual illustration. Carbon dioxide, water and light energy directly determine this process, which is also to some degree regulated by temperature (Whiting et al., 2010).

Terrestrial plants' leaves have supportive structures for the photosynthesis process to a particular light environment (Chapin et al., 2011). From the atmosphere, plants use CO_2 for the photosynthesis through the outside of the leaf to the chloroplast (organelles inside photosynthetic cell). At first, CO_2 diffuses by the leaf surface layer then through the stomata (small pores in the leaf surface). Inside the leaf CO_2 diffuses between the cells through their air spaces and dissolves in the cell surface water and then diffuses to the chloroplast. The overall diffusion CO_2 from the free air to the Rubisco (Ribulose bisphote carboxylase oxygenase) is influenced by the boundary layer, stomata and cellular water. The increasing rate of CO_2 diffusion from the volume of air to chloroplast depends on the thin and flat shape of leaves as well as the abundance of air spaces inside the leaves.

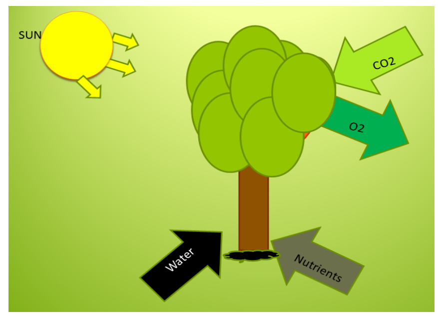

Figure 1. Photosynthesis, exchange of CO_2, O_2 and nutrients in presence of light energy.

Different plant functional types use physiologically different kinds of photosynthetic pathways (Taub, 2010). Around 90% of the plant species use the so called C3 pathway, while the rest use the C4 or CAM pathway. The C4 pathway differs mainly from C3 by biochemically pumping CO_2 to the Rubisco enzyme's location so that the CO_2 concentration around it is kept much higher than in C3 plants.

Photosynthesis is the heart of the nutritional metabolism of plants. Raising the availability of CO_2 for photosynthesis can have important effects on plant growth and many aspects of plant physiology (Taub, 2010)

4. PHYSIOLOGICAL EFFECTS OF INCREASING ATMOSPHERIC CO_2 CONCENTRATION

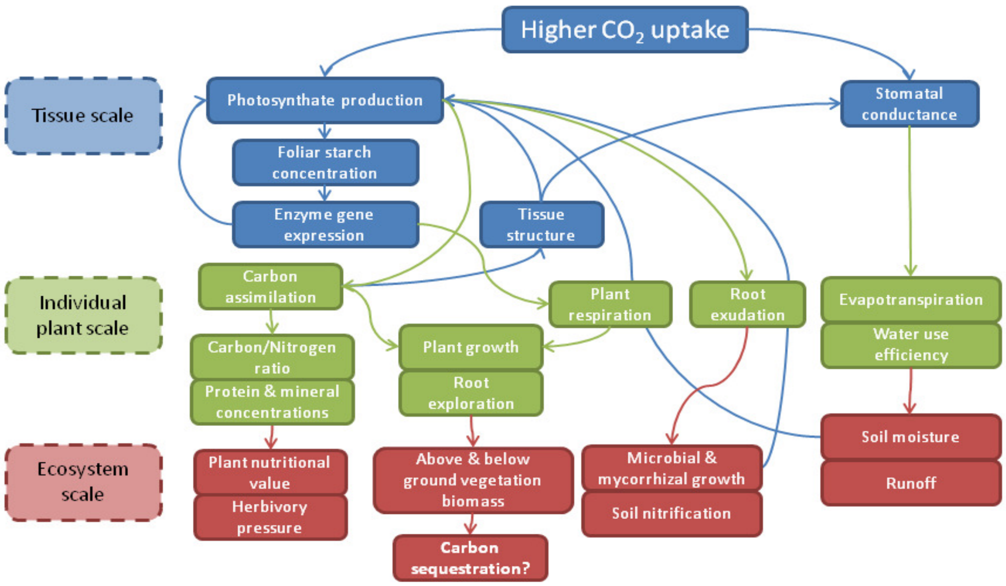

Figure 2. A summarizing diagram giving examples of plant physiological effects of increased atmospheric CO_2 with lines showing relationships between them. While not comprehensive, it illustrates some of the complexity of plant responses.

6. EFFECTS ON PLANT TISSUE SCALE

The atmospheric CO_2 concentration is continually growing. In 1959, its concentration was approximately 315 ppm (parts per million) but the current atmospheric average is approximately 385 ppm. Rising CO_2 concentrations have direct effects on the growth, physiology, and chemistry of plants. Plants take up atmospheric CO_2 by photosynthetic organisms and chemically reducing the carbon from the atmosphere. This represents acquisition of stored chemical energy for the plants and in addition provides the carbon skeletons for the organic molecules that make up a plant's structure. CO_2 concentrations are important in regulating the openness (or aperture) of stomata. Open stomata not only let CO_2 diffuse into leaves for photosynthesis, but also make available a pathway for water to diffuse out of leaves. Plants can maintain high photosynthetic rates with relatively low stomatal conductance due to increase CO_2 concentration (Taub, 2010). Through the leaf stomata plants absorb carbon dioxide for photosynthesis but when the CO_2 level increase in the atmosphere, leaf stomata get smaller leading to less water being released and as a result declining the tree's cooling power (Carnegie Institution, 2010).

Grown under elevated CO_2, the chemical composition of plant tissues have also been seen to change and leaf nonstructural carbohydrates (sugars and starches) per unit leaf area increase on average by 30–40% (Taub, 2010). Protein concentrations of grains (wheat, rice and barley, and in potato tubers) are decreased by 5–14% due to elevated CO_2. In crops, concentration of nutritionally important minerals (calcium, magnesium and phosphorus) may also be decreased due to increased CO_2.

7. EFFECTS ON PLANT INDIVIDUAL SCALE

After looking at the role of CO_2 for the photosynthesis in plants and the effects on plant tissue level of increasing CO_2, it is also relevant to observe how the increase of CO_2 affects different plants on individual level.

CO_2 enrichment of the atmosphere affects plants directly as it is a substrate of photosynthesis. The three most important reasons for the difference between the CO_2 stimulation of photosynthesis and the actual biomass responses are: a) CO_2 uptake for the photosynthesis depends on a plant's total active surface (photosynthetically) and its integrated CO_2 flux activity over time relative to its respiratory losses, b) CO_2 release by respiration which depends on tissue specific rates and on the contribution of various differentially active tissues to total biomass, and

c) the unknown export of assimilated carbon through roots (root exudation). Moreover, younger plants are more responsive to elevated CO_2 than older ones (Körner et al., 2007).

Carbon dioxide enrichment can lead to increased crop production. An initially positive response to elevated CO_2 may decline on a longer time-scale. For example, in plant species using the C3 photosynthetic pathway, a lower response from the sinks (or the use) of photosynthates, relative to the increase in photosynthetic rate occurs. This often leads to a gradual reduction of the initial response (Kanemoto et al., 2009). The difference between photosynthate production and use, from sink limitation, also leads to accumulation of e.g. sugars in the leaves. This sugar increase can also tend to inhibit production of photosynthetic enzymes by keeping down expression of the corresponding genes, which can further reduce crop yield. For instance, soybean mutations, it is shown that when plants are grown at elevated CO_2 concentration, the genetic capacity for utilization of photosynthates is critical because of increased photosynthesis (Kanemoto et al., 2009).

The responses of different plant species vary in the elevated CO_2 with other environmental variables (temperature, nutrients, water availability and ozone level), as seen in Table 1. Under the control environmental condition, the majority species response is positive due to improved photosynthetic rates, which is associated with increased biomass yields. Under the elevated CO_2, the greater percentage of crops of the semi-arid plants increases. The explanation is that the specificity of Rubisco for CO_2 relative to O_2 declines with increasing temperature. An analysis showed a positive interaction between elevated CO_2 and N but the limitation of soil N might progressively suppress the positive responses to elevated CO_2 (Reddy et al., 2010). Elevated CO_2 influences plant water relationships through its effect on stomata and increased CO_2 decreases stomatal conductance. Average stomatal conductance in grassland and crops may drop by 30 to 50 percent (Körner et al., 2007). Under elevated CO_2, increase root surface and root volume due to increase allocation of carbon to root growth enable the plants to exploit more water even from deep soil layers. Under increased CO_2 concentration in the atmosphere, decreased stomatal conductance is an interactive factor and in a low water availability environment, increasing CO_2 might be beneficial for plant productivity (Reddy et al., 2010).

Table 1. Examples of interactive influence of elevated CO_2 with different environmental variables among different plant species. Collected from Reddy et al. (2010).

Plant Species	Interacting factors	Response
Gossypium hirsutum	Temperature (high)	Positive response
Betula papyrifera	Nitrogen (high)	Positive response
Solanum tuberosum	Water stress	Positive response
Acacia farnesiana	Drought	Positive response
Eucalyptus macrorhyncha	Low soil moisture	Negative response
Betula alleganiensis	Heat stress	Negative response

The effect on soybean due to the increase of CO_2 was tested through using the Free-Air CO_2 Enrichment (FACE) method at the SoyFACE research facility (Castro et al., 2009). The results of the test showed that, unlike prior expectations, reproductive development of soybean took up to 3 days longer under increased CO_2 whereas this increased the temperature of the canopy. Moreover, increased CO_2 also resulted in the production of considerably more nodes on the main stem comparing to those produced under existing CO_2, clarifying why it took longer for "completion of reproductive development and final maturation of the crop" (Castro et al., 2009, p. 2945) under increased CO_2.

An investigation of the effect of increased CO_2 on native perennial grass and sown grass-legume pastures in southeastern Tasmania (Australia) was carried out employing a biophysical simulation model (EcoMod). Examinations of different pastures showed the tolerance of different species to environmental factors. However, the increase of CO_2 and climate change resulted in a decrease of protein content and digestibility of pastures. Moreover, the increase of CO_2 led to the reduction of soil inorganic nutrient concentrations (Perring et al., 2010).

In a study (among the specific species of C3, C4 and CAM) it has been found that most of the C3 species showed positive response under the elevated CO_2 during their growth. During carbon absorption, photosynthesis of C3 plants is influenced by the activity of three enzymes; ribulose bisphote (RuBp), carboxylase-oxygenase (rubisco) and carbohydrates (Reddy et al., 2010).

On the other hand, it has been assumed that C4 plants are not so sensitive to elevated CO_2 of the atmosphere due to its inherent CO_2 concentrating mechanism compared to C3 plants. Under natural atmospheric conditions, the bundle sheath cells (the inner ring of leaf anatomy) of C4 photosynthesis elevates CO_2 concentration to about 2100 μmol/l, where it is at least 10 times more than in the mesophyll cells (chlorophyll containing tissue located between the upper and the lower epidermis) of the C3 plants. Under the high irradiance C4 plants show increase photosynthesis in the presence of elevated CO_2 but low response under the low irradiance. It is long familiar that the growth stimulation of C4 crops is small whereas C4 weeds growth stimulation is large. The underlying mechanisms for the enhanced growth of C4 plants are still unclear though some specific plants show positive response under elevated CO_2 (Reddy et al., 2010). The positive response might arise only from reduced water loss (Leakey et al., 2009; Taub, 2010).

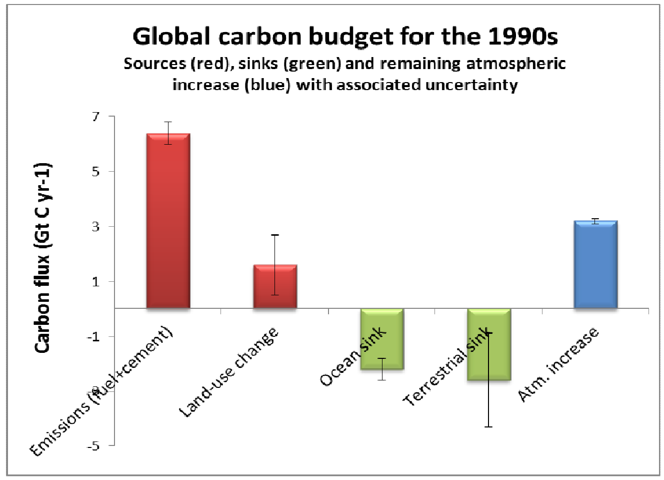

Figure 3. Global carbon budget for the 1990s, showing the large contribution from and uncertainty of the terrestrial carbon sink. Estimations from the AR4 of the IPCC (Solomon et al., 2007).

8. EFFECTS ON ECOSYSTEM LEVEL OF INCREASING CO_2

8.1 Productivity and Carbon Storage

As discussed previously, increased CO_2 uptake on the tissue scale, leading to an increased photosynthetic rate often lead to increases in plant growth on the level of individuals. The importance of gaining a better understanding of these issues, also on an ecosystem scale, is illustrated in Figure 3, which shows the estimated size of the terrestrial carbon sink in relation to the global carbon budget. On an ecosystem scale, increased CO_2 uptake or plant biomass may or may not lead to long-term increases in the carbon storage, depending on interactions with other parts of the ecosystem such as the lithosphere and local fauna. Körner et al. (2007), for example, discuss how herbivore can increase to compensate for a reduced food quality, because of the lower protein and mineral concentration already mentioned and generally an increase in the ratio of carbon to nitrogen (C/N) content. They also note how a growth boost leading to faster tree turn-over can reduce carbon stocks.

Annually, about 15% of the atmospheric CO_2 is exchanged with terrestrial ecosystems, especially forests, making them vital as carbon sinks, thus moderating the atmospheric effects of anthropogenic CO_2 emissions. Nitrogen (N) is a most important nutrient which often limits temperate forest productivity. Enriched CO_2 can lead to increased N uptake from the soil and more efficient use of the N by trees, which is crucial for sustaining the higher rate of forest net primary production (NPP; Finzi et al., 2007).

In a comparison of results from six dynamic global vegetation models (DGVMs), Cramer et al. (2001) investigated how a possible CO_2 emission and climate change scenario may affect the terrestrial carbon sink. Their simulations ran until the year 2100 and showed that the terrestrial biosphere has, largely in line with observations, buffered anthropogenic emissions by storing around 1.6 Gt C y^{-1} in recent times. The models predicted increasing sink strength until 2050, after which the carbon sink is gradually reduced. This could be explained by a weakening of the response of production to CO_2 because of a saturation effect and changes in precipitation, while ecosystem respiration continues to increase with the increasing temperatures (Cramer et al., 2001).

Real world observations from FACE experiments support modeling results, showing increases in production that seem to be valid in varying types of forest with different production levels (Norby et al., 2005, Finzi et al., 2007). Hickler et al. (2008), on the other hand, drawing on recent modeling results using the LPJ-GUESS DGVM, caution that results from boreal forests are not necessarily representative of tropical forests, with the differences originating mainly from temperature differences.

8.2Nutrient dependent response and effects on nutrient availability

While the stimulation of photosynthesis can persist even after 8 years (Bader et al., 2010), it is strongly dependent on N availability and there is evidence (e.g. de Graaff et al., 2006) supporting a hypothesis about progressive N limitation (PNL) with carbon sequestration by the terrestrial biosphere (Luo et al., 2004). This also leads to concerns about the reliability of models which does not include the nitrogen cycle (Bonan, 2008).

In the study by Finzi et al. (2007), they found that a CO_2 enriched atmosphere consistently increased NPP and that the more common response regarding N among the investigated FACE sites was an increased N uptake without a higher Nitrogen Use Efficiency. One site, however, which differed in that it was not N (or water) limited, instead used the N more efficiently without requiring an increased uptake. The common response of increasing N uptake under higher than present CO_2 concentrations is explained by a greater export of carbon to the soil. This could occur through a combination of increases in fine root production and provision of carbon substrates to mycorrhiza and microbes, both increasing nutrient availability and plants' access to the existing nutrient pool, providing a feedback to plant productivity (Figure 2).

As important as nitrogen is, it is not the only nutrient which can limit or enable plant response to an increasing atmospheric CO_2 concentration. The influence of phosphorous (P) has also been studied by e.g. Campbell and Sage (2006), whose results indicate that the plant response was negligible under P limitation and they note the great implications of this in light of nearly a third of Earth's ecosystem potentially suffering from P limitation. Cavagnaro et al. (2011) further discuss how, in the long term, P limitation may play an increasingly important role as the global availability of P fertilization is expected to decline in the near future. This, also leading to increasing relevance of plant-mycorrhizal interactions as Cavagnaro et al. (2011) point out that the portion of P originating from such interactions can reach 100% in some plants.

8.3Hydrological effects

On an ecosystem scale, there are significant impacts of the CO_2 increase-induced stomatal closure. Taub (2010) points out that even though stomatal conductance of water has been shown to decline, the effects on ecosystem hydrology are also affected by e.g. plant size. This way, increased productivity leading to greater leaf area could offset some of the decreased stomatal conductance. However, in a meta-analysis of FACE experiments by Ainsworth and Rogers (2007), stomatal conductance was shown to drop by 22% on average. An overall drop in stomatal conductance can in turn lead to increased run-off and soil moisture (Leakey et al., 2009), altering the entire ecosystem hydrology.

9. DISCUSSION

While the understanding of plant physiology in general and its response to increasing levels of CO2 in particular seem to be advancing rapidly, there are still many unknowns and current measurement techniques provide difficulties to overcome. For example, in FACE experiments the CO2 concentration around each plant or leaf etc. cannot be kept as stable as the actual atmospheric concentration. On the other hand, in closed chamber, open top or screen FACE experiments, the environments are always altered making any conclusions less valid for completely natural systems.

Modelling studies also bear uncertainties, e.g. as pointed out there is a great need to accurately incorporate nutrient cycles and, we expect, also plant-microbial/mycorrhizal interactions in models. As always, there is also the issue of scale, with the necessarily limited spatial and temporal resolutions potentially limiting the accuracy of current models.

Of the processes described in this report, the increased plant productivity seem to be the most influential on the global carbon budget of today, as models and observations alike mostly show a net terrestrial carbon sink during recent times. In the future, however, changing climate (e.g. increasing temperature and altered hydrological cycle), nutrient availability and plant physiology itself can counteract the benefits to the terrestrial vegetation. It is difficult to make a decision about the net impact of elevated atmospheric CO2 on plant physiology because of its interactive relationship with different environmental factors including temperature, radiation, water availability, sun ultraviolet radiation, soil nutrition, soil salinity and soil micro-organisms. To get a fruitful result regarding the elevated CO2 with interactive environmental factors, a careful scientific study is needed. Besides, to ascertain a complete approach of the whole ecosystem with all the interactions and feedback mechanisms requires large scale and long term experiments.

The global coupling between atmospheric CO2, temperature and the biosphere will affect us profoundly in the future, disturbing not only every natural ecosystem on Earth but also the yields of crops we rely on, putting our very sustenance at risk.

10. CONCLUSIONS

Increasing atmospheric CO_2 concentration will lead to many diverse effects on plant physiology, with far reaching implications for climate. The responses of plants depend strongly on plant type and environmental conditions such as nutrient availability. Making guesses about the future of the carbon sink is difficult because of the complexity of the system and the amount of research required to fully understand it, but we expect it to rise in the short term and then decline in the long term perspective; the rise from increased plant productivity eventually being overtaken by effects such as too high temperature increase, more drought stress and progressive nutrient limitation.

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MANAGING WATER QUALITY IN SMALL DISTRIBUTION NETWORKS USING BOOSTER CHLORINATION: A WATER QUALITY INDEX APPROACH

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ABSTRACT

Booster chlorination helps to maintain uniformity and adequacy of free residual chlorine concentration in water distribution network, essential for safeguarding against microbial contamination. Higher chlorine dosages increase free residual chlorine level but may generate potentially harmful by-products, in addition to taste & odour problems. It is possible to address these microbial, chemical and aesthetic water quality issues through maintaining free residual chlorine levels. Estimating a water quality index (WQI) based on regulatory chlorine thresholds for microbial, chemical and aesthetics criteria can help engineers make intelligent decisions. The approach is also useful for small and rural communities where free residual chlorine is considered as a fundamental water quality criterion.
Canadian Council of Ministry of Environment WQI or Canadian water quality index (CWQI) is a popular index to represent complex water quality monitoring data. In this study, a modified CWQI was developed and an innovative scheme for maintaining adequate and optimal residual chlorine concentrations is proposed. City of Kelowna (BC, Canada) water distribution network served to demonstrate the application of the proposed approach. Temporal free residual chlorine concentration predicted with EPANET was used to estimate the modified CWQI. Temporal and spatial analyses show lower water quality in summer than in winter.

Keywords: Free residual chlorine, water quality index, water distribution network, and EPANET.

INTRODUCTION

Primary disinfection at the treatment level and secondary disinfection within water distribution network (WDN) through booster stations can ensure safe levels of free residual chlorine. Residual chlorine ensures acceptable microbiological water quality and also helps to control further biofilm growth (USEPA 2004). Secondary booster disinfection not only provides adequate free residual chlorine but ensures uniform (spatial) residual chlorine concentration with minimum chlorine dosage (Hernandez-Castro 2007). Increased amount of free residual chlorine may solve microbial regrowth problems, however generates undesirable disinfection by-products (DBPs) (Bond et al. 2011; Legay et al. 2010). Many of the DBPs are potentially harmful to human health (Legay et al. 2010) and have certain negative effects. Booster disinfection can help to control these effects and provides other benefits:1) reducing the disinfection mass, 2) minimizing the cost, 3) decreasing contact time of chlorine and 4) controlling taste & odor (T&O) complaints (Boccelli et al. 2003). Therefore, an optimal range of free residual chlorine is required to be maintained and has been recommended under many guidelines and regulations, e.g., surface water treatment rule (minimum 0.2 mg/L and max 4 mg/L) (USEPA 2004). Water quality assessment can be done based on those optimal values or threshold values to ensure microbial, chemical and aesthetic water quality. The approach can be useful for small and rural community, where free residual chlorine may be the only available monitored data.

Water quality index (WQI) is commonly used to assess overall water quality. Among various WQI, CCME (Canadian Council of Ministry of Environment) WQI, also known as the Canadian water quality index (CWQI), is a popular way of representing complex water quality data in North America. CWQI formulation has been applied to source water, but can also be applied to drinking water (Khan et al. 2003). A modified version of this index called modified CWQI has been proposed in this study, where only free residual chlorine concentration is used to define WQI, unlike other indices that require a number of water quality parameters. A temporal free residual chlorine data can be combined to get the modified CWQI, where predefined threshold values are required. This simplistic formulation can be applicable for small and rural communities to represent their water quality over a certain period of time.

Levels of free residual chlorine can be controlled by optimizing chlorine dosage with booster stations (Cozzolino et al. 2005; Gibbs et al. 2010; Kang and Lansey 2010; Lansey et al. 2007). In this paper a simplistic optimization scheme based on modified CWQI has also been proposed.

MODEL FORMULATION

A series of temporal free residual chlorine data for a particular location in a WDN can be obtained by monitored data or through EPANET simulations. EPANET simulation was used in this study, where first order chlorine decay kinetics was assumed for both bulk and wall decay. Decay coefficients were adapted from established literature (Al-Jasser 2007; Hallam et al. 2003). Arrhenius equation was used to get seasonal bulk decay coefficient (Al-Jasser 2007). Ten-day simulation was performed to generate a time series of residual chlorine concentrations at a particular node in a WDN.

CWQI formulation

A WQI formulation is required to represent the data representing the water quality at particular node. Traditional CWQI consists of three factors: 1) scope (F_1), 2) frequency (F_2), and 3) amplitude (F_3).

Scope (F1):

Scope (F_1) is the percentage of failed variables to the total number of variables.

$$F_1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}} \times 100 \qquad (1)$$

Frequency (F_2)

Frequency is the percentage of regulatory non-compliance incidence (‘failed values’) for all the parameters under consideration.

$$F_2 = \frac{\text{Number of failed tests}}{\text{Total number of tests}} \times 100 \qquad (2)$$

This is basically the percentage of failed test.

Amplitude (F_3)

Amplitude refers to the amount by which the concentration value does not meet the regulatory guideline. It requires three steps:

Step 1: ‘Excursion’ calculation with the number an individual concentration is greater than (when objective is maximum value) or less than (when the objective is minimum value) the regulatory value (threshold value (TV)) for each parameter.

$\text{Excursion}_i = (TV_j/\text{Failed value}_i - 1)$, if TV > Failed value

$\text{Excursion}_i = (\text{Failed value}_i/TV_j - 1)$, if TV < Failed value (3)

Step 2: The normalized sum of excursions (nse) calculation based on:

$$\text{nse}=\frac{\sum_{i=1}^{n}\text{Excursion}_i}{\text{Number of failed tests}} \quad (4)$$

Step 3: The normalization of the previously calculated nse to obtain a value between a range (from 0 to 100).

$$F_3=\frac{nse}{0.01nse+0.01} \quad (5)$$

Finally, the CWQI can be calculated by:

$$\text{CWQI} = 100- \left(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right) \quad (6)$$

The CWQI will vary in range 0 to 100, where 0 means the worst and 100 means the best water quality. Equation (6) will be used to calculate WQI based on chlorine only (i.e., $F_1 = 0$), therefore it requires a modification such as:

$$\text{CWQI} = 100- \left(\frac{\sqrt{F_2^2+F_3^2}}{1.414}\right) \quad (7)$$

However, there are some limitations in the CWQI formulations such as:

1. Factor F_2 and F_3 can be combined together and the formulation can be more simplistic.
2. Normalization formula (Excursion) in F_3 can be modified and uncertainty can be incorporated.
3. Normalization formulation for F_3 has been assumed to posses total value of 50 instead of 100. For example, assume a failure situation for Amlitude (F_3). The individual excursion will be 1 for all the data points. Let us assume, we have 10 points and all of them have excursion value of 1. Using Equation(4) nse value will be:

   $$nse= \frac{\sum_{i=1}^{10} Excusion_i}{10}=\frac{(1+1+.....+1)}{10}=\frac{10}{10}=1$$

   F_3 value can be calculated using Equation(5):

   $$F_3=\frac{1}{0.01\times 1+0.01}=\frac{1}{0.02}=50$$

Based on the above mentioned limitations few modifications are proposed.

Modified CWQI

Modified CWQI function is presented in Figure 1, which is based on the free residual chlorine concentration. Here, the *x* and the y axis show the free residual chlorine and the function values [0, 1], respectively. The function value 0 refers to fully complying the regulation and 1 means completely defying the regulation. Four threshold values were proposed in this study denoted as a, b, c, and d representing the minimum threshold point, minimum intermediate point, moderate intermediate point, and the maximum threshold point, respectively. Practical knowledge and regulatory guideline is required to define these points. However, the points are flexible and decision makers can change these values based on the objective of the study. Threshold value of a=0.1 mg/L, b=0.2mg/L, c=0.8mg/L and d=1 mg/L were used in this study. It should be noted that the minimum intermediate point ('b') is based on the USEPA surface water treatment rule minimum recommendation of 0.2 mg/L free residual chlorine. Maintaining a maximum free residual chlorine value of 4mg/L may not be practical or healthy in terms of chemical and aesthetic water quality. For example, a maximum threshold level of 0.6 mg/L has been suggested by Australian Guidelines (Health Canada 2009). However, the maximum threshold point depends on personal choice and sensitivity for T&O complaints. A moderate intermediate point ('c') and the maximum threshold point ('d') of 0.8 and 1mg/L were proposed in this study.

Modified CWQI function has gradual decease or increase in the function, which gives flexibility and incorporates uncertainty in the formulation. A fuzzy excursion (denoted as FE and which may not necessarily related to fuzzy logic) is proposed instead of excursion. For example, free residual chlorine value of 0.18mg/L gives a FE value of 0.2 (Figure 1). The normalized sum for fuzzy excursions (nsfe) can be calculated unlike the CWQI such as:

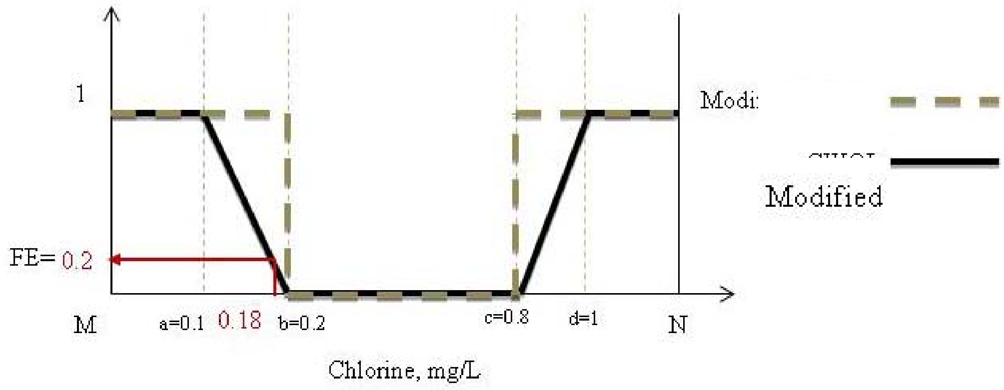


Figure 1: Modified CWQI function *vs*. traditional CWQI function

$$nsfe = \frac{\sum_{i=1}^{n} FE}{\#\ failedtest} \qquad (8)$$

where FE = Fuzzy excursion

An amplitude value denoted as V can be measured using this *nsfe* as follows:

$$V = \frac{nsfe}{0.005 nsfe + 0.005} \qquad (9)$$

It should be noted that Equation (9) assumed a total amplitude failure value of 100, unlike CWQI which was 50.

Finally, the modified CWQI = 100 - V (10)

The value is expected to be in between 0 and 100, where various ranges of the WQI represent different states of water quality, we assume [0-20]: *poor*; [21-50]: *marginal*; [51-70]: *fair*; [71-80]: *good*; [81-90]: very *good*; and [91-100]: *excellent* water quality.

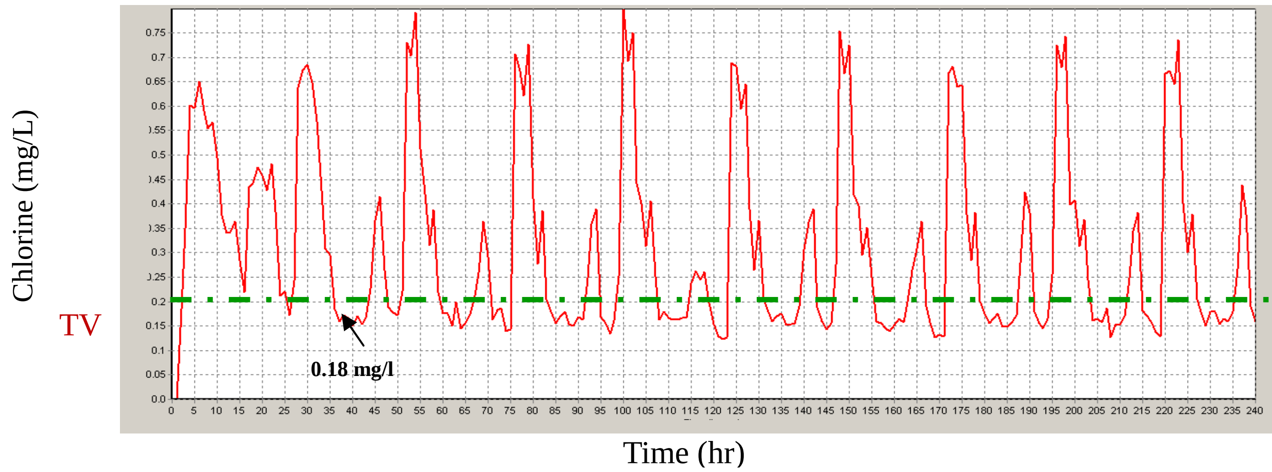


Figure 2: Temporal variations in residual chlorine concentration at a given node

Figure 2 shows a time series free residual plot which will be converted using the modified CWQI. The points will be accounted only from 49 to 240 hrs to calculate the index. There were 103 data points not maintaining the threshold values (**Error! Reference source not found.**). Equation (8), (9) and (10) were applied to estimate *nsfe*, amplitude V and modified CWQI such as:

$$\text{nsfe} = \frac{0.2+0.3+............+0.4}{103} = 0.175$$

$$V = \frac{0.175}{0.005*0.175+0.005} = 29.8$$

Modified CWQI=100 - 29.8 = 70.2

The CWQI of 70.2 represents the water quality as *good* for the particular time series of residual chlorine in Figure 2.

A CASE STUDY

The modified CWQI concept has been applied to the City of Kelowna (British Columbia, Canada), which provides drinking water to ~107,000 inhabitants. There are 2,586 water mains consist of asbestos cement (AC), cast iron (CI), concrete (CONC), and ductile iron (DI). There are five water sources to supply the water and twenty tanks (based on the EPANET model provided by the City) for storage (Figure 3a). Information was collected about the existing booster stations (Figure 3b). Sixteen existing booster stations maintain booster chlorine dosage from 0.6 to 1 mg/L. The network was divided into eight zones denoted as Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, and Z_8 for spatial analysis (Figure 3b). Three representative points were selected in each zone such as one middle point, and two extreme points. The average water quality of these points is assumed to be the water quality of that particular zone. Finally, the data were divided for two seasons for simplicity, i.e., winter (November to April), and summer (May to October).

Temporal and spatial water quality assessment

Modified CWQI shows comparatively lower water quality in summer than in winter for the eight zones (Figure 4). Residual chlorine was lower due to higher reaction rate in summer and resulted in relatively poor water quality. Zone 1 and 2 comparatively show poor water quality in summer (Z_1-*fair*; Z_2-*marginal*). The water quality was also assessed using traditional CWQI. The results show similar trend using both indices with a strong correlation of ~0.96 (Table 1).

Table 1: Temporal and spatial results

Zone	Summer		Winter	
	CWQI	Modified CWQI	CWQI	Modified CWQI
Z_1	66.8	70.5	80.2	76.2
Z_2	32.5	31.2	34.3	32.2
Z_3	96.0	86.9	98.6	92.9
Z_4	73.0	60.2	81.7	60.4
Z_5	96.2	93.5	99.1	96.9
Z_6	86.8	68.2	97.0	91.9
Z_7	71.0	55.4	90.1	73.8
Z_8	99.2	97.2	97.8	94.5

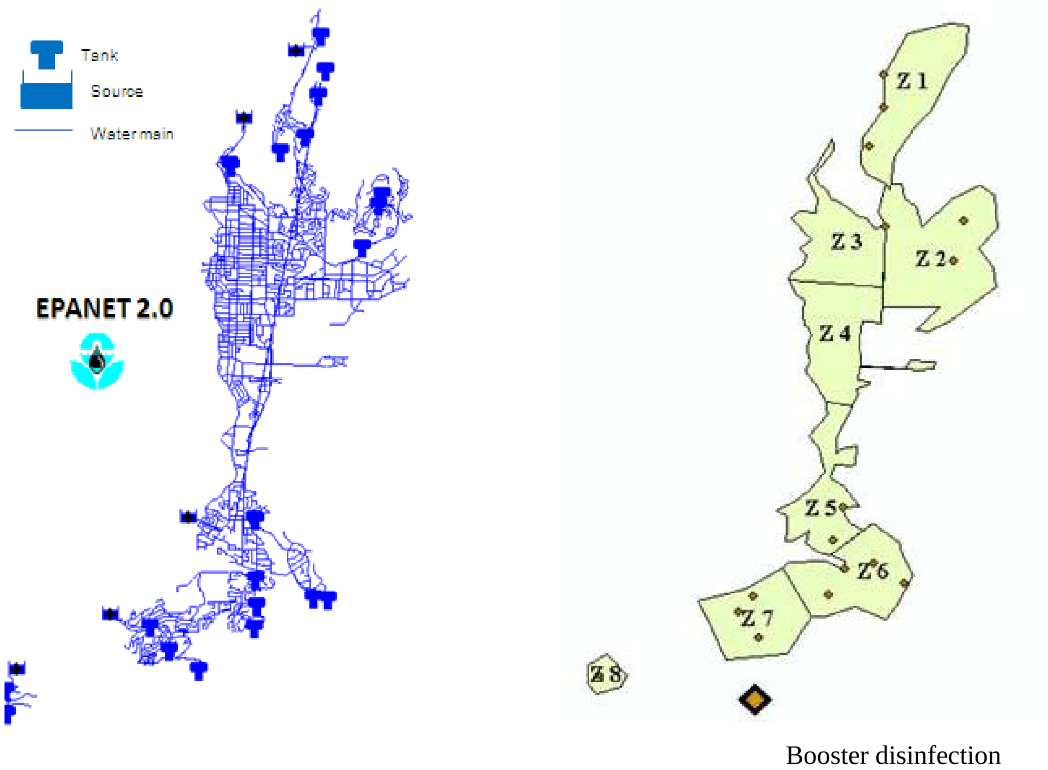


Figure 3: City of Kelowna a) EPANET model, and b) existing booster locations

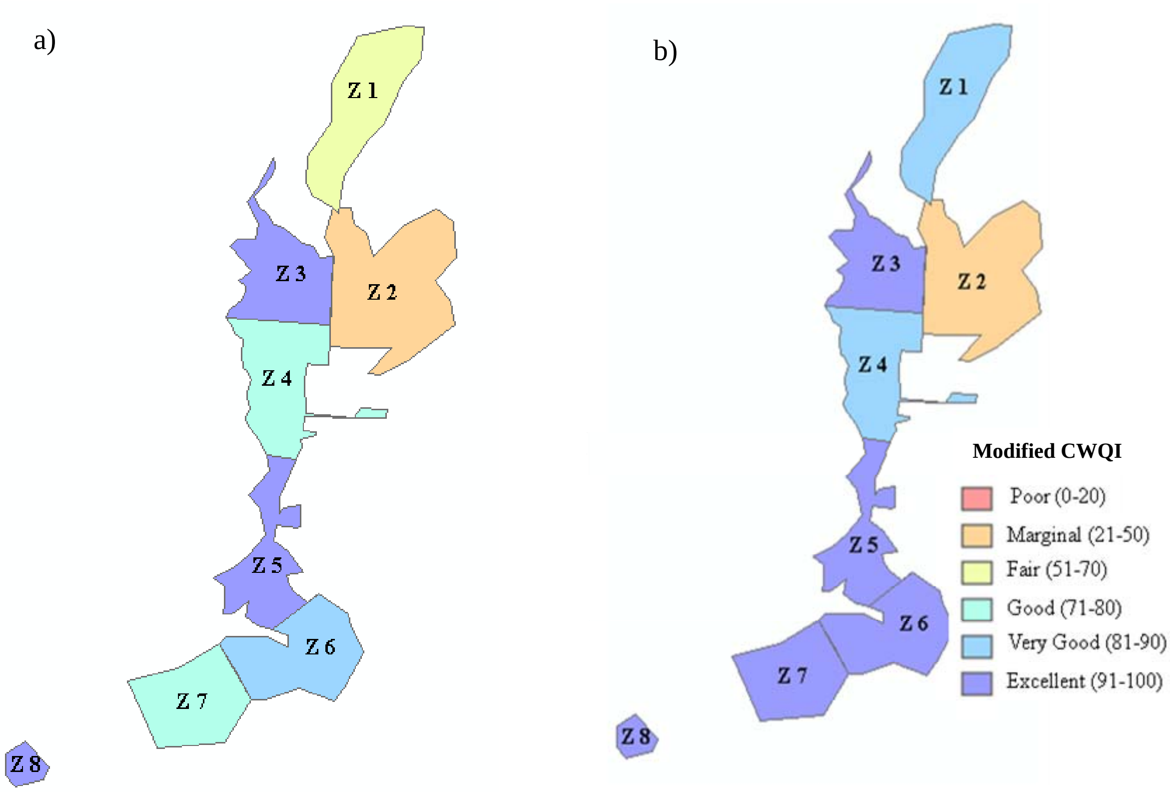
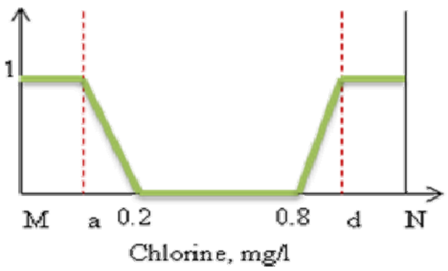


Figure 4: Temporal and spatial analyses for, a) Summer, and b) Winter

Model sensitivity

Model sensitivity has been tested by changing the threshold value of 'a'and 'd'. Figure 5 shows various combinations and the R^2 value. A threshold combination of a=0.15, d=0.9 gave the highest R^2 value of 0.919, while lowest value came for a=0.15, d=2. In some special cases, modified CWQI proves to be more logical. For example, a node has a time series of chlorine concentration from 0.17 to 0.22mg/L. The estimated modified CWQI came 70.2, while CWQI came 48. It should be noted that the regulation suggests a minimum value of 0.2mg/L and CWQI value of 48 out of 100 is much strict than the modified CWQI value of 70.2. Therefore, modified CWQI is more logical, flexible and practical to assess water quality.



Comb. no	a	d	R^2
1	0.01	0.9	0.743
2	0.01	1	0.743
3	0.01	1.5	0.803
4	0.01	2	0.720
5	0.05	0.9	0.803
6	0.05	1	0.867
7	0.05	1.5	0.796
8	0.05	2	0.714
9	0.1	0.9	0.886
10	0.1	1	0.919
11	0.1	1.5	0.789
12	0.1	2	0.711
13	0.15	0.9	0.949
14	0.15	1	0.938
15	0.15	1.5	0.762
16	0.15	2	0.691

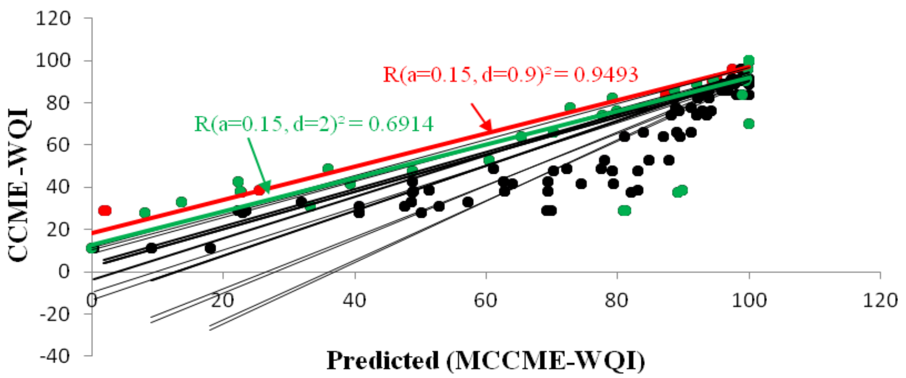


Figure 5: Sensitivity analysis for modified CWQI

Proposed booster optimization

There are many optimization schemes (Cozzolino et al. 2005; Gibbs et al. 2010; Kang and Lansey 2010; Lansey et al. 2007; Ostfeld and Salomons 2006; Parks and VanBriesen 2009; Prasad et al. 2004; Propato 2006; Tryby et al. 2002) proposed by the decision makers to optimize booster concentration, station numbers, and costs. Their objective functions are different such as minimizing total mass, cost, and booster location numbers. A new optimization scheme can be made using an objective function of modified CWQI (Figure 6). Here, the objective functions will be:

1. Maximization of modified CWQI, and
2. Minimizing booster dosage

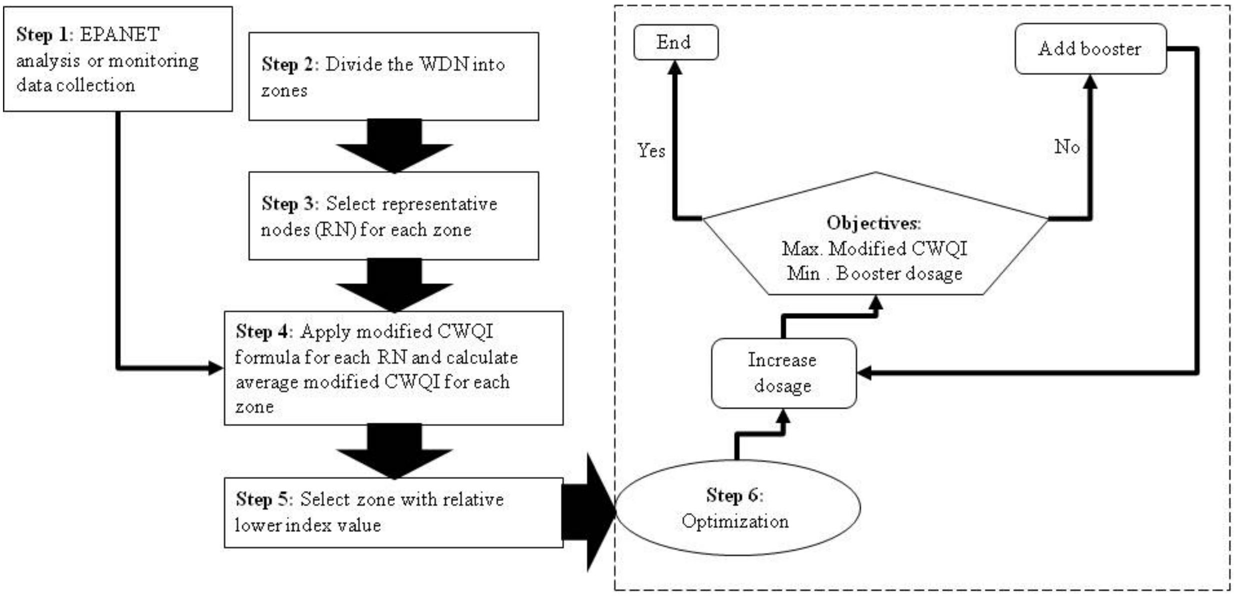


Figure 6: Proposed optimization scheme

Figure 6 shows a brief summary of the proposed optimization scheme. Firstly, EPANET simulation must be conducted or some monitored data should be collected in the field. The WDN should be divided into zones and for each zone some of the representative nodes should be selected. Modified CWQI should be estimated for the zones only and zones with comparatively lower water quality would be selected to apply the optimization scheme (Figure 6).

Summary and future recommendations

Disinfection is essential to inactivate microbial pathogens in water distribution network, but can generate potentially harmful by-products, taste & odour problems. Booster disinfection is useful as it can ensure relatively uniform free residual chlorine concentration and can ensure microbial, chemical and aesthetic water quality. A modified version of CWQI has been proposed to describe the overall water quality using chlorine concentration only. Modified CWQI proves to be more logical in particular situations and can deal with uncertainty and provides flexibility in the formulation. Furthermore, the model formulation is simpler than the traditional CWQI. City of Kelowna was selected as a case study to demonstrate the proof of the concept. The EPANET model simulation gives residual chlorine concentration for a certain period of time, which was converted into modified CWQI. The preliminary temporal and spatial analyses show relatively lower water quality in summer. Modified CWQI can be useful for small and rural communities as chlorine concentration is often used to describe overall water quality.

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TROPICAL CYCLONE DISASTERS: TRENDS AND IMPACTS IN BANGLADESH

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ABSTRACT

Tropical cyclones present major threats to coastal communities worldwide. In the currents years the severity of cyclones have increased globally causing human deaths and economic loss. Bangladesh is one of the most susceptible regions of extreme tropical cyclones which cause extensive damage. This review paper describes the trends and impacts of tropical cyclone disasters in Bangladesh. IPCC report (2007) and relevant scientific paper were reviewed to depict this conditions. Due to Bangladesh's physio-graphic conditions (e.g. the triangular shaped head of the Bay of Bengal, the sea level geography of its coastal area etc.) makes the country more vulnerable to tropical cyclones and here about 6-10% of world tropical cyclone formed. In Bangladesh, there is a large variability of severity from year to year of land-falling tropical cyclones. The sea surface temperature (SST) is increasing in all latitudes due to global climate change and accompanied with this the intensity of cyclones have increased. During the last 35 years the intensity of cyclones increased in Bangladesh could be the part of global warming. Cyclone Sidr (in 2007) with wind speed 250km/h is the most severe cyclone compare to previous another severe cyclones. El Niño-Southern Oscillation (ENSO) events also influence the formation of cyclone in Bangladesh. Most of the experiments showed that there is less certainty in the significant changes of frequency but the mean intensity of cyclones increased markedly. In Bangladesh, tropical cyclones have considered the first killer in all of the disasters during the last 30 years. The impacts of tropical cyclones in Bangladesh mainly represent large number of death and serious economic damage. These results were due to not only large precipitation and fierce wind but also others associated disasters such as surges.

Key words: Tropical cyclones, Climate change, ENSO, vulnerability, Bangladesh

1. INTRODUCTION

Tropical cyclones, are also named as typhoons and hurricanes, are almost certainly known as crushing atmospheric phenomena and cause large number of human destructions and economic devastations around the world (YOSHIMURA, et. al., 2006). Globally, in recent years the strength and frequency of cyclones have increased. In the twenty-first century, additional increase of temperature might lead to an increasing trend of cyclones (Paul, et. al., 2011). Globally, the number of cyclones has increased more than three times during the last 36 years (1970-2006). Worldwide, near about two million people died over the past two centuries due to tropical storms, including cyclones, hurricanes and typhoons (Haque, et. al., 2011). Deplorably, the Bangladesh coast is frequently hit by tropical cyclones with cause heavy loss of life and economic property (Paul, 2010). In the coastal belt of Bangladesh, Meghna estuary is the most affected region (Dube, et. al., 2004). In each year, the coast of Bangladesh affected by at least one major tropical cyclone with strong tidal surges. This disaster impacts on millions of lives vigorously, and make this country more unsafe compare to other regions of the world. In the Bay of Bengal, total 174 severe cyclones formed with causing extensive loss of life and property in the period of 1891 to 1985. During 1969-1990, annually an average 13 depressions were formed and among that five developed into cyclones (Paul, et. al., 2011). In April 1991, a gigantic cyclone with sea surge height 6-7.6 m. causes $2.4 billion material damage and life loss was approximately 140,000. Another deadly cyclone in 1970 causes half of million human casualties. Recently (in 2007) cyclone Sidr with wind speed of 250km/h and 5 m. height of sea surge struck the coastal region that killed more than 3,300 people (Alam, et. al., 2010). In an average, after every three years a severe cyclone strikes the Bangladesh (Mallick, et. al., 2011). Indeed, due to cyclone and sea surges more than 50% of total deaths of the world occurred in Bangladesh (Paul, et. al., 2011).

2. AIM AND OBJECTIVES

The main aim of this review study is to understand the aspects of tropical cyclones focus on Bangladesh.
The specific objectives are:

- The straightforward exposition of tropical cyclones intensification due to climate change in Bangladesh,
- To overview the trends and intensity of tropical cyclone disasters in the aforesaid area and,
- Finally, to offer some recommendations for preparedness and mitigations of the cyclone disasters.

3. METHODOLOGY

To fulfill the aim, the climatology of tropical cyclones and the reasons that tropical cyclones generated worse disasters in Bangladesh than other regions were reviewed in this paper. IPCC report in 2007 was the main source of considered, and the previous researches on Cyclones in Bangladesh were collected and accorded as well. In addition, the specific location of the country and the specific economic situation would be referred to analyze the impact of cyclone on the country.

4. BACKGROUND

Globally, there were about 80 tropical cyclones each year (Emanuel, 2003). Tropical cyclones generally develop depending the right environment, which are light winds, high humidity in a deep layer extending up through the troposphere, and warm surface water temperature (26.5^{o}C or greater) over a vast area (Ahrens, 2009). After tropical cyclones exist, they always move from low latitude to high latitude, and will survive for a long life time if they move over warm water. Conversely, tropical cyclones will always rapidly dissipate if they travel over warm water with unfavorable interactions with other wind systems or cold water or land (Emanuel, 2003). However, when tropical cyclones land fall, they can still cause disasters especially in coastal area, such as the coast of Bangladesh.

The Coast of Bangladesh is one of the most affected areas by tropical cyclones in the world. Tropical cyclones never attacked from January through March to Bangladesh, but frequently occur during the pre-monsoon (May–June) and post-monsoon (October–November) seasons (Islam & Peterson, 2008). Islam & Peterson (2008) counted that there was a total of 117 tropical cyclones attacked the coast of Bangladesh from 1877 to 2003. By landfall locations, Islam & Peterson (2008) also mentioned that the most violent area under attack is Khulna coast, which is located to the southwest corner of Bangladesh; it faced the number of 36(31%) tropical cyclones during 1877–2003. The second most serious area is Barisal, where was under attack 31(26%) tropical cyclones in 1877–2003. Chittagong and Cox's Bazar are very close to each other by the number of hits, 21(18%) and 20(17%), respectively. The lowest number (9, 8%) of tropical cyclones hit the Noakhali coastal (Islam & Peterson, 2008).
When tropical cyclones close to the Coast of Bangladesh, fierce winds cause big waves on the sea surface. While tropical cyclones land fall the Coast of Bangladesh, big waves will become storm surges and cross fending dykes, and cause flooding devastation in land areas. Thus apart from fierce winds, storm surges and flooding are major reasons that cause serious human casualty.
Bangladesh is one of the most vulnerable regions of severe tropical cyclones which cause extensive damage (Dube, et. al., 2004). Tropical cyclones commonly form over the some parts of tropical Ocean in between 10^0 and 30^0 latitudes of both sides of the equator. They become stronger when they are originated in between 20^0 and 30^0 latitude and geographically Bangladesh is located in between ($20^0$34´N and $26^0$34´N) this range of latitude (Islam, et. al., 2009). In the Bay of Bengal, the basic prerequisite physical and climatological conditions are exists for the

generation of tropical cyclone and here 6-10% of the total world tropical cyclones formed. This sea is considered an ideal ground of cyclogenesis (the development or strengthening of cyclonic circulation in the atmosphere) (Paul, 2011). Haque, et.al. (2012), Paul, et al. (2011) and Dube, et al. (2004), mentioned some specific reasons for the vulnerability of this country to cyclones and induced surges: (a) The geographical location, (b) unusual characteristics of tropical monsoon climate, (c) high astronomical tides, (d) favorable cyclonic track, (e) shallow continental shelf with the confluence of three mighty river (Ganga-Brahmaputra- Meghna) systems, (f)location at the triangular shaped head of the Bay of Bengal, (g) sea level geography of its coastal area, (h) thickly population density in low-lying islands and (i) lack of coastal protection systems.

5. RESULTS

5.1 Climate Change and Tropical Cyclones

The power of cyclones depends on sea surface temperature and the temperature difference between the ocean surface and the upper atmosphere because cyclones get their power from rising humidity which releases heat during condensation. For example if the ocean surface temperature increase due to global warming but not the upper atmosphere, the tropical cyclones will get more power due to this temperature difference. The sea surface temperature is increasing in all latitudes and in all oceans (Dasgupta, et. al., 2010). In the event of climate change, Bangladesh is one of the most susceptible countries in the world. Practically the climate change impacts come to this country from the south where the Bay of Bengal is situated. This water is the main source to form tropical cyclones in Bangladesh (Ali, 1999). The scientific study (Vulnerability of Bangladesh to Cyclones in a Changing Climate, 2010) denotes that increase sea surface temperature will lead to strengthen the cyclone activity with high sea surges. Cyclone Sidr (November 2007) in Bangladesh is the recent example of the strongest cyclone in the Bay of Bengal and its category was 5 in Saffir-Simpson scale. In the last 35 years, the increase in the frequency and intensity of tropical cyclone could be the part of global climate change. If the projected sea level rise due to global warming, the tropical cyclone intensity would rise with continue to warm the earth (Dasgupta, et. al., 2010). The environment in which tropical cyclones form is changed because of climate changes and sea surface temperatures (SSTs) continue to increase. Increase SSTs are generally leads to increase water vapor in the lower atmosphere which acts like a fuel in fire and its increase convection and thunderstorms. Cyclone form where SSTs above 26^0 C and including this other factors like wind shear in the atmosphere, El Niño- Southern Oscillation (ENSO) and variations in monsoons factors influence the generation and tracks of tropical cyclones development. In the southern pacific, ENSO fluctuations have a strong impact on the development and frequency of tropical cyclone patterns. But it noted that there is uncertainty with respect to future ENSO behavior contributes to uncertainty with respect to tropical cyclone behavior (IPCC, 2007). In a scientific analysis (Bangladesh Floods, Cyclones and ENSO,1994) it has been observed that during the strong El Niño years Bangladesh is not affected by catastrophic cyclone disasters. In the year when the El Niño is weaker and the years when the ENSO trends is positive (La Niña) that time is more favorable for the cyclone formation in the Bay of Bengal. The explanation is during positive index of ENSO, the walker circulation is stronger. In this case the atmospheric pressure in the southeastern Pacific is high and in the Asian region atmospheric pressure is low as a consequence the wind is easterly. On the other hand when the ENSO index is negative (El Niño), the easterly wind will be weakened or reversed. So, in case of Bangladesh during the strong El Niño years this country is safe from catastrophic cyclones but if the El Niño is weak allows forming tropical cyclone in the Bay of Bengal and cross over the Bangladesh (Choudhury, 1994).

5.2 Trends and Intensity of Cyclones Disasters

Tropical cyclones can be thought of as a natural heat engine. In this perception global warming can influence the maximum potential intensity of tropical cyclone (IPCC, 2007).The thermal energy of the upper surface ocean water strongly influences the formation of tropical cyclones (Karim and Mimura, 2008). Over the past 35 years, the number of tropical cyclones and cyclone days as well as cyclones strength has increased due to increase sea surface temperature. It has been observed that the largest increased occurred in the North Pacific, Southwest Pacific and the Indian Oceans. But the increasing percentage was smallest on the North Atlantic Ocean (Webster, et.al. 2005). There is fewer models simulation in the context of tropical cyclones in climate change than other factors (sea level, precipitation, precipitation), so there is less certainty in the changes of frequency and intensity of tropical cyclones on a regional basis (IPCC, 2007). In the IPCC report (2007) have addressed more recent modeling experiments that is focus on possible changes of tropical cyclones in a warmer climate. In a study (model grid resolutions that only represent some aspects of individual tropical cyclones characteristics) with 100km grid spacing shows a decreasing trend in tropical cyclone frequency globally but regional increase over the North Atlantic and no significant changes of maximum intensity. This report also included that regional changes of tropical cyclones are depended on SST pattern, and precipitation near the storm center could increase in the future time. Another study (global warming simulation with about 300km grid spacing) shows that the development of global tropical cyclone frequency did not change extensively but the mean intensity increased markedly. Thus there is no consistent evidence for large changes in either frequency or intensity but these grid models can represent only the earliest stage of tropical cyclone development and more responsive for intense precipitation from future storms in a warm climate.

According to IPCC report (2007), in general there is no clear picture of changes in the frequency and movement of tropical cyclones at a regional basis but the strength of cyclones have increased. In theoretical manner, SST rise is the fact for the more frequent and intense cyclones but this assumption is not fully supported by a study (observed cyclone) based on all kinds of cyclones (1877 to 1995) form in the Bay of Bengal. The analysis (observed cyclone) showed that the frequency of cyclone is not increase even though temperature was increased. But the frequency of severe cyclones increased during the November (Karim and Mimura, 2008).

Table 1: Cyclone severity index with wind speed in Bangladesh (1960-2010)

Year	Speed of Wind (km/h)	Severity Index
1960	210	5
1961	146	5
1963	203	5
1965	210	5
1966	146	5
1970	223	6
1973	122	5
1974	162	5
1985	154	5
1986	100	4
1990	102	4
1991	225	6
1994	200	5
1995	100	4
1996	70	3
1997	225	6
1998	112	4
2007	250	6
2008	80	3
2009	95	4

Source: Haque, et. al. (2012)

In Bangladesh, during the last 50 years the strength and severity of cyclones have varied greatly (Table 1). But during the last 20 years, this country has managed to reduce the deaths and injuries to cyclones, as for example most recent devastating cyclone Sidr caused near about 4000 deaths that is 100 fold reductions compare to severe cyclone 1970.

On the basis of IPCC (2007) assumption, if the temperature rise of a lower bound 2^0 C and an upper bound of 4.5^0 C by 2100, the corresponding cyclone wind speed will increase 10% and 25% respectively to the present threshold temperature of 27^0 C in the Bay of Bengal. Even so, the above intensity of cyclone has not yet confirmed by the observations and numerical experiments. The possibility of any increase in peak intensities would increase the future storm surges higher than those that are observed currently due to projected temperature increase. This will cause serious implication for the countries which are already vulnerable to cyclone (Karim and Mimura, 2008).

5.3. Impacts of Cyclones

In Bangladesh's history, there were three major tropical cyclones disasters: Cyclone Sidr (November 2007) hit the coastal areas on 15 November 2007. It affected 87,000 people, killed 3,363 and injured 55,282; Cyclone (1991) occurred in April 1991 in Chittagong killed 138,000 people. The total damage was $ 1.5 billion; Cyclone (7015B), due to the cyclone and subsequent flood that occurred in November 1970, about 300,000 people were killed. The total damage was US$24 billion. (ADRC, 2008)

Human Casualty, in the past 30 years (1980-2010), tropical cyclones has been a first killer of all types of disasters in Bangladesh. According to United Nations International Strategy for Disaster Reduction (ISDR, 2011) data Storm caused 87.2% deaths in all number of people killed by disasters. In this time period, the most serious disaster event (1980-2010) occurred in 1991, which the tropical cyclones made landfall at Chittagong coast and caused 138,866 deaths (Islam & Peterson, 2008).

Islam & Peterson (2008) in their research shows the total number of deaths from cyclones in the five coastal segments of Bangladesh in 1904–2000 (Table 2). He mentioned that the subdivisions of Barisal and Chittagong had a large number of deaths compared to the other coastal subdivisions mainly due to the 1970 super tropical cyclone that is among the worst natural disaster in the world. In 1970, the tropical cyclones hit the Barisal coast and killed 300,000 people at night, and the time of disaster occurred was a significant reason that a large number of people dead. Khulna had largest number of tropical cyclones landfall but fewer deaths, Islam & Peterson (2008) analyzed, because Sundarbans forest in this subdivision so that against the winds, storm surges and flooding. The coastal subdivision of Cox's Bazar had least number of deaths because there was low population density in this subdivision (Islam & Peterson, 2008).

Table 2: The total number of deaths from cyclones in the five coastal segments of Bangladesh in 1904-2000

Coastal subdivision	Number of deaths
Khulna	5,267
Barisal	354,326
Noakhali	25,616
Chittagong	157,445
Cox's Bazar	413
Total	543,067

Source: (Islam & Peterson, 2008).

Infrastructural and Economic Destruction, Bangladesh is a less developing country. According to the World Bank (WB, 2011) data, The Gross national income (GNI) per capita is $700, which belongs to low-income country with population about 148 million (2010). It is important to note that employment in agriculture was 48% of total employment in 2005 (WB, 2011). It means the development of country considerably depend to a stable of climate.

However, in the period of 1980-2010, there were average 3.48 tropical cyclones attacking Bangladesh and damaging around 50 million dollar per each cyclone (ADRC, 2008). Crops, some wood buildings, vehicles were almost utterly destroyed, when tropical cyclones were landed fall with high storm surges and floods. The worst economic damage was occurred in 1970; it caused 24 billion dollars loss (ADRC, 2008). Recently, Sidr (November 2007) hit the coastal areas on 15 November 2007. It affected 87,000 people, caused economic damages of 2.3 billion dollars (ISDR, 2011).

Coastal Flooding and the Storm Surges, Rain, strong winds, and storm surges are three main factors that cause the damage from land-falling cyclones (Dube et al., 2009). Strong winds and rain are significant characteristics of tropical cyclones, and blowing all objects on land, but they are hard to cause ruinously destructive to the modern building, so people can be safe if they stay in buildings. However, if tropical cyclones land fall a shallow basin, strong winds will blow over a large surface of water that lead a rapid rising of the sea water on the coast area so that cause a flood in coastal regions. In addition, heavy raining will conditionally encourage damages of floods. Heavy raining cause the level of rive rising, at the same time, the sea water flood coastal areas, so that the protections along coast sometime will lose efficacy because of sea water move up in rives and extend the damage to inland areas (Dube et al., 2009).

Bangladesh suffers most from storm surges of all the countries surrounding the Bay of Bengal, and the reasons may be: shallow coastal water, convergence of the bay, high astronomical tides, thickly populated low-lying islands, favorable cyclone track, and largest rive system in the world (Dube et al., 2009). One reason cannot lead a serious damage from a disaster. In 1970, the cyclone (7015B) was able to take a large number of people's lives because not only strong tropical cyclone but also astronomical tide. During the period of tide, the sea level raised much more than in normal time. Thus, if a tropical cyclone storm surges come with astronomical tide, the heights of storm surge may be in excess of 10m so that attacking the coast of Bangladesh very strongly.

5.4 Preparedness and Mitigation

After suffered lager numbers of disasters, Bangladeshis have evolved several steps to reduce their losses and to save their belongings. In summary, habitants living in coastal areas or islands will hid their valuables in the earth or move to safer areas, and they will move as well; households consider will tie their houses to surrounding big tree to save them, and; farmers will try to collect their crops and move their domestic animals to high areas, but if a cyclone is too strong, they will set animals free. All preparing steps depend on the presence of local signs and the cyclone signal hoisted by the BMD (Alam & Collins, 2010).

Actually, people can do less during a water surge. If people cannot arrive to cyclone shelters, they will usually go up to their rooftops of their house. People help each other, but these helps are very week facing a strong cyclone surge. After cyclone surges ebbed, rescues and aids are two major needs of after-cyclone people. Searching by survivors is very important before outside aids arrive. Survivors search, apart from their families, food and drinking water which can help them live four or five days (Alam & Collins, 2010). House and food problems require urgently to be solved after outside aids arrive. In addition, accomplishment after-cyclone reconstruction depends on the government of Bangladesh and reinsurance.

Retreat, accommodation and protection were three adaptive options (Ali, 1999), however; High density of population and limited land cause an unsolvable problem on retreat. Reviewing the previous serious tropical cyclones disasters, the coastal subdivision of Khulna had fewer deaths compared other coastal areas in Bangladesh, even though Khulna suffered highest number of tropical cyclones (Islam & Peterson, 2008). The reason, Islam & Peterson (2008) analyzed, were the Sundarbans forest in Khulna, which was as mitigation against the wind and storm surge during tropical cyclones. From this perspective, protecting forest or plant big-branched trees around the homestead (Alam & Collins, 2010) will improve the quality of mitigation against tropical cyclones disasters.

Constructing cyclone shelters and raising the height of the houses' plinths are very helpful to save people's lives during tropical cyclones surges arrived. Nowadays, the numbers of inhabitants in the coast of Bangladesh have raised the height of the plinths on average to around eight feet above the level of cropland (Alam & Collins, 2010), and it had a great performance during the cyclone Sidr in 2007. Construction of embankment in the coastal areas is played a very important role of mitigating the damage of storm surges. Embankments block surges directly, even if surges cross them, the energy of surges will decrease rapidly. Government plays a significant role when disasters come. In 1972, the government of Bangladesh established the cyclone preparedness program (CPP). This program included cyclone warning system, public cyclone centers and Killa-livestock shelter (Paul, 2009). In 2007, when the cyclone Sidr suffered Bangladesh, CPP succeed to control the number of death under 4,000.

The U.S.A. is a country which always suffers tropical cyclone as well as Bangladesh, however; the U.S.A. has a developed communication and a great economic basis. This presents accurate forecasting and advanced equipment. In addition, the U.S.A. has a good education on taking precautions against disasters (FEMA, 2012). In Japan, typhoon is not main disaster comparing with earthquake, but it still faces the most of typhoons from northwest Pacific Ocean. As facing earthquake, the preparations have become part of the culture in Japan (Survival and Prosperity, 2011). All cellphone can receive warning when earthquake or storm surges coming, and the equipment for lifesaving just near every person.

6. DISCUSSION

For the relation between climate change and tropical cyclones, an theoretic truth is that the sea surface temperature (SST) increasing would lead a larger difference of temperature between sea surface and atmosphere, so that tropical cyclones would get more power. However, no research was able to confirm the positive result of increasing both the intensity and frequency of tropical cyclones in a specific area by observing.

Based on the results of literature reviewing, a comment viewpoint was that the intensity (max wind speed and life time) of tropical cyclones has been increased since 1970 in the Bay of Bengal, but the frequency had no increase. There might be two following reasons causing these changes.

First, the environment of tropical cyclones formation is not certain. Even though the factors, which are both temperature (26^{o}C/26.5^{o}C or higher) and light winds, of tropical cyclones formation are certain, Scientists still cannot accurately forecast the location and the time of local tropical cyclones formation. It means that these two factors is not enough to explain the changes of local tropical cyclones. Thus, it cannot be said that tropical cyclones must be stronger or more frequency when the global temperature increasing.

In addition, earthquake is a process of energy transportation or energy release from plate friction, similarly; tropical cyclones can be seen as processes of energy transportation or energy release through atmosphere or from global warming. The tropical cyclones bring a lot of water vapor and high speed wind with powerful rotary force, blow from the south Bay of Bengal to the north. This process lead the energy transferring from south to north, so that the south Bay of Bengal release energy and need a period time to collect energy to form tropical cyclones. Therefore, a more powerful tropical cyclone will transfer more energy, so that the number of tropical cyclone will be decrease or no change if the environment energy is constant or not obviously increase.

For the impacts of tropical cyclones to Bangladesh, serious damages and large number death were usually not associated with fierce wind or rainstorm but surges. Compare with other region, the maximum wind speed of the tropical cyclones in the Bay of Bengal is not highest in the world, but the damages cyclones caused were the most serious. There might be three following reasons leading the vulnerabilities.

First of all, the vulnerability is associated with high density water system. As Dube et al. (2009) mentioned that Bangladesh has the largest river system in the world, however; there are many large river systems under attack by tropical cyclones, but why those areas were not caused so serious results. The reason must be no please to buffer those water.

Therefore, the topography should be the second reason of the vulnerability on tropical cyclones. The level from south to north in Bangladesh is low to high, and there is the Himalayan Mountains with top height 8,848m. The distance from the coast of Bangladesh to the foot of the Himalayan Mountains is only about 600km, so a strong cyclone will bring a large number of precipitations on windward slope where is upper reaches to Bangladesh. These precipitation will pressure the river level going higher while surges across embankments. In addition, the steep slope from the coast of Bangladesh to the Himalayan Mountain causes no buffer behind the coast of Bangladesh, so that the water levels will rapidly rise after surges across embankments. Moreover, the especial shape of the Bay of Bengal cause that routes of tropical cyclones are hard to predict, which was an important reason that a large number of death in 1970 disaster. Furthermore, high population density is a significant reason of the vulnerability on tropical cyclones. High population density cause not only less land to avoid cyclones but also make it more difficult on movement to avoid cyclones.

7. CONCLUSION

This review paper has organized numbers of researches on tropical cyclones in Bangladesh from 2000 to 2011.Bangladesh is highly vulnerable to tropical cyclones compare with other coastal countries in the world due to geographical and climatic conditions. Most of the reviewed papers showed that the frequency of cyclone has no change significantly but the strength of cyclone increased markedly with the change of climate in Bangladesh. The reason might be associated with energy transportation and releasing. However, scientists still have not observed a markedly results that showing the relation between tropical cyclones and climate change. If the projected temperature increase according to IPCC (2007) report due to global climate changes the strength of cyclone could be increase more by the year 2100 that will be more severe for the coastal countries especially for Bangladesh.

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CHARACTERIZATION OF LEACHATE AND SOLID WASTE OF DHAKA CITY CORPORATION LANDFILL SITE FOR SOLID WASTE STABILIZATION

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ABSTRACT

Rapid urbanization of Dhaka city has created immense pressure on its urban services including solid waste disposal. Both city corporations (Dhaka North, DNCC and Dhaka South, DSCC) have been facing tremendous problem to maintain sustainable waste management over the last few decades. At present, the DNCC and DSCC dump 68% of the total solid waste to the sanitary landfill site at Matuail. Decomposed solid waste is a potential source of heavy metals and toxic chemicals that pollute the soil as well as the surrounding water body. For environmental sustainability, it is now essential to reduce the load of decomposed solid waste at landfill site through the conversion of waste into re-usable product. Proper characterization of solid wastes is pre-requisite for efficient management and solid waste stabilization. In this paper, it is therefore aimed to investigate the physical and chemical characteristics of decomposed solid waste and leachate collected from Matuail landfill sites. The average concentrations of Fe, Cu, and Ni in leachate samples collected from treated pond were found to be 19.11 mg/l, 0.71 mg/l, and 2.5 mg/l respectively exceeding Bangladesh standards. The presence of heavy metals in decomposed solid waste was also found to be significant. In order to reduce the scale of pollution it is recommended to stabilise solid waste to use it as a construction material. Physical properties that were analysed in this study will also be helpful for selecting stabilizing additive for perfect stabilisation.

Keywords: Decomposed solid waste, Heavy metal, Landfill, Leachate.

INTRODUCTION

Solid waste management of Dhaka North and South City Corporation becomes a vital issue for environmental sustainability demanding the reduction of waste volume at landfill site. Being a fast increasing populated area (DNCC and DSCC), the amount of generated solid waste is found to be more than 4,000 ton/day, but for the lack of proper services only 2,500 ton/day is collected for disposal in open dumping sites (DCC, 2011). Till now, there is no full sanitary landfill for ultimate disposal of solid waste. Matuail landfill being constructed by DNCC and DSCC is not properly operated to protect the environment and the neighbourhood from adverse impacts of landfill gas and leachate. Besides, potential health hazards as well as vegetation damage, unpleasant odors, soil and water pollution are major concerns (Mamtaz and Chowdhury, 2006). Leachate from decomposed solid waste (municipal, industrial and clinical) conveys heavy metals such as Fe, Cu, Cd, Ni, Cr etc. that may get into surface water body or percolate groundwater causing potential water contamination. Such contamination of water resources may possess substantial risk to the local natural environment. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby landfill site unless significant thickness of natural clay lining or artificial lining (i.e. geotextile) is in place (Mor et al., 2006). In context of Bangladesh, the dumping site is found to be highly polluted with toxic metals requiring detail characterization and appropriate remedial measure (Mamtaz and Chowdhury, 2006). To reduce the volume at landfill site it is essential to take the initiatives for stabilization of solid waste via solidification that convert the waste into re-usable products such as construction material, filler material etc. In this current study, the chemical analysis of decomposed solid waste and leachate were carried out to observe the toxicity level of heavy metals and justify the necessity of solid waste stabilization and re-use. Matuail landfill site (having area of 40 hactre) has been selected as study area.

MATERIALS AND METHODS

Sampling Procedure

In the present study, three different types of samples: a) decomposed solid waste from waste disposal area, b) converted soil (soil used for vegetation) in dumping sites and c) leachate from leachate pond were collected from Matuail landfill site to determine the physical and chemical parameters including heavy metals concentration. Decomposed solid waste samples were collected from 5 sampling points (SP) of the landfill site (Fig. 1). Sampling points were selected based on the age of decomposition of solid waste as presented in Table 1.

Table 1: Sampling criteria for the selection of sampling points at landfill site

Sampling Points	Sampling Criteria
SP-01	7 years old decomposed solid waste
SP-02	5 years old decomposed solid waste
SP-03	4 years old decomposed solid waste
SP-04	3 years old decomposed solid waste
SP-05	1 year old decomposed solid waste

Converted soil samples were collected from 5 different aged vegetate locations whereas the leachate samples were collected from untreated and treated (aerated) leachate pond of Matuail landfill site. The procedure followed by Mamtaz and Chowdhury (2006) was applied in this current study for soil sample collection.

Analytical Method

After collecting the decomposed solid waste, samples were dried in air and sieved as the requirements of laboratory experiment. To determine the dry density, bulk density, specific gravity, water content of solid waste samples the methods of ASTM-D2216, AATM-D2937-00, ASTM-D854-00 were used accordingly. pH was determined using the LIDA-PHS-25 pH precision meter. Each test was performed 3 times for confirming the reproducibility of experimental data.

Both the decomposed solid waste and converted soil samples were digested for chemical properties analysis using Aqua-Regia digestion method. Parameters related to heavy metals such as Fe, Cu, Cd, Cr and Ni were determined in this study. The concentration of Fe, Cu and Cd were analysed using flame emission atomic absorption spectrophotometer (AAS) (Spectra AA Varian), whereas Cr and Ni were estimated using Hach DR/4000 Spectrophotometer (Method: 8023 and 8037).

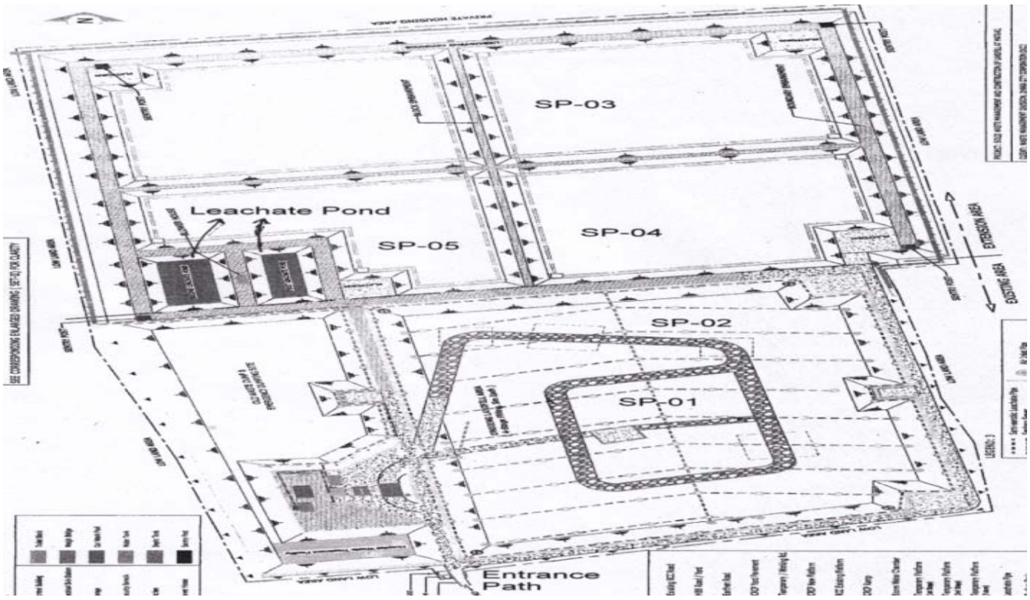

Fig. 1: Location of sampling points of solid waste at Matuail landfill site

The percentage of organic carbon in the decomposed solid waste sample was determined using the methods established by the laboratory of University of Limerick, Ireland (O'Flynn and Liston, 2011)

Leachate samples were collected from the untreated and treated (aeration) leachate ponds. Physical characteristics of leachate samples such as TS, TDS, TSS, pH and turbidity were determined following the standard methods (APHA, AWWA and WEF, 1999). Heavy metals concentration from leachate samples were analysed using AAS and Hach DR/4000 Spectrophotometer.

RESULTS AND DISCUSSIONS

Table 2 represents physical characteristics of decomposed solid waste samples with standard deviations (SD). Dry and bulk density show values less than 1 g/cm^3 indicating the presence of organics in soil samples (http://en.wikipedia.org/wiki/Bulk_density). Though the soil was found to be sandy through sieve analysis, the average specific gravity of waste samples was found 2.15 representing very low value as compared to gravel, sand, silt and clay soil (Bowels, 1997). The maximum value of porosity ranges from 57.85% to 64.55%. In addition, the soil samples were found to be slightly alkaline having the pH in between 7.68 and 8.02.

The average concentrations of Fe, Cu, Cd, Ni and Cr in decomposed solid waste and converted soil samples are presented in Fig. 2. The study reveals that heavy metals concentration in decomposed solid waste is significantly higher than that of converted soil (used for vegetation) pointing out a potential risk of heavy metals insertion into food chain. The average concentration of Fe in decomposed waste and converted soil was found to be12249 and 3411 mg/kg. Previous study conducted by Mamtaz and Chowdhury (2006) also observed a very high concentration of Fe (9600 mg/kg) in decomposed solid waste at Matuial. Though the presence of Cd was not identified, the existence of Cr was detected in this present study. While Cr for SP-01 (oldest sample) was estimated 9.15 mg/kg, the concentration was found as high as 16 mg/kg at SP-05(youngest sample). In addition, the accumulation of Ni was detected in this study showing higher concentration as compared to the observation of Mamtaz and Chowdhury (2006).

Table 2: Physical characteristics of decomposed solid waste at Matuail landfill site

Sl. No.	Parameter	Value ±SD					Average ±SD
		SP-01	SP-02	SP-03	SP-04	SP-05	
01	Dry density (g/cm^3)	0.671±0.05	0.746±0.05	0.780±0.05	0.709±0.03	0.70±0.06	0.72±0.04
02	Bulk density (g/cm^3)	0.772±0.08	0.873±0.05	0.885±0.05	0.856±0.03	0.801±0.06	0.83±0.04
03	Specific gravity (%)	2.10±0.04	2.15±0.05	2.10±0.5	2.14±0.02	2.26±0.07	2.15±0.06
04	Porosity (%)	63.23±0.3	59.40±0.2	57.85±0.12	60.0±0.15	64.55±0.2	61.0±2.78
05	Water content (%)	15.13±0.10	17.1±0.11	13.47±0.09	20.6±0.12	14.7±0.15	16.2±2.78
06	pH	7.80±0.04	7.87±0.03	7.68±0.04	7.74±0.08	8. 02±0.03	7.83±0.12

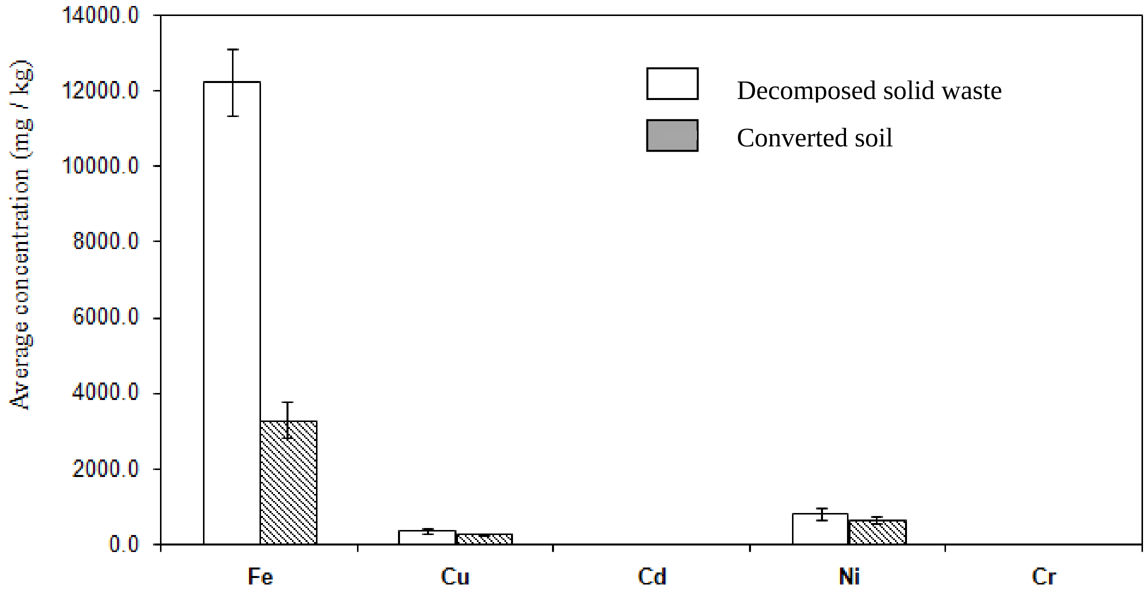

Fig. 2: Average heavy metal concentration in decomposed solid waste and converted soil sample

The study reveals that both the untreated and treated leachate ponds are safe from Cd and Cr contamination (Table 3). Average concentrations of Fe, Cu and Ni at untreated leachate pond are 25.3 mg/l, 1.5 mg/l and 4.46 mg/l respectively. The conventional treatment process fails to keep these parameters within Bangladesh standards (Table 3) leading to severe water pollution around the landfill site. This demands the pollution source identification and prevention. Though the improvement of the treatment process might be a solution, volume of solid waste at landfill site is the most effective option for sustainable solid waste management.

Table 3: Average concentration of heavy metals in leachate samples (in mg/l) with standard deviation

Sl. No.	Parameter	Leachate of Matuail Landfill site		BECR, 1997 (for inland surface water)
		Untreated Sample	Treated Sample	
01	Fe	25.3±1.75	19.11±1.33	2.0
02	Cu	1.5±0.05	0.71±0.03	0.5
03	Cd	0	0	0.5
04	Ni	4.46±0.23	2.5±0.11	1.0
05	Cr	0.36±0.02	0.31±0.01	0.5

Table 4 represents the physical characteristics of leachate samples. In this current study, all physical parameters gave similar values as observed by Mamtaz and Chowdhury (2006). The treatment of leachate was failed to keep the TDS (7178 mg/l) and TSS (1384 mg/l) below Bangladesh standard (Table 4). This aggravates the surface water pollution around the solid waste dumping site.

Table 4: Physical characteristics of leachate parameters

Sl. No.	Parameter	Present study		Previous study (Mamtaz and Chowdhury, 2006)	BECR, 1997 (for inland surface water)
		Untreated Sample	Treated Sample		
01	pH	7.87±0.14	7.73±0.12	7.96	6-9
02	Turbidity (FTU)	120±8	97±7	--	--
03	TS (mg/l)	8562±135	7889±115	9607	--
04	TDS (mg/l)	7178±171	6697±147	6133	2100
05	TSS (mg/l)	1384±23	1192±17	3474	150

From this current study, it is very clear that the existing solid waste management system at Matuail landfill site is not safe enough for the environment since the waste contains objectionable level of suspended, dissolved solids and some heavy metals that may cause severe surface water pollution. In addition, the concentration of heavy metals in vegetation area (converted soil sample) is found to be reduced significantly when comparing with decomposed solid waste sample indicating the possibility of heavy metals to get into the crops. Entrance of toxic chemicals to the food chain may prolong adverse impact on human and livestock (Ryskamp, 2010). Moreover, groundwater contamination may take place due to leaching of heavy metals unless proper lining that is hardly exercise at solid waste dumping sites in Bangladesh. Stabilization of solid waste is practiced in many countries because this process reduces not only the volume of solid waste at landfill site but also reduce the risk of environmental pollution. Contaminated soil can be stabilized by stabilizing additive. After the analysis, average percentage of organic matter in decomposed solid waste was estimated as 19.68% indicating significant quantity of organic matter for which Portland cement can be used as stabilizing additive (USACE, 1984).

CONCLUSION

In this current study leachate and decomposed of solid waste samples collected from Matuail landfill site of Dhaka City Corporations were experimented for heavy metals analysis. Investigation shows that the converted soil used for vegetation around the landfill site contain relatively less concentration of toxic elements as compared to decomposed soil samples indicating substantial quantity of heavy metals to transport to leachate as well as a high possibility to get into the food chain. The analysis also reveals that the quality of leachate sample fail to satisfy the inland surface water quality standard of Bangladesh, even it has been treated through conventional aeration process. Mitigation measure is therefore essential to prevent soil and water pollution. For a sustainable management, it is reasonable to convert solid waste to re-usable product via solid waste stabilization and solidification. Physical analysis of decomposed solid waste was therefore carried out for appropriate stabilizing additive selection and stabilization process optimization. The outcome of this current study is expected to contribute to the next phase research work of investigating the suitability of using stabilized solid waste as construction material.

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MICROBIAL FUEL CELLS A NEW SOURCE OF ENERGY FROM WASTEWATER TREATMENT

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ABSTRACT
World energy demand is increasing day by day and also wastewater treatment for sustainable development. Especially in rural areas, the energy scarcity is very high and at the same time need to build healthy environment to them by wastewater management. Most of the present energy sources are not sustainable for environment as well as for global warming. So energy should come from a source, which are available and would be sound to the environment. Renewable energy will be great source to meet these energy needs in a sustainable and environmentally sound way, which may reduces the dependency on fossils fuel and/or hydropwer. Microbial fuel cell (MFC) is a device where half reactions of microbial reduction-oxidation run in separated compartments and electron transfer goes through external circuit. Such devices allow running biological processes of water treatment and simultaneously generate electric power. In this work principles and challenges of MFC technology are described. Possibilities of application of MFC both for small- and a large scale for improving energy balance of wastewater treatment and decreasing impact of wastewater treatment on global warming are evaluated.

Key words: microbial fuel cell, renewable energy, wastewater treatment

INTRODUCTION

Energy demand is increasing day by day and in future it will need more from present condition. It is expected that world energy demand will be raise from $444\cdot10^{18}$ joules in 2003 to $594\cdot10^{18}$ joules in 2015 to $762\cdot10^{18}$ joules in 2030 (Mathuriya1 et al., 2010). In present condition energy comes to meet the requirement from different source like fossil fuel, natural gas nuclear plant etc. but these sources of energy are limited in the world and also create environmental pollution by emitting greenhouse gases which are highly responsible for global warming. So energy should come from such source which are not limited and also should friendly to the environment. Renewable energy will be great source to meet these energy needs in a sustainable and environmentally sound way, which also reduces the dependency on fossils fuel. One the other hand, to make environment sound it is needed to invest adequate resource for wastewater and water treatment infrastructure.

In view of high energy requirement for wastewater treatment, there is advocate for sustainable treatment technology that will require less energy and may produce useful products from wastewater treatment. Research has led to discovery of various technologies which seek to reduce energy consumptions by wastewater treatment plants. Microbial Fuel Cells (MFCs) is one of the new technologies to produce energy from waste water treatment system. It has been found out that wastewater treatment in MFC is a sustainable approach because there is cut of cost from aeration and it also involves production of electricity from the operation (Min et al., 2004; Zielke et al., 2006).
Aim of this work is to evaluate possibilities of MFCs application in wastewater treatment technologies both at the low and large-scale and assess the impact of such applications on emission of greenhouse gases.

MICROBIAL FUEL CELLS

The work is based on literature review of studies on research and application of MFC technology in waste and wastewater treatment areas. Also, some possibilities of its application for wastewater treatment are outlined based on basic knowledge about MFC principles and wastewater treatment processes.

Classification and working procedure of MFCs:
Microbial fuel cells have a number of potential applications. MFCs are versatile and are able to produce energy in a variety of forms. Currently, MFCs have been applied in various sectors. Fuel Cell is one of the electrochemical devices which are capable to produce electricity directly from chemical energy. Fuel cell produces energy from external fuel sources and withdrawn electron and when these electrons transferred through a close circuit its produce electricity (Barron et al., 2010). Microbial Fuel Cells (MFCs) are those which diverse chemically as bacteria that powered the cells and drawn worldwide interest as a direct electricity generation from organic material like wastewater.
A MFC is that types of devices which use bacteria to catalyze the conversion of organic material to electricity. Bacteria generate electrons and protons in anode from oxidized substances and electrons are transferred through an external circuit. Here protons diffuse through the solution to the cathode and electrons combine with protons and oxygen form water (Mathuriya1 et al., 2010).
Microbial fuel cells for energy production have both advantages and disadvantages but an operational and functional advantage over other convention electricity production is directly electricity generation from organic substances. This process has comparatively high efficiency to produce electricity from substrate energy, its work in ambient temperature. Not only that but also no need to gas treatment due to MFCs are enriched in carbon dioxide that’s why has no useful energy content. Other advantages are no need to provide energy for aeration because cathode already aerated. This system is suitable for that place where electricity scarcity is high. The main disadvantages are its installation cost is higher than others; efficiency is lower than hydrogen fuel cells. But MFCs system is advantageous due to work as a wastewater treatment in same time during energy production.
In wastewater treatment system MFCs can convert 1 kg of chemical oxygen demand (COD) to 4 kWh, but with anaerobic digestion 1 kg of COD could be converted to roughly 1 kWh (Zhao et al. 2005). The average power density of MFCs is about 40 W/m3 (Logan B.E., 2008).
During consideration as a wastewater treatment system, the percent COD removal is very low if it is compared with treatment performed by USAB reactors. By degreasing the flow rate to 0.18 m^3/min, the percent COD removal is increased by 60%. This represents the best compromise between treatment efficiency and energy recovery (57% Columbic efficiency), but implies a HRT of approximately 102 h. In contrary with UASB reactors operating at loading rates one thousand-fold higher (12-20 kg COD $m^{-3}d^{-1}$ compared to 0.028 kg COD $m^{-3}d^{-1}$), HRTs as low as 4-8 h can be used (Lorenzo et al., 2009).

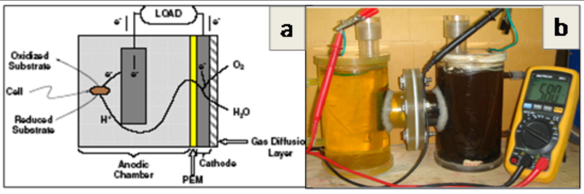

Figure 1. (a) single chamber MFC (Mohan et al. 2007); (b) dual chambered MFC used in the experiments (Mohan et al. 2007)

Working System in MFCs:

Table 1. Range, mean and ratio of BOD Biosensor and BOD 5 for different effluents (CPCB 2005).

	Effluent	BOD Biosensor	BOD 5	Ratio (Biosensor/BOD 5)
Dairy Untreated effluent	Min	626	665	0.8
	Max	3605	3670	1.3
	Mean	1414	1406	0.99
Dairy Treated effluent	Min	9	8	1.1
	Max	49	53	1.3
	Mean	33.1	30.3	1.1
Brewery Untreated effluent	Min	316	300	0.9
	Max	1880	1820	1.2
	Mean	781.3	760.4	1.0

Microbial Fuel Cells comprised with an anode and a cathode, these are separated by a proton exchange membrane (PEM). In anode compartment electron donors are oxidized by bacteria and produce free electrons and protons and bacteria transfer's electrons to anode which are insoluble electron acceptor. After deposition of electrons on anode these transfer to cathode through an external circuit (electricity production) and protons travel through wastewater and PEM. At the end protons and electrons travel to cathode where oxygen reduces to produce water (Fig.1).

Electron Transfer system:

In microbial fuel cells a situation occurs where bacteria can feed food (Agricultural or industrial Waste, human sewage waste). Bacteria create oxygen lacking situation which helpful for them to grow in slow, oxygen act as electron acceptor. Electrons from sugars, fats, proteins or other bio available molecules are taken by bacteria and transfers through a metabolic pathway in a way that electron may use as electricity supply in a cell. Here oxygen act as driving force within this system. So, without oxygen electron transfers rate will reduce and electricity production by MFCs will also reduces consequently. Although cells always use substrate molecules in waste stream in the absence of oxygen but energy receive is greatly reduced (Lovely D., 2011).

Different Compartment systems:

Single compartment MFCs system is simple and cost effective system where only an anodic chamber where no need for aeration in cathodic chamber because cathode is placed outside and aerated normally but this system is difficult to maintenance. Electrons produce in anode chamber is transfers through circuit to cathode placed outside; figure 2a shows a schematic diagram of single compartment MFCs system. Anode is made of Carbon paper.

One the other hand two-compartment MFCs is not so simple in operation and also for constructions its need skill operation system and it still in laboratory for exhibition. Some time anode and cathode are separated by PEM or sometimes two separated chamber of anode and cathode and connected by salt bridge to allow proton transfer from anode chamber to cathode chamber. This system is suitable for long term energy sources. There are different shapes and sizes of two compartment system figure 2b is one of them. For more energy production by this system new research is going on and for electricity supply in a large scale multi compartment system is suitable and it is in under investigation. Figure 2c shows a typical multi compartment MFC (Zhuwei et al., 2007).

APPLICATION

Biosensors

Biochemical parameters like biological oxygen demand (BOD) is very critical in pollutant analysis. The conventional method for measuring BOD takes 5 days to complete, which is quite a long time. It is demonstrated in studies that the microbial fuel cell can be used to measure BOD values either by reading the

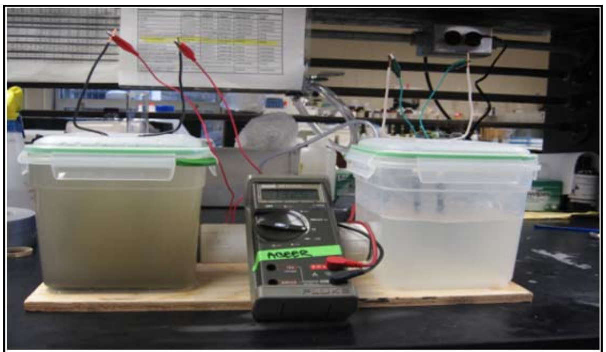

Figure 3: A lab scale MFC for wastewater treatment

maximum current or by calculating the coulomb. In MFC system, an increase of organic material content causes immediate increase of energy production by the MFC, therefore by continuous pumping wastewater through cathodic chamber of MFC and measuring energy production, BOD of wastewater can be determined. With the MFC-type biosensor, measurement of BOD is made possible owing to the relationship between the Coulombic yield of the MFC and the strength of the wastewater.

Studies have found out that microbial fuel cell-type biosensor can be used to determine BOD concentration in wastewater with the advantage of long stability compared with BOD sensors based on DO monitoring that has a limited stability due to the nature of a DO probe. Kim et al (2003) reveal that a biosensor which used mediator-less microbial fuel cell could have a lifespan of about five years. In another study on MFC based biosensor for BOD test, Lorenzo et al (2009) experimented that a single-chamber MFC biosensor could be used to measure BOD within 40 minutes. This application of MFCs therefore reduces cost of money and time of determining BOD in a WWTP. One study showed no significant difference between the conventional BOD-5 test and the BOD biosensors in terms of results meanwhile the latter could be done within a short time (Table 1). Since the main purpose of MFC in this case is neither wastewater treatment nor electricity production, small volume cheap units can be used. Such units can be installed in different places of WWTP systems and allow for monitoring loading to and performance of WTP to improve treatment quality and decrease unnecessary energy consumption.

Lab-scale research on MFC technology

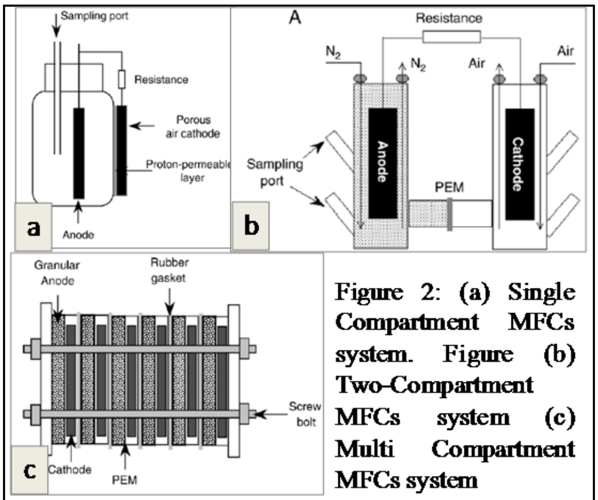

Figure 2: (a) Single Compartment MFCs system. Figure (b) Two-Compartment MFCs system (c) Multi Compartment MFCs system

Figure 4: Building simple MFC for lightening of a village in Tanzania (Grifantini, K. ,2008)

Various researches have been on carried on laboratory scale on microbial fuel cells. Studies have targeted on strategies of improving the efficiency of power generation and wastewater treatment capacity. Studies have shown that MFCs are capable of generating electrical power of 309 mW m^{-2}, which quite a good quantity of energy for use in any small application (Min et al., 2004). Moreover, Catal et al. (2008) demonstrated that MFC could generate power of density ranging between 1240 and 2770 mWm^{-2} using different kinds of carbon substrates. Since substrate are been degraded by the microorganisms, obviously removal of COD and BOD from the wastewater is made possible. MFCs for treatment of wastewater with energy recovery have been studied in detailed (Fig. 3). Ghangrekar and Shinde recorded COD and BOD removal efficiency of 90.86% and 90.67%, respectively. Kim et al. (2008) reported that MFCs can yield 50-90% less excess sludge. This will eventually lead to the reduction of cost of sludge handling. Just this, Emefcy an Israeli company has develop a process based on MFCs which can reduce the total cost of wastewater treatment by 30 to 40 percent by eliminating spending on energy, and also reduces the amount of sludge by up to 80 percent (Kalman M., 2011).

Small-scale application for WWT and power generation

In the MFCs bacteria oxidize substrates in wastewater and produce electrons and protons in the anode chamber of MFC. The electrons in the anode are conveyed to a cathode by external circuit and protons are transferred through the membrane internally producing potential difference is between anode and cathode chamber. MFCs are capable of generating electrical power of 309 mWm^{-2}, which quite a good quantity of energy for use in any small application (Min et al., 2004). Many communities in developing countries do not have access to from-the-grid electricity.

Moreover, these communities have problem with waste management with its accompanied health implications. The composition of waste in such areas is almost 100% biodegradable. The simple MFC technology has been employed in some rural areas in Africa for instance Uganda to produce power for lightening and in so doing managing of waste. These communities have very low standard of living and do not require so much power. With these projects, it does not require much start-up cost and therefore very affordable. In MFCs membranes are the most costly part of the system. Meanwhile in such projects soil layers can be used as membrane for transporting hydrogen ion from the anaerobic anode part to the aerobic cathode. Energy produced depended much on the electrode area and was enough to power LED-lamp (Fig. 4)

In future, wastewater can be used as an energy source in MFCs. In this case either surface- or air-cathode can be used, which does not require any aeration. In contrast, energy for lighting or charging electronic devices will be produced. Reduction of greenhouse gas emissions can be expected due to the fact that other sources of energy (fossil fuels) for electricity production would be used otherwise. Also, since organic material is destructed through aerobic pathway, emission of methane gas from wastewater treatment is much lower.

Application for a large-scale WWT

Since the technology of MFCs is new and still in development, currently, there are no applications of MFCs in large-scale WWTPs. There is only one pilot plant with total volume of around 1 m^3, where brewery wastewater is treated (MFC, 2011).

Proton exchange membranes, which are often used in MFC design, have high cost, which is one of the limitations of MFC use. It was reported that if materials which are used in laboratory-scale experiments were used for constructing full-scale WWTP, capital cost of such plant would be orders of magnitude higher than those of conventional WWTPs (Rozendal et al., 2008). That is why currently, the biggest interest is integration of MFC into existing biological processes of WWTP to improve energy efficiency and decrease greenhouse gas emissions.

One of the possibilities studied by Liu et al. (2011) is a partial removal of organics by use of MFC submerged into aeration basin of activated sludge process. In the studied system wastewater, which has low dissolved oxygen concentration and high BOD is supplied to a MFC unit, where part of organics is removed and the effluent is further treated by heterotrophic bacteria present in aeration basin. Membrane-less unit was used, where cathode chamber of MFC was separated from the main volume of aeration basin by non-woven cloth, which results in a low cost of MFC unit. 18.7% of COD from wastewater was removed in MFC unit, which occupied only 12% of reactor volume. At the same time electricity was produced with the maximum power production of $2.34 W/m^3$.

Since requirements for wastewater treatment include also removal of nutrients, several studies have been made on nitrogen compounds removal with MFC technologies. According to theoretical principles of fuel cells, positive ions are transferred from anode chamber to cathode chamber. Ammonium, which is present in municipal wastewater, should also be transferred together with hydrogen ions and reaching cathode be transferred to protons and ammonia. It was proved (Kim et al., 2008) that ammonium transfer and conversion to ammonia is the main mechanism of ammonium removal.

Large part of WWTP greenhouse gases emission comes from handling of sludge. The main part of methane is produced from sludge in anaerobic digestion step and is collected for energy recovery. However, methanogenic processes start already in primary sedimentation and especially in a sludge thickener. In order to reduce production of methane, which is emitted to atmosphere, anode, proton-exchange membrane and air cathode could be installed in for example sludge thickener. That would create more oxidizing conditions in thickener (higher redox potential) and prevent anaerobic oxidation to happen.

The same approach could be applied for sludge storage. In order to assure sludge sanitization, sludge has to be stored for at least 1 year before it can be used in agriculture as a fertilizer. During storage of sludge lower layers have anaerobic conditions which cause production of methane and N_2O. Preliminary estimations (Flodman A., 2002) showed that if all sewage sludge in Sweden is stored during one year, then the emission could be about 1100 tons of N_2O per year, corresponding to 5% of the total Swedish N_2O emissions. The top layer of sludge contacts with air so aerobic conditions prevail. Installing bottom and lower electrode into a sludge cake allow “pumping” protons to the bottom of sludge and highering redox potential. In that case, emissions of greenhouse gases from the storage could be lowered.

CONCLUSIONS

Microbial fuel cells technology is a promising tool for improving energy balance of wastewater treatment. However, based on literature review it can be concluded that it is not ready for application in a large-scale wastewater treatment facileties, mainly because of high investment cost, long hydraulic retention time which increases space requirement and unsatisfactory treatment efficiency. Further research on design and operation of MFCs can lead to implementing it as substitutes for parts of wastewater treatment process and by that moving closer to energy-positive wastewater treatment with little greenhouse gas emissions.

With a current level of knowledge simple MFCs can already now be applied for simultaneous wastewater treatment and energy generation in areas where no grid electricity is available. This small amount of electricity can really improve people’s level of living and at least a little improve situation with wastewater treatment in the area.

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EFFECT OF DIFFERENT FACTORS ON BUILDING MATERIALS EMISSION IN INDOOR AIR

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ABSTRACT
Different type of pollutants emitted from the different building materials. These types of materials emission are influenced by the different type of factors. Some materials have specific dominating factors. Sometimes building materials shows the extreme emission with different combination. Temperature has little influence on the building materials whether expressed in two important terms sensory or chemical. The most effective one is humidity which has found significant impact on the waterborne materials such as floor varnish, wall paint etc. Different environmental factor also co-related with the coefficient for inside material's diffusion and evaporation. Air exchange rate is directly proportional with the material surface emission rate but increase of air exchange rate can reduce the pollutant concentration. New materials always emitted higher amount of Volatile organic compounds (VOCs) and aldehydes at the beginning time of installation. This paper summarized the factors which have an effect on material's emitted pollutants. For a sustainable building construction, those factors are always keep in mind to provide a good indoor air quality.

Keywords: Humidity, temperature, weather, air velocity, air exchange rate, time.

INTRODUCTION

The indoor air quality is a matter of great concern of last couple of decades. Within last two decades, around 250 publications addressing the chemical reaction in indoor air [5]. It is also a topic, required good understanding about the selecting materials, usages, fitting or fixing, environment impact etc. Many research are going on this sector and now develop a idea how indoor air is affected by the building materials emission, and this emission influenced by the different factors such as humidity, temperature, weather condition, air velocity, air exchange rate, time, building structure as well as geographic location. Source of indoor air pollutants is much more complex than the outdoor air. Science proves that the quality of the indoor air quality is closely related with our health. The three pollution sources like building, decoration, building materials, furniture have over 300 kinds of volatile compounds. Among them few are very important. They are formaldehyde, VOC, ammonia, radon and the radiation from stone. These five kind of pollutants are called the main five healthy killers. However, there are still lacks of knowledge on this section. Still researcher need to give proper solution for upcoming generation.

WEATHER IMPACT

Normally VOCs concentration in the cold season are much higher than the warm season. Many organizations have been found out the relation between the indoor air pollutants and the weather impact. Investigation on 12 German home shows pollutants concentration in winter at least 2 or 3 time more than in summer [1]. In Leipzig, Germany, study showed the concentration difference in winter which are much higher than compare to summer. This is may be the reason of closing window in winter. Normally, the European countries are much more aware about the building air-tightness. The buildings in Europe have lower opportunity for passive ventilation because of outside cold environment. Building's air-tightness another possible reason too. On the other hand, some aldehydes have higher concentration in summer compare to winter. It is totally opposite compare to VOCs concentration. The reason is, when the temperature is high, it increase the volatilization from the source. Some research papers show the result of some European countries. In English home, higher concentration was measured in autumn[13]. In Denmark, it shows higher concentration from spring to autumn during the first year of completion [1]. Some alkenes, terpenes, butanol and butyl concentration are also higher in warm season. In Finland, the concentration of newly building also had checked and found the maximum concentration in the autumn [14]. This is may be the reason of highly temperature and lack of ventilation. Normally in autumn to spring the outside weather is not so warm that's why the ventilation system like the winter but the inside temperature is not like in winter. Inside temperature is much more comparing to winter's home. This two criteria may be the reason for increasing the inside formaldehyde concentration.

AIR VELOCITY

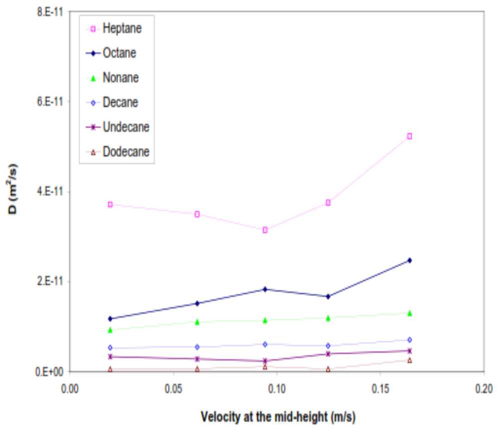
Environmental factor such as air velocity have an impact on VOCs emission in indoor air. Lot of researches are still going on this topic. In dynamic chamber test, it is a mass transfer model and having two mechanisms: diffusion which contain inside the material and other is evaporation from the material's surface. The air concentrations depend on the diffusion and evaporation coefficient.

From the mass transfer equation [17]:

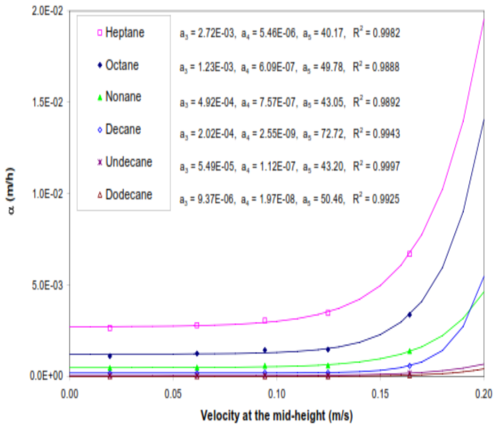
$$\frac{C-C1}{Cx-C1} = 1 - \sum_{n=1}^{\infty} 2\gamma \exp(-\beta^2 Dt/\, l^2)\, cos\,(\beta x/l) \Big/ [(\beta^2 +\, \gamma^2 + \gamma) cos(\beta)] \quad \text{--------- (1)}$$

Where,

C	= Chemical concentration in the specimen (mg/m^3),
C1	= initial concentration,
C_x	= concentration equilibrium with the vapor pressure in the atmosphere,
D	= Diffusion coefficient (m^2/s),
l	= Specimen thickness,
$\propto$	= evaporation concentration coefficient (m/h).
t	= time,
x	= distance upwards from the substrate.



(a)



(b)

Fig 1: a) Velocity vs. Diffusion coefficient. b) Velocity vs. evaporation coefficient [17]

These two coefficients are depending on indoor air velocity. In this figure shows the different type of alkenes behavior. Their diffusion coefficient is increase with increase of air velocity (Fig 1a). But diffusion coefficient is not so strong function of air velocity. It is very negligible. But after the 0.10 m/s the diffusion rate is much higher than before. In the Fig 1b, it can easily find out the velocity impact on the evaporation concentration coefficient. After the 0.10 m/s the evaporation concentration is going so first. The graph shows the power law relationship between "v" and "$\propto$". The equation suggest the relation

$$\propto = a_2 \text{ EXP } (a_3 * v) + a_1 \qquad \text{-----------(2)}$$

Where,

a_1, a_2, a_3 correlation coefficient

$\propto$--evaporation concentration coefficient

v -- air velocity at the mid height of the inner chamber (m/s)

HUMIDITY

Emission from the building materials also influenced by the humidity that's why it is recommend to consider the humidity factor when design the ventilation system of a building. Humidity is responsible to stay pollutants long time in the air. Studies indicate that low relative humidity is responsible to increase the eye irritation symptoms. From ASHRAE, suggested the acceptable humidity is within the range 30% to 60% in both summer and winter season. But it is better to keep the humidity less than 50% because if the humidity is more than 60% than there are a chance for microorganisms growth and if humidity more than 50% than it is quite difficult to control dust. If the humidity rate is high its means water content in the air is high which make an effect on the building surface, furniture (wood fittings), leather fittings etc.

TEMPERATURE

Temperature is another important factor. It has a bad impact on the indoor air. When temperature is increase, that means chemical reaction also increase. So temperature is proportional to reaction. A strong impact on material emission was found by Andersen et al., 1975. He found that within the range between (14 - 35)° the formaldehyde emission rate were going up double for every 7°C of temperature changed [3]. Temperature has directly control by the humidity. If temperature increases the relative humidity also increase because warm air contains much more humidity. Temperature and humidity have a good impact on the building materials emission. Different types of combination are use to show the actual things for different building materials such as carpet, PVC flooring, sealant, wall paint, floor varnish. These five types of building materials are always found in the building. The materials were placed in 9 Chamber for Laboratory Investigations of Material, Pollution and Air quality (CLIMPAQ) based on the different combination of different temperature and different humidity. The CLIMPAQ were reconditioned with the clean air with temperature23°C, humidity 50% and finally released from the diffusers. The principle had already discussed by Fang [7]. Different types of chemical were emission from the different building materials. Their behaviors are also different in different temperature and humidity. For that reasons, some common VOCs are selected. For carpet, available data about 2-ethyl-1-hexanol, Nonanal, 4-phenylcyclohexen, Decanal in different temperature and humidity combination. For PVC flooring 4-ethyl-toluene, 2-ethyl-1-hexanol, 2(2-butoxyethoxy) ethanol, Undecane, 1, 2, 4 - tri methyl benzene, 4-methyl-2-pentanol, Toluene, Phenol were considered. Acetone, Hexane, 3, 7 dimethyl-1-octanol were considered for the sealant. 1 -methyl-2-pyrrolidion, Butylacetat, 2(2-butoxyethoxy) ethanol, 2, (2-ethoxyethoxy) ethanol, and 2- butoxy-ethanol were considered for the floor varnish. 1, 2 - propandiol, 2-(2-butoxyethoxy)-ethanol, texanol, Undecane were consider for the wall paint.

Table 1: Temperature and humidity effect on the building material emission [7].

Chemical emission from 5 different building materials of different temperature and relative humidity combination. ($\mu g/m^2$*h).			
Temperature	18°		
R.H	30%	50%	70%
Carpet	8.561	10.3	18.45
PVC	37.23	57.24	55.39
Sealant	57.56	56.83	58.29
Floor Varnish	198.31	604.33	909.76
Wall Paint	394.63	1278.8	1922.7
Temperature	23°		
Carpet	8.897	13.834	22.27
PVC	57.84	53.89	67.66
Sealant	73.36	60.45	68.13
Floor Varnish	494.32	1062.4	2030.2
Wall Paint	442.09	1259.3	2884.3
Temperature	28°		
Carpet	13.945	23.5	24.881
PVC	76.069	74.82	86.93
Sealant	86.86	75.78	195.52
Floor Varnish	757.7	1657.5	3878
Wall Paint	938.25	1491.1	2575.2

This table, 1 shows different concentration of pollutants emission from the building materials. Analyzing the result, the maximum emission were observed in maximum temperature with maximum humidity. The emission from the carpet, the effect of humidity and temperature is not so high. But, for the PVC temperature have a huge impact. 5° increase the temperature within the same humidity the emission from the materials was almost double. Comparing the effect of humidity, it was not so effective like temperature. The same effect of temperature also found in sealant. Humidity variation was not so higher compare the temperature. Around 25% of emission increase due to the increase of the 5° temperature. But the opposite condition is Floor varnish and wall paint. There emission pollutants were increase highly respective to humidity. In winter, inside temperature are higher than outdoor, so there is a chance to absorb more water inside the air which increases the humidity inside the room. At that time the wall paint and the floor varnish that times are play the main emission pollutant materials. Nordic countries having cold climate. So the impact of humidity has a long term impact on the materials emission. There is a relation between humidity and the temperature. Both are proportional to each other. At the last column the maximum temperature and maximum humidity, and that time the emission from the materials were also maximum. The emission rate directly proportional with the vapor pressure. From the gas law pressure, pressure is proportional with the temperature. Research result shows that the emission from the material increase with increase the temperature. Humidity also related with the temperature. Increase temperature means increase humidity and increase humidity are responsible to increase the emission from the building materials specially the wall paint and floor varnish. Before starting the test all the materials were well vented for 21 days that's means the materials also subjected by air velocity where evaporation coefficient and the diffusion coefficient plays an important role. At first the emission control by the evaporation coefficient and 3 weeks later VOCs emission were going down and the emission were controlled by the diffusion. And from the definition of the diffusion, it is dependent on the temperature. So increase temperature means the material's inside energy is increase to make vaporized VOCs from the surface. Some research papers show the impact of humidity on the VOC emission specially the waterborne floor varnish and the wall paint. The increase moisture in the air always leads to extract VOCs from the material surfaces which indicate increase emission. The emission behavior of VOC is not same for all the materials. It depends on the different type of building materials. The different type of emission are possible because of their different combination. From this study it can conclude that the material emission are depending on the temperature as well as the humidity.

AIR EXCHANGE RATE

Building material realize lot of pollutants inside the room. If the building is airtight and without having proper air exchange facility or air purifying technique, it is quite difficult to keep a good indoor air quality. This section focus on the emission from the building materials and their impact on indoor air. The emission rate is very high at the beginning human occupancy. People make close the entire window before leaving the house for a job. After having 10 hour without ventilation, the inside air condition are growing so poor. VOCs and CO are the two important pollutants in indoor air. To control such type of fact, it is a better solution to control the source or provide a good indoor ventilation system. But this ventilation system is directly related with the energy consumption. To concern the fact, it's a demand of modern day to provide maximum ventilation facilities within the low energy building criteria and other way to control the source emission. It is the most effective solution. Some study conclude that the impact of ventilation on indoor pollutants also depend on the building operation, maintenance, source strengths, process of determining VOCs or other pollutants.

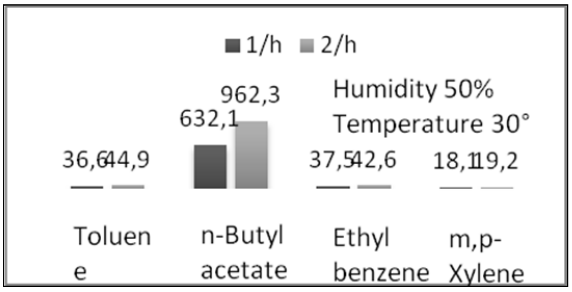
The VOCs and other pollutants should be control by source control measure and adequate ventilation in office buildings. Conditioning ventilation air consumes considerable energy to keep a good indoor air. But now a day, new construction practices have already developed the solution where give focus on maintaining adequate good indoor air. Some papers show the mathematical figure about the air exchange impact. A wooden floor has already tested and it shows the difference. "Increasing air exchange rate from 1 to 2 h^{-1} the VOC concentration decreasing 9-40% and the VOC surface emission rate is increased almost 6-98%" [4].

The previous part have already discussed about the humidity impact on the VOCs concentration. This four important VOCs, the pollutant concentration going down when air exchange rate is 2/h instead of 1/h. Toluene, n-butyl acetate, ethyl benzene and m,p-xylene equilibrium Concentration decreased respectively 32 - 47%, 32 - 33%, 38 - 43%, 46 - 59%. The data in table 2, shows the effect of RH. When RH is 50%, the impact of air exchange rate is lower than RH is 80%. Normally higher RH shows the higher pollutant emission in the indoor air, but higher range of air exchange rate minimizes the pollutant concentration. Higher RH and higher air exchange rate could increase the emission rate from the materials surface but the pollutant concentration going down because of increase of air exchange rate. Higher air exchange rate always dominate criteria for reduction concentration of VOCs in indoor building. But this air exchange rate is not satisfied the low energy building criteria.

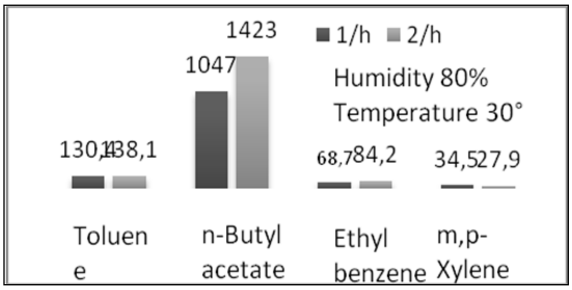
Table 2: Impact of air exchange rate on VOC concentration in Indoor Air [4].

VOC	RH (%)	50	50	80	80
	ACH (H-1)	1	2	1	2
	TEMPERATURE	30	30	30	30
TOLUENE	C_{INT}	262	125	306	164
	C_{EQ}	19.4	11.9	69.1	36.6
	E_{INT}	685.8	725.7	694	845
	E_{EQ}	36.6	44.9	130.4	138.1
N-BUTYL ACETATE	C_{INT}	2280	1060	2650	1216
	C_{EQ}	335	225	555	377
	E_{INT}	5198	6004	6120	7043
	E_{EQ}	632.1	962.3	1047	1423
ETHYLBENZENE	C_{INT}	49	24	69.7	35.1
	C_{EQ}	19.9	11.3	36.4	22.3
	E_{INT}	122.9	161.6	144.2	182
	E_{EQ}	37.5	42.6	68.7	84.2
M,P-XYLENE	C_{INT}	20.8	10.4	27.6	14.7
	C_{EQ}	9.6	5.1	18.3	7.4
	E_{INT}	42.7	50.7	55.6	72.4
	E_{EQ}	18.1	19.2	34.5	27.9

** C_{INT} , C_{EQ} Initial & equilibrium concentration(μg/m3).
E_{INT} , E_{EQ} Initial & equilibrium SER (μg/m2*h).



(a)



(b)

Figure 2: Air exchange impact on material SERs (a) Constant temperature & Humidity 50%), (b) Constant temperature& Humidity 80% [4].

These two graphs (Fig 2a, 2b) are very clear. In the (Fig 2a, 2b) shows the impact of air exchange on surface emission rate. According the graph, when increasing the air exchange rate from 1/h to 2/h than the SER also increase. The equilibrium SER of Toluene, n-butyl acetate, ethyl benzene and m,p-xylene also increase respectively 5 - 22%, 36 -52%, 13- 22%, maximum 6%. The data shows the effect of RH. When RH 50%, the surface emission rate SER is lower comparing with RH 80%. And it is because of humidity. More humidity means more chance to more pollutant emission. When increase the air exchange rate than the surface emission rate also increase because of more chance to expose the object. So increase the air exchange rate increase the SER which reduce the VOCs concentration inside the material. The concentration of pollutants is always higher at the beginning time of occupancy. With passing time, the emissions rates are going down. So increasing SER are also helps to reach a steady state VOCs concentration too. When Temperature is increase, the emission pollutants also increase but if increasing air exchange rate 2/h instead of 1/h than the pollutants reduction rate is much higher. The temperature and humidity have a higher impact on indoor air quality but if provide a good indoor air quality (Higher humidity and higher temperature) than increasing the air exchange rate will be the effective solution.

TIME

Volatile organic compounds (VOCs), Ammonia (NH_3), Formaldehyde (HCHO) emissions from the indoor materials depend on the duration of the material's exposure. Most of the time, the intensity of emission depend on the material age, character, material behavior, material inside chemistry. For the VOCs, some common sequences are observed. Some VOCs emissions are decreasing from high initial concentration to nearly zero level. Sometime initially the emissions from the materials are high. After a few months, it reached the level of constant emission. Sometimes the reverse things also happened. The emission level is going increasing from zero to peak after several hour of application or manufacture. Some organic compounds have different combination that can be the reason of different emission behavior of different time. Some material surface is dry and some of the wetly. That's could be the reason to emit a group of dominant VOCs at different stage of product as well as the concentration of VOCs. Considering the upper factors, emission can be divided into few groups such as Immediate emission (within 12 hour after manufacture or install), mid emission (First 14 days), late emission (within 3 month), long time emission or constant emission (More than three month).

CONCLUSION

This study, focused on temperature, relative humidity, air velocity, air exchange rate, weather condition, time duration and their impact on the material's emission. Impact of temperature had a positive effect on VOCs and pollutant concentration. Relative humidity had aggressive impact such type of waterborne materials. Low air exchange rate strongly support to accumulate volatile substance in indoor air and responsible for high formaldehyde level. The enhancement effect of air exchange rate was much weaker than RH and temperature. The study shows the linear correlation between air velocity and evaporation coefficient which had higher impact on material SERs compare with the diffusion coefficient. Material selection and increased ventilation are generally the common practice to reduce the pollutants but increased ventilation increase the energy consumption. Sometimes it does not satisfy the low energy building criteria. Furthermore, all these factors and materials selection should be consider for sustainable buildings.

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WATER SUPPLY AND SANITATION'S ECONOMIC IMPACTS AND FINANCING: ASIA AND BANGLADESH PERSPECTIVE

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ABSTRACT

Sanitation is a neglected aspect of development in countries where spending is limited, and where many other priorities crowd the agenda. Sanitation coverage has increased gradually as economic growth has spread to Asia's poorer countries as well as Bangladesh. However, hundreds of millions of people in the region still lack access to improved sanitation, which is seen more as a result, rather than a cause, of economic growth. Few governments and households identify poor sanitation as an impediment to economic growth. Water supply, sanitation and hygiene are expensive interventions which require careful financial planning. Cost comprises both the initial investment costs and the long term costs of maintenance and operations as well as auxiliary cost such as education, promotion, surveillance, regulation and management. While these costs appear high the benefits are often significantly higher. This paper analyses the health, water, environmental impacts associated in poor sanitation in Asia and Bangladesh. By analysing the economic impacts of poor sanitation, and the potential gains from improved sanitation, this study provides important evidence to support further investments and financing in water supply and sanitation. It also provides some factual data on costs of water supply and sanitation systems. This study based on evidence from other investigations, surveys and databases. The impact measurement reported in this paper focuses mainly on sanitation (human excreta management and related hygiene practices). The measurement of water resources impact included release of gray water to water bodies, and the measurement of environmental impact included poor solid waste management.

INTRODUCTION

Asian nations are on a development path that is lifting large numbers of people out of poverty and improving access to goods and services that improve quality of life. However, an economic development model that prioritizes economic growth risks ignoring environmental degradation, which affects health and resource productivity. Modest government and household budgets generally neglect services needed by low-income groups and those with a limited political voice. Water supply to poorer people and most importantly sanitation is one such neglected aspect of development. In countries where the public purse is severely limited and population needs seemingly boundless, sanitation is not deemed attractive or important enough to gain the attention of politicians or journalists. It is often seen as a 'private matter' to be handled by the household or local community. Also, institutionally, sanitation and water supply is sidelined by lack of clear ministerial responsibilities. A study in Bangladesh showed that both men and women in slums indicated that access to safe drinking water is their most important problem, as much time and money is invested in fetching drinking water. On average they pay TK 1 for 18 litres of water while better of users linked to the city's piped water supply received 280 litres of water for TK 1 (Danida, 1997) .Water is an economic and social good, and its service has to be paid for. Tariffs are the most used mechanism to cover the operation and maintenance cost and recovers all or part of the investment cost. More and more users are willing to pay for water, provided they get a quality service and provide the expected benefits (Visscher, 1997). If sanitation is to become a higher priority for governments and households, evidence is needed that measures its socio-economic importance and ties it to other Millennium Development Goal's (MDG), including gender equality, the reduction of hunger and poverty, the improvement of child health, access to safe drinking water and slum-dwellers' quality of life.

IMPACTS EVALUATION

Poor sanitation has many actual or potentially negative impacts on populations and national economies. The study focuses on five impacts because of their importance and/or amenability to analysis using credible information and data sources:
<>. Health Impacts
<>. Water Resource Impacts
<>. Environmental Impacts (focusing on the outdoor environment)
<>. Other welfare impacts (focusing on preference for latrine type)
The estimated economic losses of these impacts include additional expenditures, income or productivity losses, and the value of premature death associated with poor sanitation. Non-pecuniary welfare impacts were assessed, but not quantified in monetary units.

Health Impacts
Poor sanitation causes substantial illness and premature death, especially in younger age groups. Figure 1 show the estimated number of episodes and deaths attributed to poor sanitation for selected diseases in the three countries from East Asia and one country from South Asia, specifically Bangladesh. I selected these four countries on the basis of their GDP and other economic condition. Of the diseases included, diarrhoea related diseases account for 80% of episodes and 48% of premature deaths.
During the International Drinking Water Supply and Sanitation (IDWSS) decade (1981-1990) water and excreta related disease remained the major cause of mortality and morbidity in Bangladesh (Rashid and Rahman, 1994). From 122 deaths for every 1000 live births in 1981.In 1990 it came down to 110.Still the percentage is about 6%-7.5%.

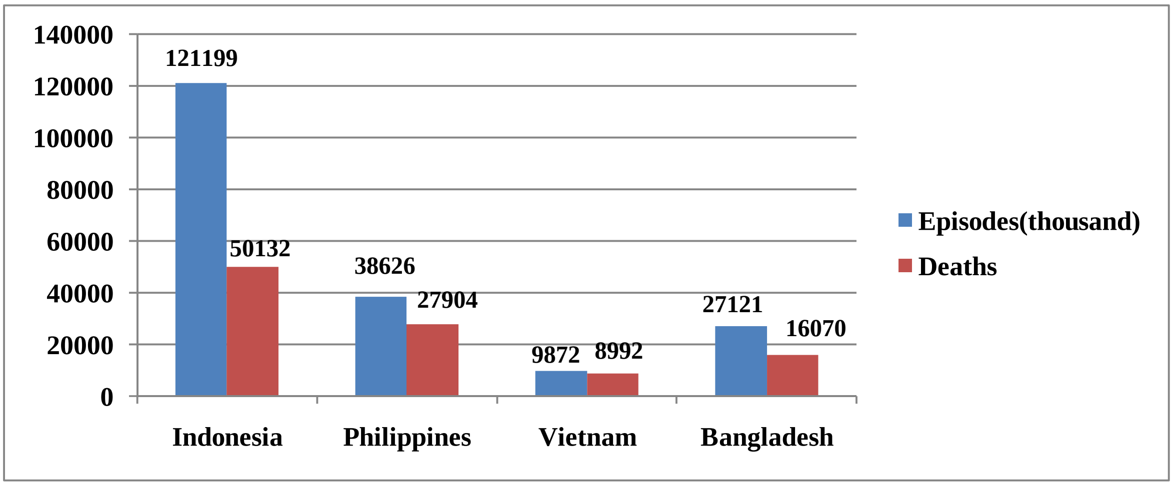

Fig. 1 Total annual disease episodes and deaths attributed to poor sanitation

Diseases resulting from poor sanitation impact expenditure patterns, productivity and the income of households, governments, and enterprises. Figure 2 shows the quantified economic impacts of selected diseases. It mainly shows the annual per capita health-related economic costs. The major contributor to economic cost is premature death, mainly of children under 5. Premature death is valued as the individual's discounted sum of future earnings, which is called the 'human capital approach' (HCA).

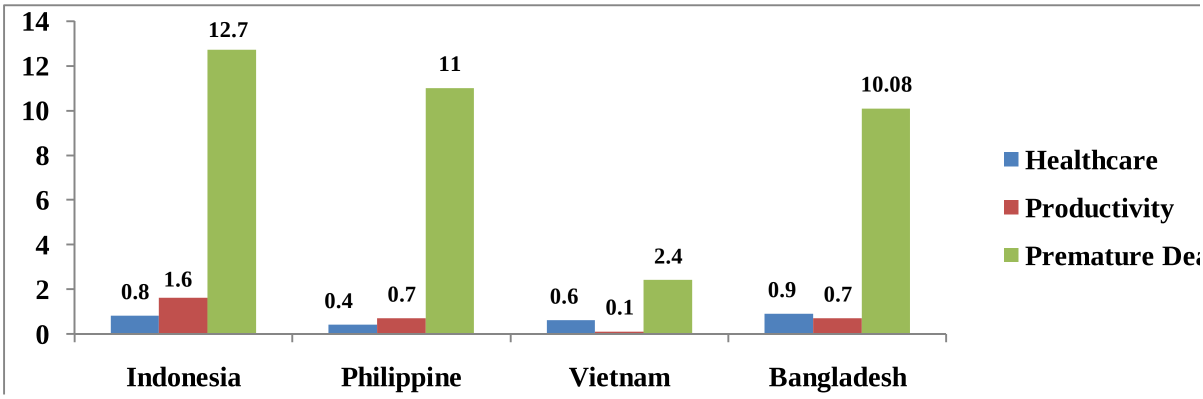

Fig. 2 Annual per capita health related economic costs of poor sanitation (US$)

Sanitation programs implemented alone have been found to reduce disease rates by an average 32%, while hygiene programs have been found to reduce disease incidence by 45%.

Water Impacts

Households are known to use one or more of several mitigation strategies when local water sources are polluted. The price of water per cubic meter from different sources is presented in Table 1. The ranges reflect rural-urban differences. For many households, especially in urban areas, pipelines supply water, which is usually purchased on a metered basis. This is generally the preferred option, as it costs less than other mitigation options such as bottled water or water sold by vendors. Piped water is most common in the Philippines (89% of households). Indonesia has the highest rate of vendor-supplied or bottled drinking water (5.2% of households). In all countries, rainwater harvesting is common in the rainy season and reduces the need for buying water. A significant proportion of households are reported to treat their water before drinking (from 44% in the Philippines to 90% in Indonesia). This adds considerably to the cost of water for drinking purposes. Many households that purchase water still treat it for drinking, which suggests the water is, or is perceived to be, not directly potable.

Table 1. Unit prices of alternative water sources, and proportion of households treating water

Country	Piped from Plant	Vendors	Bottled	Home Bottled	Household treatment (%)
Indonesia	US$ 0.17	US$ 5.4	US$ 53	US$ 21.3	90%
Philippine	US$ 0.20-0.33	US$ 1.0-1.6	US$ 326	US$ 6.2	44%
Vietnam	US$ 0.155-0.50	-	-	US$ 5.0-8.0	30%
Bangladesh	US$ 0.12	US$ 3.8	-	US$ 7.0	55%

Figure 3 represents the annual per capita water-related economic costs of poor sanitation. Due to Bangladesh's large population, the cost of accessing safe drinking water there dominates the four countries' overall cost.

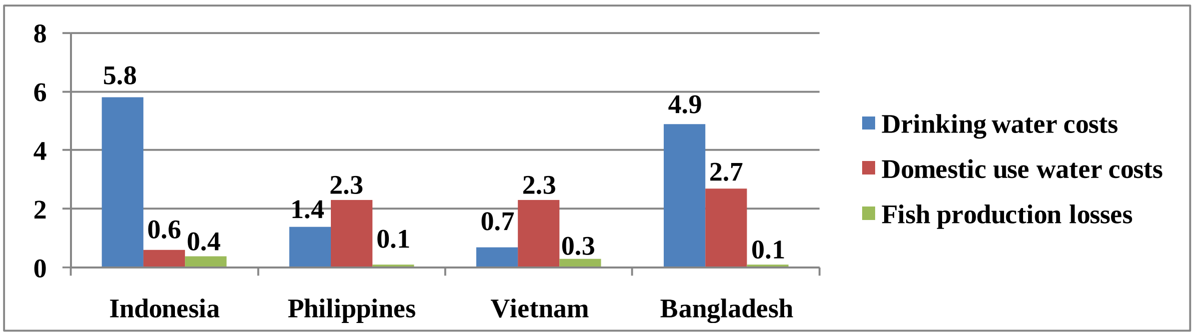

Fig. 3 Annual per capita water-related economic costs of poor sanitation

Whether these costs can be fully mitigated with improved sanitation depends on several factors, including the extent of water pollution from other sources, and the behaviour of households in relation to perceived changes in water quality. If concern about existing water sources containing bacteria is the major driver of household water treatment, then a reduction in water pollution from human excreta could lead to significant financial and economic savings.

Environmental Impacts

Open defecation and poorly managed latrines spoil the environment and people's enjoyment of it. Poorly managed solid waste leads to streets lined with rubbish. Decomposition of organic waste attracts flies and animals. This causes smells and poor sightlines for residents, visitors and businesses, affecting the liveability and usability of land. These impacts are hard to quantify in economic terms, and few previous studies have rigorously examined the population effects of poor environmental sanitation. In terms of the sanitation-related environmental impacts, this study focuses on solid waste management. Good practices generally consist of sanitary landfill or sometimes incineration. These have only reached a small proportion of the population, mainly in urban areas. In urban and rural areas, the lack of coverage of waste management services means littering is the norm, household garbage is left lying in streets, and garbage is burned, creating local air pollution. In rural areas, garbage is commonly buried in the ground. In urban areas, garbage blocks drains and ends up in rivers and lakes.

In Indonesia, even when household solid waste is collected, about 90% of the waste is disposed of illegally through open dumping. In the Philippines, an average 40% of waste is collected, with rates reaching 70% in some cities. Of the waste collected, 88% lands in open dumps or other facilities, 10% is composted, and only 2% ends up in sanitary landfills. The collection of solid waste became a national issue in the Philippines in the early 2000's, when Metro Manila's disposal sites reached capacity and were closed, In Vietnam, 12 of 64 cities have sanitary landfills. Fifty three percent of households burn their rubbish, causing air pollution and debris, while 13% throw solid waste into rivers and 19% bury it. Only 22% of households have garbage collected, mostly in urban areas. In Bangladesh at 1998 estimated waste generation rate were maximum (0.5 kg/cap/day) at capital city Dhaka and the port city Chittagong. At that time waste generation rate was 2983 ton/day at Dhaka and 1310 ton/day at Chittagong and among them 50% are collected (Diaz et al. 1998). But after 14 years at present no correct statistics showed the amount of waste. The amount of waste at Chittagong increased more than three times. But collection rate is not increase. Government has to increase budget at solid waste management sector. But poor sanitation system impacts at total budget.

Other Welfare Impacts

The type of a household sanitation facility has a range of impacts on population welfare. An important but difficult to quantify aspect is the impact on individuals and families that have no latrine or use a sub-standard, uncomfortable latrine. These less tangible aspects of human welfare have limited direct financial implications, and cannot be easily captured by market values. For women and girls, a private sanitary latrine with running water is particularly important, and has considerable impact on quality of life. There can be physical dangers of using distant toilets or open spaces, especially at night. In some cultures this can damage a person's status. Vulnerable groups tend to be more affected by poor sanitation, due to frailty (senior or disabled people) or dangers (e.g. children) of poorly functioning latrines and open defecation.

Table 2 presents indicators of latrine conditions and access. In Indonesia, 40% of the population practices open defecation or uses shared latrines. The proportion is 27% in Vietnam, 6% in the Philippines and 29% in Bangladesh. In Bangladesh females more frequently use a neighbour's latrine or shared latrine (27.2%) and are much more accustomed to defecate in the jungle (27.7%) than their male counterparts (14.4%) use shared latrines and 12.8% defecate in the jungle. There is a gender variation among the adults in using public toilets because of the lack of security. People with no latrine or sub-standard latrines spend time travelling to open defecation sites or public latrines, or waiting in line for insufficient shared or public latrines per capita. This time spent has an economic value because it could be used for other productive or leisure activities. This measures the time to visit a defecation site once daily and does not include urination, which adds further time loss, especially for women who seek more privacy than men. The hourly time value of time spent accessing latrines equals 30% of average income for adults and 15% for children. The condition or absence of latrines in institutions also affects people's ability to go to school or work. A significant proportion of schools do not have latrines. Almost a fourth of Bangladeshi rural schools and half of Vietnamese schools lack latrines. Water supply is lacking in 40% of Bangladeshi schools and 34% of Philippine schools. Even if schools have toilets, consultant and media reports indicate there aren't enough toilets, or they have poor technical standards, maintenance and sanitary conditions. Many workplaces also lack adequate water and sanitation, affecting time use, productivity, and employment decisions, especially of women. Poor sanitation in schools contributes in part to a student's decision not to enrol or to drop out, especially for menstruating girls. The heightened transmission of disease due to poor school sanitation leads to absences. For all pupils and teachers, inadequate latrines cause significant discomfort and inconvenience.

Table 2. Indicators of latrine condition and access (millions)

Country	Population (millions)		Average access time (minutes/day)		Economic loss (US$ million)
	No latrine (Open defecation)	Shared toilet facilities	No latrine (Open defecation)	Shared toilet facilities	
Indonesia	22.2	15.7	15	20	1220.0
Philippines	9.1	15.2	5	5	24.5
Vietnam	2.2	3.1	10	15	41.6
Bangladesh	28.6	14.9	7	24	>450

Overall Economic Impacts

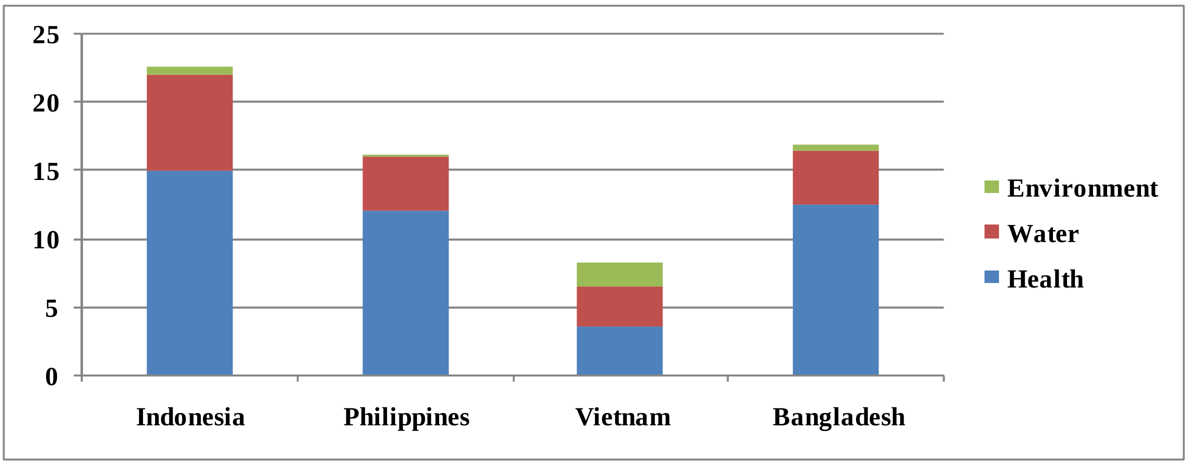

Fig. 4 Annual per capita losses by impact (US$)

So it is too necessary to improve sanitation and water supply. Improved sanitation and water supply can mitigate this economic loss. From a policy viewpoint, it is important to know how much the estimated losses resulting from poor sanitation can be reduced by implementing improved sanitation options. For some impacts such as health, improved sanitation and hygiene do not totally solve the problem, so the overall estimated losses cannot be fully mitigated. This study estimates the potential benefits of certain features of sanitation improvements. Table 3 represents an initial estimate of the likely gains from improving these features.

Table 3: Features of sanitation improvement for assessing economic gains

Intervention	Detail	Gains evaluated
Making toilets cleaner and safer	Improved: position or type of toilet seat or pan; structure; collection system; ventilation; waste evacuation	Avert health impacts (32% reduction)
Hygiene	Availability of water for anal cleansing; safe disposal of materials for anal cleansing; hand washing with soap; toilet cleaning	Avert health impacts (45% reduction)
Latrine access	Toilets closer and more accessible (private rather than shared or public)	Save latrine access time
Isolation of human waste from water resources	Improved: septic tank functioning and emptying; flood-proof; treatment; drainage system	Avert costs of accessing clean water for drinking and other household uses; avert losses to fish production
Re-use of human waste	Composting of feces for fertilizer; biogas production	Value of replaced fertilizer and fuel

COSTING OF WATER SUPPLY AND SANITATION SYSTEM

Cost is a critical factor in determining the success of improved sanitation of water supply projects and programmes. Table 4 represents indicative capital cost estimates for whole Asia region (average) and a number of different service levels based on World Health Organization analysis.

Table 4: Annual costs (US$) per person of water and sanitation improvements

Water Improvement					
Stand post	Borehole	Dug well	Rainwater	Disinfected	Regulated piped water in houses
4.95	1.26	1.63	2.51	0.26	9.95

Sanitation Improvement				
Pour Flash	Septic-tank	VIP*	SP**	Household sewer connection plus partial treatment of sewage
4.60	9.10	5.70	3.92	11.95

*VIP: Ventilated Improved Pit-latrine

**SP: Simple Pit-latrine

In Bangladesh user contribute to the investment costs of tube wells, for instance. TK 700 for shallow tube wells and TK 2,000 for deep tube wells with a hand-pump. In case of shallow tube wells operation and maintenance is handled by the users who pay for the recurrent costs themselves. In case of deep tube wells operation and maintenance is taken care by the Department of Public Health Engineering, DPHE. (Danida, 1997) But now a day’s cost is too higher as compared before. But budget is not increasing in proportion. Table 5 shows some estimates of costs for CLTS (Community Led Total Sanitation) from a 2008 study of Bangladesh Water-aid Programmes.

Table 5. Costs of CLTS interventions (US$)

	Village Education Resource Centre (VERC)	Unnayan Shahogy Team (UST)
Per Household	07	06
Per Latrine	12	42

DECISION & DISCUSSION

In East Asia & Bangladesh, huge amount of USD losses every year due to poor sanitation and water supply. Necessary data and graph are representing at this paper. Overall economic impacts are also included for realizing the situation. It also shows the necessity of giving priority at sanitation sector as it is the fact for many economic and educational losses. So improvement at sanitation and water supply sector is necessary and it mitigates the economic loss for long term. Improved sanitation and water supply costing data are also provided at the end of the paper.

CONCLUSION

Poor sanitation causes huge annual economic loss at East Asia and Bangladesh as compared with their GDP. A greater share of the socio-economic burden of poor sanitation falls on the population without improved sanitation – especially women, children, the senior population and the poor - making worse inequities in society. By improving sanitation and water supply, a significant proportion of these socio-economic impacts can be mitigated. Governments and other stakeholders should jointly reassess the current and planned spending levels on sanitation and related sectors, covering health, water resources, environment, rural and urban development, fisheries and tourism. Sanitation should be given increased political importance and budget allocations.
The socio-economic impact of poor sanitation varies between different countries. This paper presents crude but realistic estimates of economic impacts at the national level. Given the lack of sanitation-related information in official reporting systems and surveys, several impacts of poor sanitation could not be evaluated, or assessed at the local level. For improving water and sanitation annual costs of per person also recommend at last.

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A STUDY ON WATER QUALITY OF THE RIVER SYSTEM AROUND DHAKA CITY

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ABSTRACT

Dhaka, the capital city of Bangladesh, is one of the most quickly growing mega cities in the world. Dhaka city is surrounded by a circular river system. The river system includes the rivers Buriganga, Turag, Shitalkhya, Balu and Dhaleswari. Sufficient quantity of water remains in these rivers during the five months of monsoon season but the flows are practically nil during dry period except tidal backflow from the Meghna river. Due to large number of population and increasing trend of urbanization, subsequent socio-economic activities the water quality of these rivers has been deteriorated significantly. This is why it is the demand of the time to evaluate the quality of surrounding surface water bodies. It is observed that required dissolved oxygen for sustaining aquatic lives (5 mg/l) prevail only in the Dhaleswari River and very short downstream reach of the Shitalakhya River throughout the year. However, Ammonia level in the different reaches is well above the permitted value specified in the USEPA to avoid toxic effect. Concentrations of Nitrate, Phosphate, Zinc, Chromium, and Lead are well below the allowable limits in different Environmental Quality Standards (EQS). The assessment of this study identifies that water of some least polluted river reaches like the Upper and Lower reaches of the Shitalakhya River (Demra to Rupganj and Siddhirganj to Kalagachia) and the Dhaleswari river (Nabinagar to Kalagachia) could be used in city water supply providing required treatment.

Keywords: Water quality, Dissolved oxygen, Ammonia level, water treatment, River System around Dhaka City.

INTRODUCTION

The present water demand in Dhaka city is 2370 million liter per day. Dhaka Water Supply and Sewage Authority (DWASA) tries its best to afford sufficient water for meeting up demand of the city.

By the year 2025 its population will be 21 million. At present supply deficit is 40% of the total demand of Dhaka & the deficit will be 60% by 2025. Depletion of ground water table is very alarming. It is very crucial to diversify the sources of water supplied for the city. Diminution of dependency on the groundwater and to make provisions to meet demand of the city from surface water is now very essential. Wastewater being discharged from major drains/khals contains domestic as well as industrial wastes and is ultimately disposed into the peripheral rivers. Since the peripheral river system gets no upstream inflows during dry season, the high waste loads deteriorate the water quality tremendously. A thorough assessment of water quality in the peripheral rivers is essential for their sustainability and also to rescue the city water supply system from every possible upcoming adversity. The objective of the study is to assess the sustainability of peripheral river system of Dhaka as potential surface water sources for Dhaka city water supply to cope up the increasing water demand of the city.

METHODOLOGY

The assessment of water quality scenario comprises evaluation of peripheral river system around Dhaka city including its extend, topography and hydraulic condition; groundwater resource, depletion of groundwater table underlying the city; present water supply practice and treatment facilities; the levels of content of different elements, compounds and materials co-existing with water. It also necessitates dealing with characteristics of water body (extend, source, storage volume and hydraulics), characteristics of pollutants (source, volume and type), climatic condition for supplementing the evaluation.

River network

Five river reaches encompasses the Dhaka city which include Buriganga, Shitalakhya, Dhaleswari, Turag and Balu River (Figure 1). There are some drainage channels inside the city like Dholai khal, Begunbari khal, Norai khal and Kallayanpur khal which are linked with the peripheral rivers. Few of them are controlled through several structures. The river reaches have general slopes from north to south. The river system experience flood flows during monsoon from upstream inflows of the Turag, Dhaleswari and Shitalakhya River. The river system gets no inflows during dry season. The rivers experience semi tidal influence in downstream reaches during flood seasons. Whereas tidal back flows from the Upper Meghna River penetrate far upstream during dry periods.

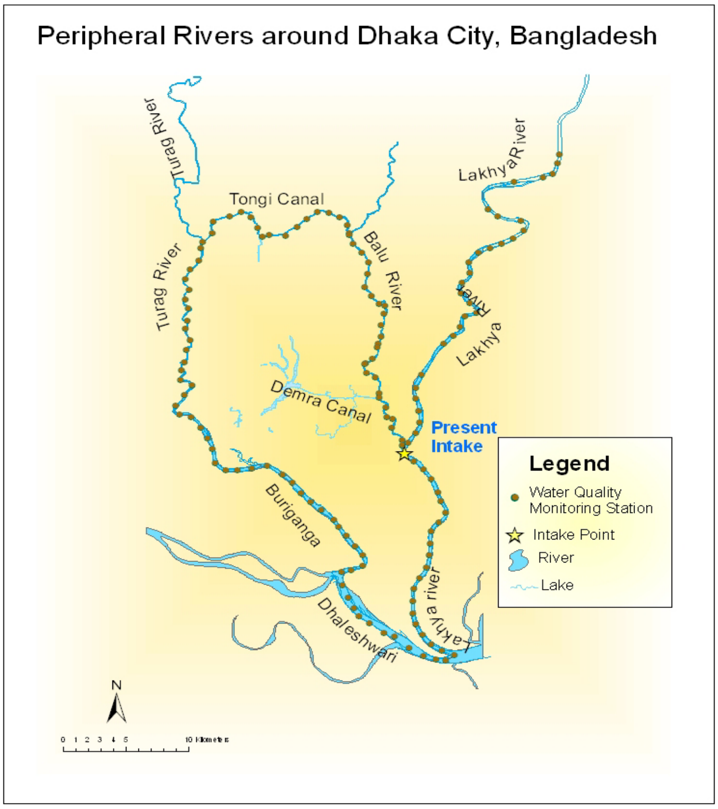

Figure 1: The River Network surrounding Dhaka

Data Collection

Measurement of water quality and storage volume is very expensive, requires skilled manpower, sophisticated instruments and well organized laboratory facilities. As a government organization, Department of Environment (DoE) measures some water quality parameters at some selected locations in the peripheral rivers around Dhaka city. Some water quality parameters DO, BOD_5 (at 20°C), COD, turbidity, pH, electrical conductivity, alkalinity, total dissolved solid (TDS), total suspended solid

(TSS), total coliform (TC), fecal coliform (FC). NH3-N, NH4-N, NO3-N, PO4, chromium (Cr), lead (Pb), mercury (Hg), zinc (Zn) etc are measured by DoE, IWM and DWASA at several stations.

Stations of Data Collection

Department of Environment has established some water quality monitoring stations at different reaches of the rivers system. Stations for collecting samples of Buriganga are Hazaribag, Kamrangir char, Chadinaghat, Forasgonj, Sadarghat, Dholai khal, Bangladesh China Bridge and Pagla. Stations of Shitalakhya are Demraghat, Narayanganj and Siddirganj. Stations of Dhaleswari are at Nabinagar, Reckabibazar and Kalagachia.Stations of Balu River are at Keodala and Balurpar while those for Turag are at Mirpur Bridge and Bashila.

Method of Assessing Suitability of Sources

The study of water quality of peripheral rivers as potential sources of water supply for Dhaka city has been based on existing water quality of the different reaches of the circular water system. Water quality is evaluated on the basis of water quality standards according to Bangladesh Standard.

Estimation of Pollution Load

Pollution loads contributed by the point sources, have been calculated in wet method. Wastewater discharge period has been assumed to be 12 hours out of 24 hours considering tidal influence of the receiving rivers as well as water consumption practice. The expression used in computation of pollution load in Wet method is as follows:

Pollution load = Concentration (mg/l) * Flow (m3/s) * Flow time
= Concentration (gm/m3) / (1000 gm/ kg) * Q (m3/s) * 3600 s/h * 12.0 h/d
= Load (kg/d)

RESULT AND DISCUSSIONS

Stream Water Quality

Stream water quality has been assessed keeping attention on the drinking standard as well as sustainability of aquatic lives. Water quality observed in different measurements in the river system is illustrated in the following articles.

Dissolved Oxygen

Dissolved oxygen concentration remains low in the dry seasons (i.e. January to April) and it maintains the level more than 5 mg/l (required for sustaining aquatic habitats) from May to December in the entire peripheral river system. Minimum dissolved oxygen required for drinking is 4 mg/l. Minimum dissolved oxygen in the river system is summarized in “Table1”.

Table 1: Minimum Dissolved Oxygen

River Name	Minimum DO (mg/l)
Turag River	Below 1.0
Buriganga River (Hazaribag to Keraniganj)	Nearly 0.0
Buriganga River (Keraniganj to Fatulla)	Below 1.0
Dhaleswari River (Fatulla to Nabinagar)	Around 2.0
Dhaleswari River (Kashipur to Kalagachia)	Around 5.0
Shitalakhya River (Kalagachia to Mosinabanda)	Above 4.0
Shitalakhya River (Siddirganj to Rupganj)	Below 1.0
Balu River	Below 1.0

Biological Oxygen Demand

High BOD generally occurs at Kamrangirchar in the Buriganga River (50 to 60 mg/l). BOD hardly crosses 10 mg/l in the Dhaleswari River and Shitalakhya River. In the Balu River it varies from 5 mg/l to 70 mg/l while that for Turag river varies from 5 mg/l to 40 mg/l. Maximum allowable BOD5 is 3 mg/l. Maximum BOD5 (at 20°C) in the river system observed in the dry season is summarized in "Table 2".

Table 2: Maximum BOD5 at 20°C

River Name	Maximum BOD5 (mg/l)
Turag River	Around 30
Buriganga River (Hazaribag to Keraniganj)	35 to 55
Buriganga River (Keraniganj to Fatulla)	Around 12
Dhaleswari River	Around 12
Shitalakhya River (Kalagachia to Mosinabanda)	Around 10
Shitalakhya River (Siddirganj to Rupganj)	Around 07
Balu River	Around 08

Chemical Oxygen Demand (COD)

COD in the Turag river and upper reaches of BuriGanga river remains high varying from 50 mg/l to 60 mg/l except Hazaribag having COD of around 90 mg/l. COD is drastically reduced to below 20 mg/l from Pagla in Buriganga to entire Dhaleswari river. Along the Shitalakhya River COD varies from 20 to 45 mg /l. Maximum COD observed in the dry season is stated in "Table 3"

Table 3: Maximum COD (Dichromate value)

River Name	Maximum COD (mg/l)
Turag River	50 to 60
Buriganga River (Hazaribag to Keraniganj)	60 to 90
Buriganga River (Keraniganj to Fatulla)	Around 20
Dhaleswari River	Below 20
Shitalakhya River (Kalagachia to Mosinabanda)	30 to 40
Shitalakhya River (Siddirganj to Rupganj)	Below 20
Balu River	40 to 60

Total Coliform

Presence of coliforms in surface water bodies in Dhaka is very common. River system of Dhaka contains coliforms of 100 to 9000 CFU/100 ml while the allowable limit is 10 CFU/100 ml. But coliforms are removable by surface water treatment plants.

Nitrogen

Nitrogen content at three states i.e., NH3-N, NH4+-N and NO3-N have been evaluated in the river system. High ammonia nitrogen concentration (around 10 mg/l) is observed at Kamrangirchar and Keraniganj on Buriganga river. Same is case with the Balu River. In the Shitalakhya River its concentration ranges from 3 to 8 mg/l. Maximum NH3-N concentration in the river system is above the USEPA guideline (0.02 mg/l) to avoid toxic effect on fishes. Ammonia content is low in the Dhaleswari River. Ammonium concentration reaches nearly 20 mg/l in the Turag river and Buriganga river. Dhaleswari and Shitalakhya River experience ammonium concentration of 2 mg/l or less except at Sarulia. The concentration ranges between 4 to 12 mg/l in Balu River. Nitrate content is below 10 mg/l in the entire river system except at Hazaribag. Nitrogen concentrations during dry season are stated in "Table 4".

Table 4: Nitrogen concentrations

River Name	NH3-N (mg/l)	NH4+-N (mg/l)	NO3-N (mg/l)
Turag River	1	20	7
Buriganga River (Hazaribag to Keraniganj)	12	18	17
Buriganga River (Keraniganj to Fatulla)	9	16	5
Dhaleswari River	0	3	3
Shitalakhya River (Kalagachia to Mosinabanda)	0	4	5
Shitalakhya River (Siddirganj to Rupganj)	8	7	5
Balu river	11	12	4

Other Water Quality Parameters

For the evaluation of water quality scenario other water quality parameters like pH, TDS, TSS, turbidity, total coliform are also significant. But their extents in the peripheral river system are acceptable for water supply purpose after proper treatment. Values of different water quality parameters are stated along with their Bangladesh Standard values in “Table 5”.

Table 5: Ranges and standard of water quality parameters

Quality parameter	Ranges in river system	Bangladesh standard
pH	6.1-7.8	6.5-8.5
TSS (mg/l)	11-176	250
TDS (mg/l)	50-440	1000
Turbidity (NTU)	2.6-8	5

Estimation of Pollution Load

The estimated pollution load is based on a single measurement on a day. Therefore it is very crude estimation and calculated value may not represent the daily pollution load discharged into the river system. However we can get a tentative idea about the volume of pollution load. The estimated pollution loads into the peripheral river system around Dhaka and Narayanganj is summarized in “Table 6”.

Table 6: Pollution load in river system

Type of Load	Volume of Pollution load (ton/day)
BOD5	230
Ammonia (NH3)	5
Phosphate (PO4-)	8
Chromium (Cr)	0.50
Lead (Pb)	0.10

CONCLUSIONS

- Sufficient quantity of water remains in the river system in the five months of monsoon season but the flows are practically nil during dry period
- Required dissolved oxygen for water supply prevails only in the Dhaleswari River (downstream of Nabinagar and Kalagachia) and in the short downstream reach of Shitalakya River (from Mashinabanda to Kalagachia) throughout the year.
- The rest of the river reaches maintain DO level usually less than 1.0 mg/l in the dry period.
- oxygen content in the dry season is gradually reducing in the river system which is very alarming.

- Very high BOD and COD value along with high concentrations of nitrogenous compounds are the indications of the severe extent of pollution in the entire river system.
- Concentrations of phosphate (PO4-), chromium (Cr), mercury (Hg) are within acceptable limits with negligible exceptions in few reaches.
- Shitalakhya and Dhaleswari are two potential rivers for water supply. However, water quality in some reaches of these rivers is not satisfactory.
- The Dhaleswari River (downstream of Nabinagar and Kalagachia) and the short downstream reach of Shitalakhya River (from Mashinabanda to Kalagachia) are the least polluted reaches.
- These two reaches can be used for water supply providing required treatment for few contaminants
- The study findings highlights that it is essential to make provisions for improving water quality in the peripheral river system to sustain city water supply system and the ecosystem in the rivers.

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