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INVESTIGATION OF PHYSICOCHEMICAL PARAMETERS OF EFFLUENT FROM TEXTILE INDUSTRIES OF BANGLADESH

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ABSTRACT

Though textile industries have major contribution to run economic wheel of the country, their adverse effects on environment and human health is noticeable. Textile industries pollute environment and cause health hazard by producing huge amount of waste water that contains obnoxious pollutants. This paper investigates different effluent quality parameters of Effluent Treatment Plant (ETP) outlets. The samples were taken from two industries ETP outlets named Denim Plus (BD) Ltd. and Jeans 2000 Ltd situated in Chattogram EPZ. The effluent of outlets was dark color due to presence of coloring agent. A comparative study was also done over consecutive six-month sample data for both the industries and also compared with ECR 1997 water quality standards. The highest dissolved oxygen (DO) were 7.6 in September in Denim Plus Ltd effluent and 8.8 in August in Jeans 2000 Ltd.
The pH values for both the industies were withinin the ECR 1997 limit. But BOD showed higher value in June and COD value get higer than standard limit in August for Jeans 2000 Ltd.Tough most of the textile indutries have ETP plant but they show reluctance to treat water. The effluents contains chemicals,salts,dyes,bleaches which contaminates water and pollute environment. By analyzing the physicochemical parameter of effluent of these two industries it is found that after treatment effluent outlets ensure standards quality with few exceptions.

Keywords: *Textile industry; Effluent; ETP; Water quality; Pollutants.*

1. INTRODUCTION

Textile and garment industries play a vital role in socio-economic development of Bangladesh. As worlds one of the biggest exporters Bangladesh holds 5% share in global market. About 85% of Bangladesh's export earnings and 10% of GDP comes from ready-made garments (RMG). Bangladesh Garment Manufacturers and Exporters association (BGMEA) has recently set a target for garment sector to reach $50 billion of exports by 2021 and $82.5 billion by 2030.To achieve the goal and to accelerate economic development of Bangladesh huge amount of water is necessary. In different stages of operation in textile industries about 85% of water is used and discharged (World Bank Group, 2015). Mainly the washing and dyeing sections consume large quantity of water. The highly polluted and toxic wastewater is discharged into the rivers, lands or drains by the industries without any kind of treatment. This irregular and unplanned disposal of wastewater has created environmental pollution problem. During the production process large amount of effluent is ejected from the industries either treated or untreated. According to environmental conservation rule (ECR 1997) the textile factories are supposed to have ETP for effluent treatment but a large number of factories are violating the rules and are continuing without ETP. As a result, the effluent discharged from the industries pollutes the surface as well as groundwater.

The effluents contain heavy metals, trace metals, colouring agents and some toxic elements. The effluent discharged into the rivers goes far away and used by people for their day to day activities and irrigation (Sarkar et al., 2015). Consequently, the physiochemical parameters of water such as pH, BOD, COD, TDS, DO get degraded due to the polluted water. It will contaminate the food chain and ecosystem. These make water very toxic and harmful for human begins crops and aquatic livings. This causes serious diseases such as cancer, damage of infant brain, body shrinkage etc on human beings, reduces soil fertility and damages crops (Munnaf et al., 2014). The environmental hazard due to wastewater is very alarming for developing countries like Bangladesh. Many international investors are now aware of environmental pollution and looking for whether textile factories have ETP or not for safe emission of effluents. It is appreciable that most of the factories are nowadays installing ETP for wastewater treatment and safe disposal of the effluent. However, to reduce environmental pollution proper monitoring is needed for efficient functioning of ETPs. The industries should be aware of the effect of polluted effluent in the environment as well as the threat it has on human life. Therefore, in this paper a comparative study was carried out in six different months to observe the change in effluent quality ejected from the ETPs of Denim Plus Ltd and Jeans 2000 Ltd in Chattogram, Bangladesh.

2. METHODOLOGY

The study area was located at CEPZ (Chattogarm Export Processing Zone), South Halishahar, Chattogram, Bangladesh. The ETP (Effluent Treatment Plant) of M/s. Demin Plus (BD) Ltd. (Sector-7, Plot-3-8) and M/s. Jeans 2000 Ltd. (Sector-7, Plot-67) is established at 22° 17' 36.16"N Latitude and 91° 46' 55.59"E Longitude

2.1 Sample Collection

Water samples were collected from ETP Outlet points of the M/s. Demin Plus (BD) Ltd. and M/s. Jeans 2000 Ltd. in 500 ml dark plastic bottle. One litre water sample was collected in each month for performing the tests on physiochemical parameters from ETP outlets of the companies.Before sampling the bottles were cleaned with detergent, rinsed with 10% HNO3, and then washed with distilled water, after that bottles were rinsed three times with the water to be sampled. Alkaline potassium iodide solution was used to protect water samples from any fungal and other pathogenic attack. After collection, the bottles containing samples were sealed immediately to avoid exposure to air.

2.2 Analytical Method

The following analyses were done from the collected water samples: pH, DO (Dissolved Oxygen), TDS (Total Dissolved Solid), BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand). To provide necessary information for each sample such as date of collection, location, time etc. were recorded in the note book and each sample collected in a plastic bottle was labeled separately with a unique identification number. Water quality parameters such as pH and DO (Dissolved Oxygen) were determined by Multi-Function Environment Meter (WTW multi 9310).TDS (Total Dissolved Solids) were determined by Digital TDS Meter (Hanna Instruments® HI 96302). COD (Chemical Oxygen Demand) was measured by COD Thermoreactor (WTW CR3200) and Photo Flex (WTE) using COD Reagent vial. As BOD (Biological Oxygen Demand) value need 5 days to give the result. First prepared amber bottle and setup Oxitop immediately after collection, after 5 days BOD (BOD5) was measured by incubation (Thermostate Cabinet, WTW TS 606-G/4-i) at 20°C.

3. RESULTS AND DISCUSSION

A study was done on different water quality parameters for consecutive six months on the samples collected from outlet of ETP plant of Denim Plus Ltd and Jeans 2000 Ltd. The different parameters such as pH, COD, BOD, DO and TDS were plotted in the graph against different months shows whether the observed values are within the standard guideline of ECR 1997 or not.

pH indicates acidic or alkaline nature of water. From (fig-1) it is observed that the pH value for both the industries are within ECR 1997 standard which ranges from 6.5-8.5. In May Denim Plus Ltd has pH value 8 and Jeans 2000 Ltd shows pH value 6.5. In August Denim Plus Ltd has 7.8 pH and Jeans 2000 Ltd has 6.7 pH. Other than May and August pH value for both the industries in other months are close enough. The pH value of inlet effluent was maintained well in both the industries during neutralization process. For basic dyeing, pH correction was in acidic side and for acidic dyeing pH correction was done by adding alkali. This neutralization was done with a slow thorough mixing process in pH correction tank.

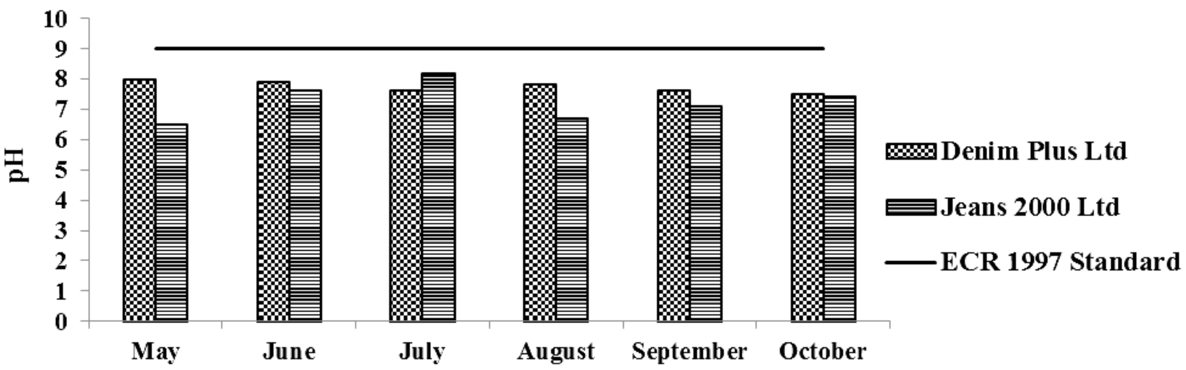

Figure 1: Values of pH in different months from May to October compared with ECR 1997 standard

Dissolved oxygen is one of the most important indicators of water quality. Naturally DO is mixed in surface water by wind effect. It is very important for the survival of fish, aquatic life for photosynthesis. After using water in industries for different purposes the water gets polluted and so DO level reduces.

When the outlet water from ETP was tested the Maximum DO was found 8.8 mg/l in August for Jeans 2000 Ltd form (fig-2) which is little higher than the standard value 8 mg/l. But in September DO level of Jeans 2000 Ltd was 3.1 mg/l which is very low and below standard level. The production rate was high in September in Jeans 2000 Ltd and the equalization tank could not work effectively because the tank did not has the capacity to hold this much of waste water. As a result the tank could not mix different types of effluent discharging from plants. So DO Level was not increased appropriately due to lack of oxygen supply and the high temperature of effluent. Whereas Denim Plus Ltd has a relatively consistent DO level in every month other than May and June. This two month shows low DO level 5.7 mg/l and 5.8 mg/l respectively due to hot weather and less use of purified water in production plants.

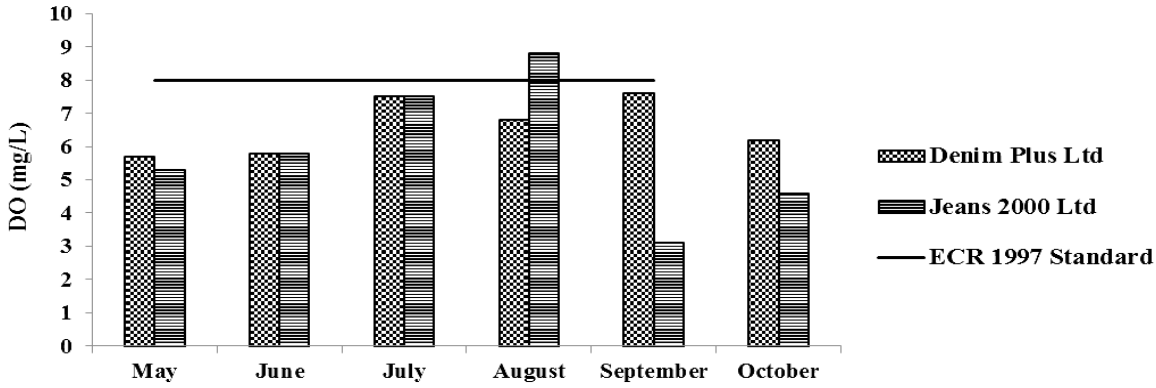

Figure 2: Values of DO (mg/L) in different months from May to October compared with ECR 1997 standard

BOD indicates the amount of organic matter in water was found higher 80 mg/l in June in Jeans 2000 Ltd. whereas the standard value for BOD is 50mg/l by ECR 1997. In sizing and desizing processing unit different pollutants such as starch, glucose, carboxy methyl, cellulose, polyvinyl alcohol etc dissolves in water which results in high BOD level. In Jeans 2000 Ltd effluent was taken into flash mixing tank after equalization tank for proper coagulation and flocculation process to skim out the oily substances and dye particles. But this process had some faults due to inappropriate dosage of coagulants and flocculants. As a result, it is observed that Jeans 2000 Ltd has in consistence changes in BOD level in different months. But in Denim Plus Ltd, the values of BOD were in permissible limit in each month as shown in (fig-3).

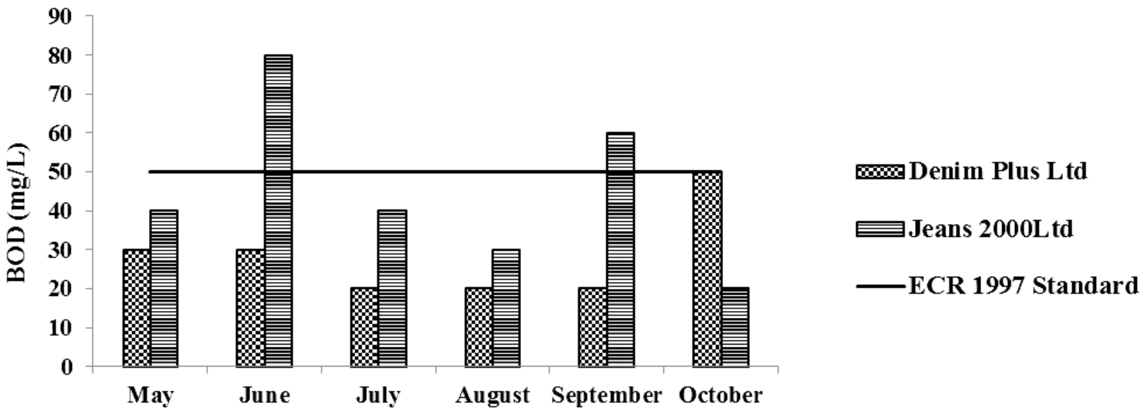

Figure 3: Values of BOD (mg/L) in different months from May to October compared with ECR 1997 standard

The COD test is done to assess the effect of discharged waste water on environment. In Denim plus the COD value observed from (fig-4) is within the ECR 1997 standard 200 mg/l but the value increased drastically to 391mg/l in August for Jeans 2000 Ltd. During scouring and bleaching process different chemicals such as dyes, salts, alkalies, Acids, Na_2S, $Na_2S_2O_2$, and soap are mixed with water and increases COD level. Different units have different toxicity level and so at first, they need to be separated according to high toxicity level. These separating stages were absent in Jeans 2000 Ltd for treating effluent. So lack of proper monitoring was one of the reasons for higher COD level.

In case of Denim Plus Ltd all COD values were very less than standard limit as they use anaerobic digestion process to biodegrade complex organic matter to treat high COD wastes. In August it shows COD 23 mg/l which is very negligible. Moreover the other COD values in each month are in reasonable range and shows a consistent trend for Denim Plus Ltd.

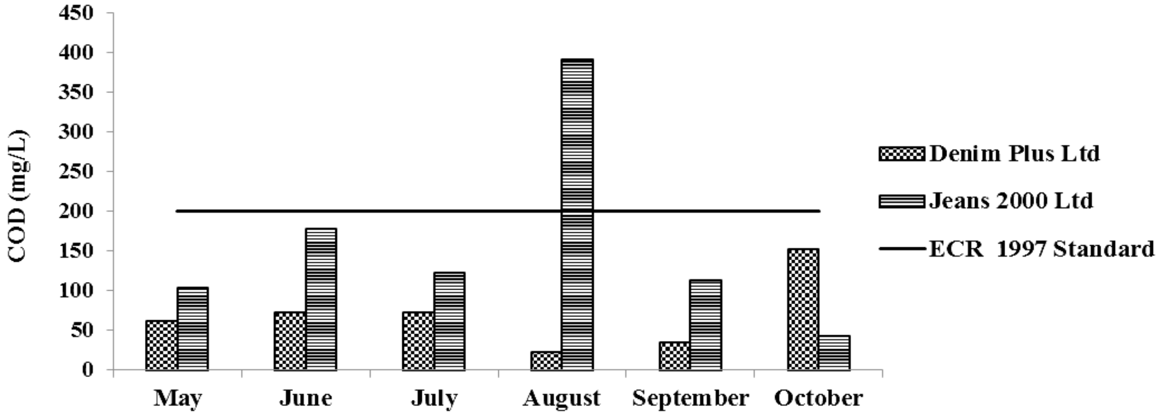

Figure 4: Values of COD (mg/L) in different months from May to October compared with ECR 1997 standard

Total Dissolved Solid (TDS) is the measurement of organic and inorganic substances present in water. Mostly TDS increases due to salts presence in dyeing operation. The six month observation of TDS in (fig-5) shows that the TDS values are within standard limit 2100 mg/l of ECR 1997 for both the factories. TDS cannot be removed totally from effluent but it can be kept within permissible limit by dilution. Jeans 2000 Ltd shows high TDS 2050 mg/l in September where Denim Plus Ltd shows TDS 1962 mg/l in same month. This limits are within standard range of ECR but TDS concentration can be reduced if the industries use salt recovery plant and practice cleaner production within factory premises.

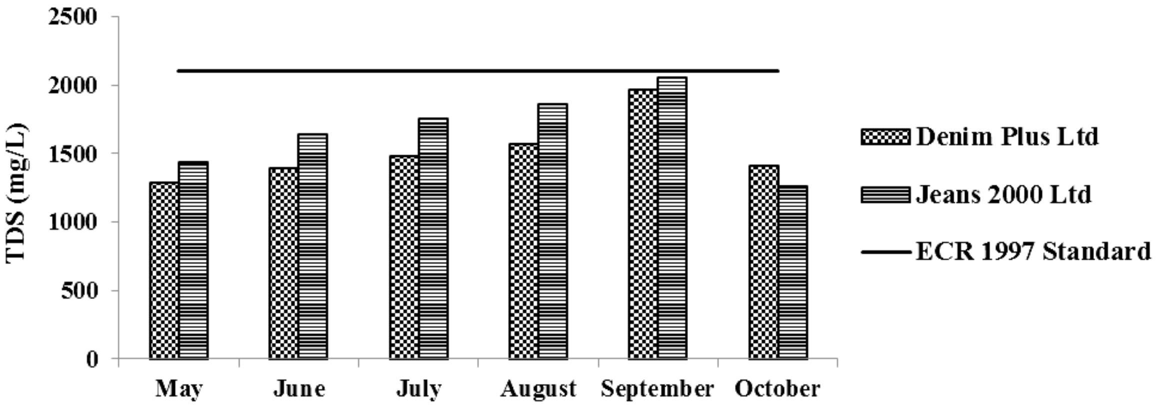

Figure 5: Values of TDS (mg/L) in different months from May to October compared with ECR 1997 standard

4. CONCLUSIONS

From the above study it is concluded that most of the physicochemical parameters of waste water that is discharged from ETP of Denim Plus Ltd are within standard limits of ECR 1997. But the parameters such as COD, BOD and DO are not within the acceptable range for Jeans 2000 Ltd. The COD level has increased significantly in August and BOD level has increased in June. The probable reason for this abnormal increment shows lack of proper management of waste water which leads to increased volume of toxic effluent. The primary treatment of effluent such as coagulation, flocculation, neutralization, sedimentation were not done properly for floatable and settleable material. As a result both the biodegradable and non-biodegradable organic matters were increased which led to higher COD and BOD level. Effluent should be properly monitored in every step of scouring, dyeing, bleaching and finishing. Selection of dyes, chemicals should be done carefully to reduce effluent toxicity level. However both the industries should give more emphasize to use synthetic sizes rather than using starch sizes to reduce BOD and COD level. Moreover complete operation of every stages of effluent treatment plant can help the industries to maintain standard quality effluent discharge.

REFERENCES

Aktar,P., Moonajilin,M.S.(2017).Assessment of Water Quality Status of Turag River Dueto Industrial Effluent. International Journal of Engineering and Information Systems (IJEAIS), 1(6), 105 - 118.

Bangladesh Garment Manufacturers and Exporters Association (BGMEA) website:www.bgmea.com.bd

Bangladesh Textile Today. (2015). Textile Effluents, Treatment and Their Discharge in Bangladesh. Retrieved from https://www.textiletoday.com.bd/textile-effluents-treatment-discharge-bangladesh/

Haque,K.M.(2008).Treatment of Textile Wastewater in Bangladesh. Retrieved from https://www.researchgate.net/publication/332440677_TREATMENT_OF_TEXTILE_WASTEWATER_IN_BANGLADESH

Khan,A.A.(2016). Effluent Treatment Plant and Its Importance on Textile andGarments Industry in Bangladesh Economy:An Analytical Exercise for Future Development. Retrieved from https://www.academia.edu/25532610/Effluent_Treatment_Plant_and_Its_Importance_on_Textile_and_Garments_Industry_in_Bangladesh_Economy_An_Analytical_Exercise_for_Future_Development.

Munnaf,A., Islam, M. S., Tusher,T. R., Kabir, M. H., & Molla, M. A. H.(2014). Investigation of Water Quality Parameters Discharged from Textile Dyeing Industries. Environmental Science and Natural Resources,7(1),257– 63.

Rabbi,M. A., Hossen ,J., Sarwar, M.M., Roy,P. K., Shaheed, S.B., & Hasan,M.M.(2018).Journal of Current World Environment,13(2), 206-214.

Sarker, M. R. H., Razzaque, A., Hoque, M. M., Roy, S., & Hossain ,M. K. (2015). Investigation of Effluent Quality from an Effluent Treatment Plant of a Textile Industry, Fakir Knitwear Ltd. Narayangonj ,Bangladesh, Environmental Science and Natural Resources,8(2), 25-31.

Sultana, S.,Ali,M.E.,Uddin,M.S., & Haque,M.M.(2013). Implementation of Effluent Treatment Plants for Waste Water Treatment. Journal of Environmental Protection,4(3),301-308.

World Bank Group.(2015). An analysis of industrial water use in Bangladesh with a focus on the leather and textile industries. Retrieved from https://www.2030wrg.org/wp content/uploads/2016/02/WRG-Bangladesh-Report.pdf

CURRENT STATUS OF URBAN ENVIRONMENT: A CASE STUDY ON PAIKGACHA MUNICIPALITY, KHULNA

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ABSTRACT

The aim of this study was to evaluate the existing situation of urban environment management of municipalities in Bangladesh, most particularly in Khulna city. Urban environment management is a potential dimension to keep pace with the adverse impacts of rapid urbanization and population growth. According to Bangladesh Paurashava Ordinance 1977, municipalities are assigned some duties regarding this issue. However, the municipality faces various problems during performing the duties, including scarcity of funds, poor monitoring process, low accountability, lack of implications of proper urban planning etc. which eventually result in poor service delivery. Paikgacha municipality area has been chosen as the study area for this study. This municipality was formed on 1 February 1998.The estimated population of the area is about 20,504 and the density of population is about 5640 per sq. km. It covers a total area of 6.94 sq. km.

Primary data were collected through questionnaire survey on 30 local people and expert opinion survey of the municipal authority of Paikgacha from March, 2019 to October, 2019. Some other secondary data sources have been used like various information gathered from Municipality office, BBS, LGED and other data. The primary data were given input in SPSS software and several analysis showing various dimensions of environment management were done. Using ArcGIS10.5 software, different maps were created indicating influence of various factors. From the perspective of drainage condition, transportation, waste disposal, waterbody condition etc. factors, the current environment status of the municipality was found to be moderate and seeks more monitoring and maintenance for its betterment. Such as the study reveals that about 33.33% of the total waterbodies were fresh, while, 30% covered by aquatic plants and 16.67% have odour problem in the municipality area. The whole study area has good connectivity of “pucca” drainage network constructed by the municipality in 2000. The drainage problem faced most by the people is water logging, odour problem and insect breeding and the prime cause of these problems is the vulnerable condition of the main discharge point. The drainage network discharged all the waste water into the Shibsa River without any treatment which accelerates river pollution. There are adequate number of community dustbins inside the area installed by the municipality but most of the people (about 60%) dump their household wastes here and there, only about 33.33% people used dustbin. The municipal authority finally dumps those raw wastes into the bank of the Shibsa River. There are not enough facilities for physical exercise in the municipal area, only one park for children is there which is maintained by the municipality. Due to lack of proper planning and sufficient technical support, Paikgacha Municipal Authority is incapable of managing the urban environment properly in response to the population dynamics.

Keywords: *Urban Environment Managements, Municipality, Environmental factors, ArcGIS.*

1. INTRODUCTION

In order to develop a sustainable, inclusive and zestful city, Urban Environmental Management reacts to the need of evaluating urban growth and environmental problems from the perspective of management and planning (Allen, 2003). Its main purpose is to address the challenge of sustainability as well as also gathers theories and aspects in established sectors of urban planning, sustainable urban and regional development, urban economics and urban governance and management studies into a distinguishable framework. The Environmental Management methodology is a proven method of finding and measuring the impact of built in environment on the whole environment (Ghosh, 2003).It allows planners to demand reliable and comparable information regarding environment. Themes include urbanization processes, spatial analytical techniques, urban indicators and monitoring, governance of urban regions, training in waste management, modeling and scenario analysis, environmental assessment etc. (Allen, 2003). In a wider sense, the urban environment consists of natural resources and living organisms and the processes of transforming the raw resources into various other useable products and services is urban environment management (Das, 2018).

Considering local government as an organ of a country, municipality is the cell of local government in urban area. A municipality may be designated as a city, village, or town (Encyclopaedia Britannica, 1998). Sao Paulo, a municipality located at the south-eastern region of Brazil, achieved significant development regarding green areas in the last decade. For this purpose, the municipality authority of Sao Paulo occupies the institutional and legal structures as well as takes initiatives to ensure community participation to make it more sustainable (Carbone, 2015). To attain sustainable development, the municipal authority also has to control its actions in such a manner so that any changes in management body do not create any discontinuity of activities. Again, without participatory and inclusive approach of the local government, no technology, capital or expertise can protect the environment (Shafqat, 2011). A successful study of urban environment management in New Zealand represents that it is possible to easily manage and improve the environmental condition with the help and assistance of the local people (Marsh, 2012).

Environmental management is another important responsibility of the municipalities of Bangladesh together with the mentioned above. A successful example of this is Chunarughat Paurashava of Habiganj District, they performed this responsibility by ensuring garbage collection, proper disposal of wastes, constructing sewerage, protecting public park and so on (Chowdhury, 2012). However, they also face some challenges during conducting these activities, including scarcity of funds, poor and irregular collection of fees, and dependence on governmental grants, poor monitoring system, low liability, and lack of urban planning. All these cause a poor delivery of services, degrading the environmental quality and quality of civic conveniences.

1.1 Novelty and Significance of the study:

The main contribution of this paper is to assess the urban environment status of Paikgacha municipality, which will in future promote more research works regarding urban environment condition of other municipal areas of Bangladesh. Very small amount of research work is conducted at municipality level of the country but municipality plays a very vital role in local government system. Paikgacha, being in the south-east region of Bangladesh is more vulnerable to natural calamities and lies in the saline zone. Due to this features the overall urban environment of this area is more disrupted than others.

This study aims to show the urban status of the environment of Paikgacha municipality. Different facilities and services of past and present (e.g. water body, drainage system, waste management system, recreation facilities, transportation system etc.) has been identified. Environmental details of this municipality and the impacts and effects of existing services on the environment have been analyzed using participatory approach. And finally the overall scenario has been graphically illustrated and described.

2. METHODOLOGY

The main concept of the study was based on objectives taken and originated from the literature review done before. A Literature Review developed on the basis of gathering knowledge about how the procedure could be performed and the collected data from field survey could be analyzed. Then Paikgacha has been chosen as the study area for the study. Different facilities and services of past and present which affects the environment and are the responsibility of the muniipality (e.g. water body, drainage system, waste management system, recreation facilities, transportation system etc.) has been identified.. Primary data were collected through phisical and household survey and secondary data were collected from expert opinion survey, municipality office, local government engineering department (LGED). After collection, data were being prepare to analyze and interpretation.Environmental details of this municipality and the impacts and effects of existing services on the environment have been analyzed. Data analysis procedure has been conducted using statistical software and different charts and analytical figures have been made to show comparisons.

2.1 Study Area

Paikgacha municipality area has been chosen as the study area for this study. The estimated population of our study area is about 20,504 and the density of population is about 5640 per sq. km (Bangladesh Bureau of Statistics, 2001). The geographical location of the study area is between 22°28' and 22°43' north latitudes and in between 89°14' and 89°28' east longitudes. It covers a total area of 6.94 sq. km. It is bounded by Tala and Dumuria Upazilas on the north, Koyra Upazila on the south, Batiaghata and Dacope Upazilas on the east, Tala and Assasuni Upazilas on the west. Paikgachha Municipality was formed on 1 February 1998 (Banglapedia - the National Encyclopedia of Bangladesh, 2012). Figure 1 shows the map of the study area.

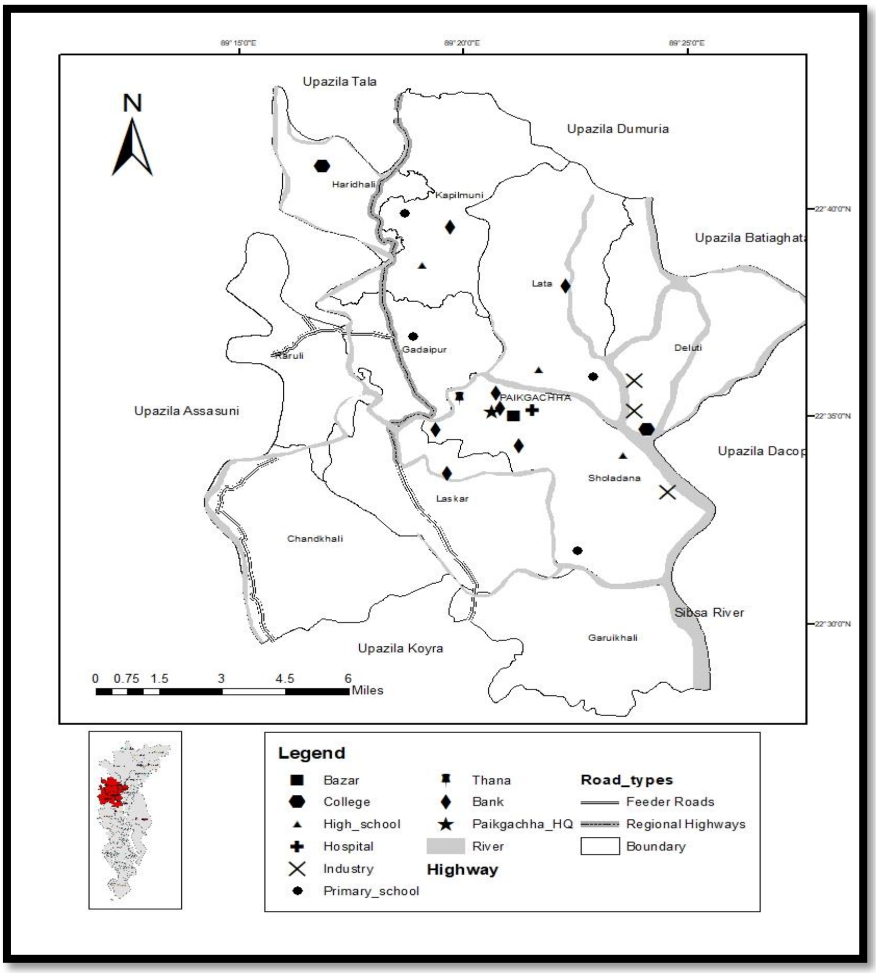

Figure 1: Paikgacha Municipality, Source: Author, 2019

2.2 Study Design

The necessary primary data of urban environment of Paikgacha Municipality area has been collected by conducting an effective field survey like, Reconnaissance Field Survey, Focus group discussion and household survey of 30 local people and expert opinion survey of the municipal authority. Some other secondary data sources have been used like various information gathered from Municipality office, BBS, LGED and other data.

The overall analysis of this study was mainly SPSS software. At first, all the data collected from questionnaire survey have been inputted to SPSS declaring its respective variables. Then statistical analysis has been done considering the factors that affect the environment in terms of water pollution and air pollution (e.g. water body, drainage system, waste management system, recreation facilities, transportation system etc.). And finally, on the basis of the analysis, pie charts and bar charts have been formed to show the results of the analysis. Co-relation between several interlinked factors have also been represented. Maps representing the influence of several factors have been created using ArcGIS 10.5 software.

3. ANALYSIS AND FINDINGS

3.1 Management of Waterbodies and Water Supply System

Supplying the people of the municipality wholesome water in sufficient quantity for private and public use is a vital responsibility of the municipality authority as well as to maintain the condition of the existing water body. The area has huge number of water body such as pond, canals etc. and also two river named Shibsa River and Kopotakkho River also flow through the area. According to the respondents, about 33.33% of the total waterbodies are fresh, 30% are covered by aquatic plants and 16.67% have odour problem. The municipal authority along with LGED worked to preserve the existing lake of the area named “Mishti Pukur”. Table 1 shows the relationship the condition of the waterbody and its use.

Table 1: Relation between condition of water body and purpose of use

Present condition of the water body	**Purpose of use**		
	Fishing (%)	**Domestic water supply (%)**	**No use (%)**
Fresh	16.67	6.67	10
Covered by aquatic plants	6.67	13.33	3.33
Odor nuisance	0	6.67	0
Total	23.33	36.67	13.33

Source: Field Survey, 2019

From Table 1 it is noticed that the maximum number of water body used for fishing purpose were well maintained. For daily household work the water with odor nuisance is used regularly which is bad for the health of the residents.

Before 2014 most of the residents of the municipality used tube well to meet the need of drinking water as well as for household purpose. In March 2014, the municipal authority together with Nabolok, a non-governmental organisation which worked for safe, portable water, installed some community tap for domestic water need. They also construct an over-head water tank with the help of the deputy commissioner along the bank of **“**Shorol Dighi”.

3.2 Drainage Condition

To maintain public health condition, it is the responsibility of the municipality to maintain an adequate drainage system by constructing, maintaining and clearing the drains within the municipality area for safe public health situation. Before discharge ensuring proper treatment of the drain water is also very important to maintain the environmental condition. The whole study area has good connectivity of "pucca" drainage network which is constructed by the municipal authority in 2000. But the residents of the area also suffering from some problem due to improper drainage system. Figure 2 represents the recurrence each type of drainage problem according to the respondents.

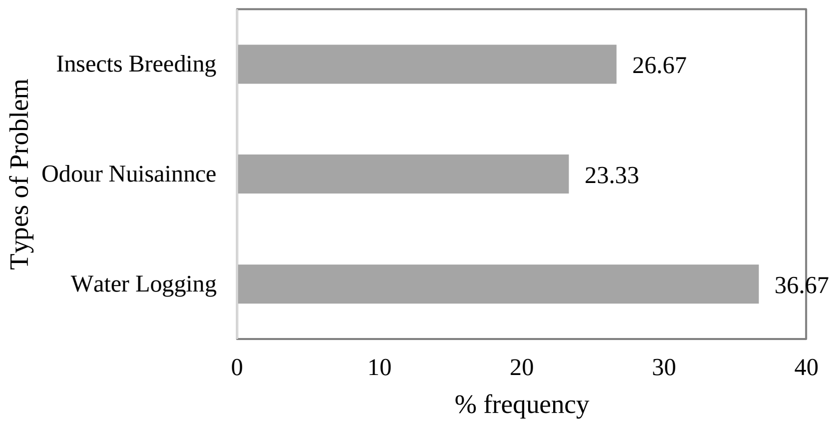

Figure 2: Effects of inadequate drainage
(Source: Author, 2019)

The problem which is faced most by the people is water logging and then insect breeding. Some people also found problem of odour due to inadequate drainage. Most of these problems arise as the existing condition of the discharging point of the drainage is vulnerable. The drainage network discharged all the waste water into the Shibsa River without any treatment which accelerates river pollution.

3.3 Solid Waste Management

Another key of public health and control of environmental pollution is proper management and safe disposal of solid waste generated from the area. Otherwise some common like low coverage, open dumping, irregular collection of wastes occurred which trigger environmental pollution. There are adequate number problems of community dustbin inside the area but most of the people (about 60%) said that they dumped their household wastes here and there, approximately 33.33% people said the wastes are thrown in dustbin. Very few people find some other way of disposing wastes. Table 2 shows the relationship the system of waste disposal and the distance of dustbin from the household.

Tabel 1:Relation between distance of dustbin and disposal system

Distance of dustbin (m)	**System of waste disposal**		
	Thrown here and there (%)	**Thrown in the dustbin(%)**	**Disposed in other way (%)**
<20	46.67	23.33	6.67
5	10	3.33	0
Total	56.67	26.67	6.67

Source: Field Survey, 2019

The Table 2 shows that most of the household have dustbin within 20 meters of their house i.e. there is adequate quantity of dustbin in the municipality but most of the people do not used it. Generally, they thrown waste along the roadside, on the pond side etc. Almost all the dustbins are provided by the municipality. The main reasons behind it is lack of concern of the residents and their previous habit as well as no maintenance of the dustbin by the municipality.

The municipal authority collects the wastes from the dustbins and finally dump those raw wastes into the bank of the Shibsa River.

3.4 Health Issue

Construction and maintenance of health and maternity centres, hospitals and dispensaries within the municipality area are the parts of promoting public health in the municipality. Weak management capacity always causes severe problems and worsens public health in the municipality.

There is only one hospital inside the area with capacity of 50 beds. The hospital is established on 1991 and later upgraded to 50 beds. The hospital is able to serve about 63% of the total municipality area.

Regular exercise is also very important to maintain a good physical and mental health. There are not enough facilities for performing physical exercise in the municipal area, only one park for children is there which is maintained by the municipality. According to the respondents 63.3% people have open space around their residence but only 26.7 % of them go to morning/evening walk daily. Figure 3 illustrate the causes of the people for not going to the existing park.

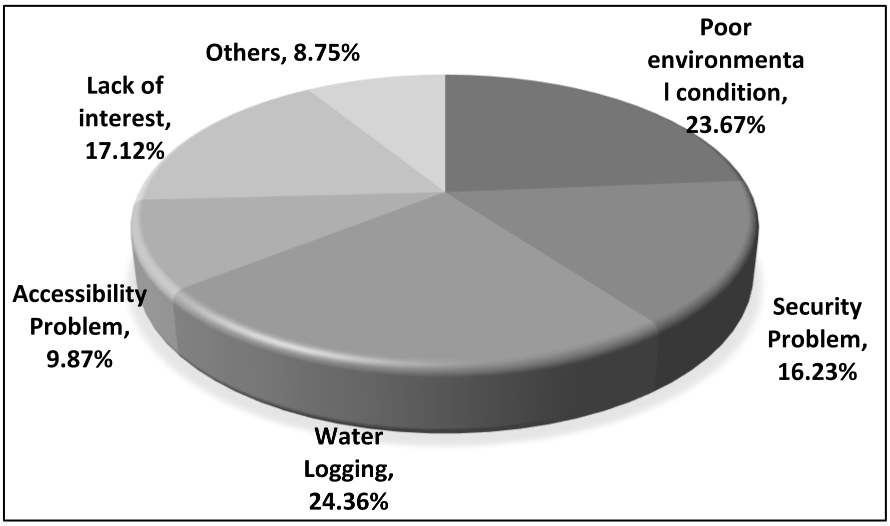

Figure 3: Causes of not going to parks,
Source: Author, 2019

3.5 Transport System

It is the duty of the municipality to control and regulate the traffic and public vehicles, constructing and maintaining public roads and other modes of communication for the favour of the local people. Almost all of the area have good connectivity of "pucca" road system.

Engineering section of the municipality authority mainly worked for the construction and maintenance of the roads of the municipality. LGED and Roads and Highway Department also worked along with the municipality authority for the maintenance and up gradations of the secondary roads.

Most of the residents of the area used non-motorized area vehicle for daily need to go to work which is beneficial for the environment as well as for the health of the local people.

Figure 4 shows the road network of Paikgacha municipality, which includes the main highway and other road types also.

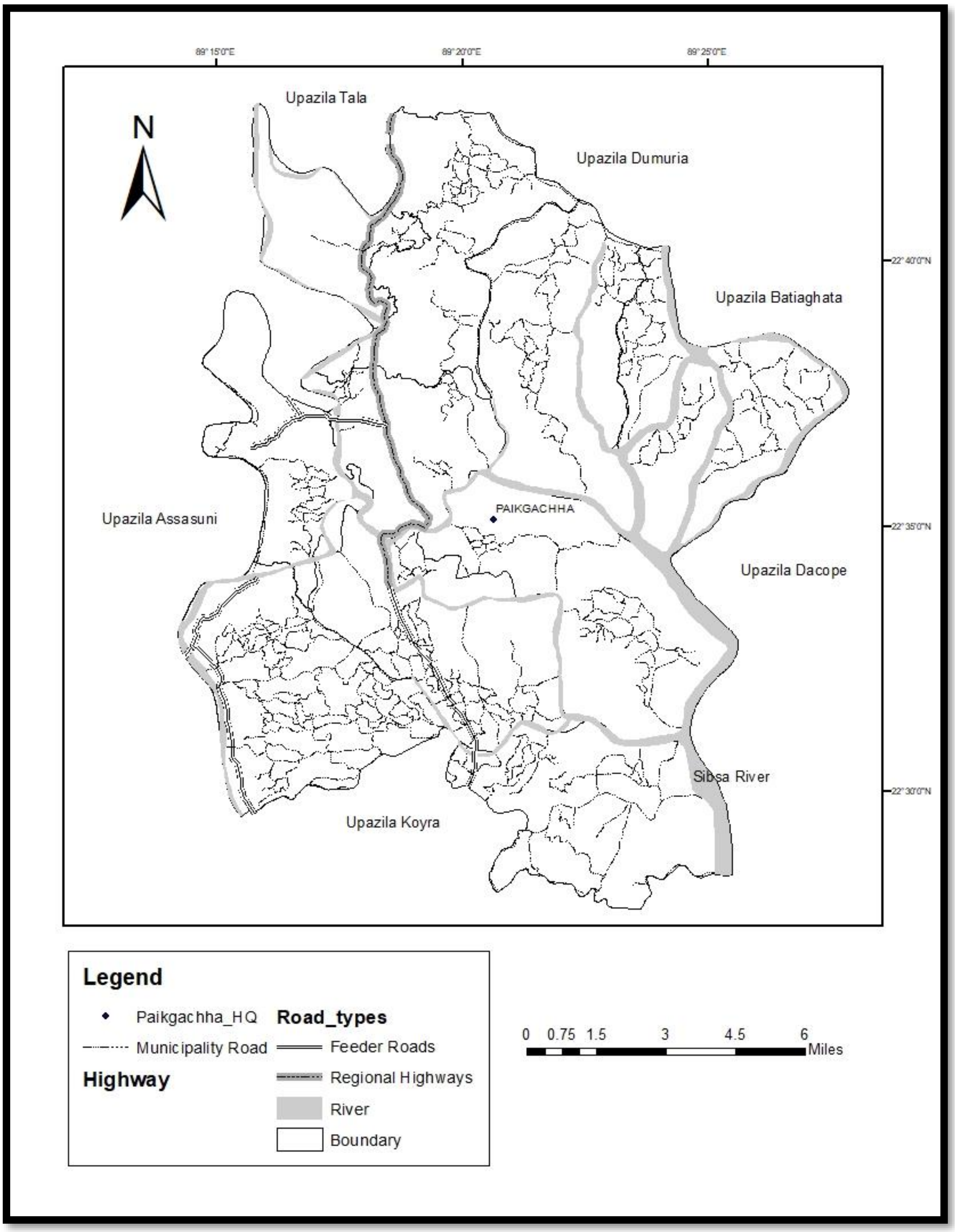

Figure 4: Road Map of Paikgacha Municipality
Source: Author, 2019

3.6 Industries of the area

The industries located inside the area are the main pollution sources. There are mainly three types of industry-rice mill, jute mill and a hatchery. During paddy processing in the rice mill, large amount of solid wastes, mainly rice husk, rice husk ash are produced and liquid wastes in the form wastewater. The major constituent of the waste generated from the jute mill are unspinnable jute fibre. The other constituents are batching oil, machine oil and grease, barks of jute plant and in-organic dirts. The hatchery is run by Bangladesh Fisheries Research Institute. Bagdha prawn and crab are mainly cultivated in the hatchery which are exported all over the country and even in abroad. The waste generated from the hatchery are mainly the uneaten feed and fecal droppings, fish that do not survive the culture process, chemicals in the form of medications, disinfectants, and antifoulants etc(Dauda et al., 2018). Figure 5 shows the areas that are being populated by the existing industrial activities.

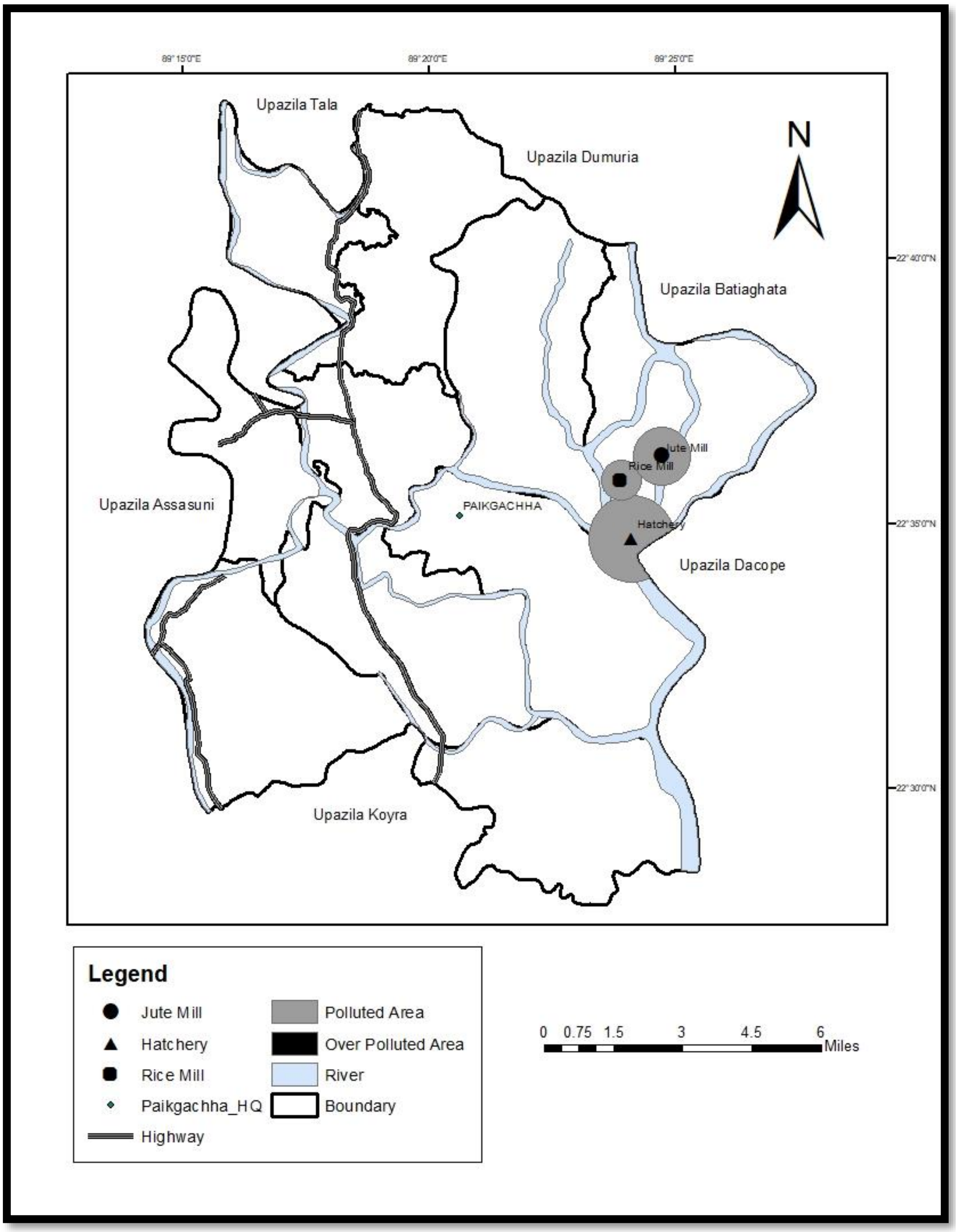

Figure 3: Influence of industry,
Source: Author, 2019

From Figure:5 it can be concluded that about 2.75% of the total area of the municipality are become polluted because of those three industries and 0.02% are over-polluted.

3.7 Homestead Garden

There are several environmental benefits of plantation within the house. Such benefits are creating habitats for native fauna, heat reduction, shading windows, reduce the speed and strength of winds, creating shelter for several microorganism and birds, improvement of air quality by removing carbon dioxide and returning oxygen to the atmosphere. Among the respondents about 63.33% have trees around their house. Most of them considered the economic benefit of trees and properly utilized their backyard and front yard area. The others do not mainly because of lack of space and time as well as interest.

4. CONCLUSION

Urban environment management is a standardized method of examining urban growth and environmental problems from the management and planning perspectives to contribute to the development of sustainable. It is one of the major responsibilities of a municipal authority to manage the urban environment of the area and minimize the effects of pollution on them. In this project the environmental details of Paikgachha municipality have been identified. The final result shows that currently, the overall environmental status of Paikgaccha municipality is moderate (27.75% of good condition and 19.38% of vulnerable condition) considering drainage condition, transportation, sanitation, waste disposal, waterbody condition etc. factors and seeks more monitoring and maintenance for its betterment.

- Three types of water bodies were found in the study area which play great role in the environmental management by providing water supply, act as natural drainage and a habitant of a large amount of species and micro-organisms. But the condition of those water body is not up to the mark, 33.33% of the total waterbodies are fresh, 30% are covered by aquatic plants and 16.67% have odor problem. The local people used this polluted water for daily uses even for cooking and other domestic use which is very threatening for their health.

- Almost the total area has pucca and semi pucca drainage system from 2000 but some drainage related problem still prevailed such as water logging, mosquito breeding in the area mainly due to lack of maintenance of the existing drainage network.

- Considering amount of negligence of the local people about their health and environmental issue are found. Most of the household have dustbin within 20 meters of their house but most of the people do not used it. Again 63.3% people have open space around their residence but only 26.7 % of them go to morning/evening walk daily. So, it is highly necessary to conduct awareness rising program in the area.

- From the study it is found that 2.75% of the total area of the municipality are become polluted and 0.02% are over-polluted because of the three industries- rice mill, jute mill and a hatchery.

Though the Paikgachha municipality authority keeps working for the management of the environment of that area, due to some technical and financial constraints they cannot give their best effort. Increasing the level of every municipalities management capacity of is a must to remove those constraints. The potentiality of the municipalities also needs to be addressed. Utilization of local resources, people oriented leadership and participation of people must be ensured alongside developing the management skill of municipality. This can ease the current pressure on the Paurashavas. And only then can they ensure a good quality of services and thereby a healthy and livable city.

ACKNOWLEDGEMENT

We wish to express our deepest thanks to the Municipality Authority of Paikgacha, Khulna as well as the local people of Paikgacha for providing data and information and for their assistance and interest in this study.

REFERENCES

Allen, A. (2003). Environmental planning and management of the peri-urban interface: perspectives on an emerging field. Environment and Urbanization, 15(1), 135-148. doi:ISSN 09562478. 15. 10.1177/095624780301500103.

Allen, A. E. (2002). Urban Environmental Planning And Management Reviewed From A Sustainability Perspective:Reform Or Transformation.

Bangladesh Bureau of Statistics. (2001). Bangladesh Population Census. Bangladesh Bureau of Statistics.

Bangladesh National Portal. (2019). Paikgasa Upazila. Retrieved from Bangladesh national portal: http://paikgasa.khulna.gov.bd

Banglapedia - the National Encyclopedia of Bangladesh. (2012). Paikgachha Upazila. Retrieved from Banglapedia - the National Encyclopedia of Bangladesh: http://en.banglapedia.org/index.php?title=Paikgachha_Upazila

CARBONE, A. S. (2015). THE MANAGEMENT OF GREEN AREAS IN THE MUNICIPALITY OF SÃO PAULO: ADVANCES AND LIMITATIONS. Ambiente & Sociedade, 201-220. Retrieved from https://dx.doi.org/10.1590/1809-4422ASOC1210V1842015

Chowdhury, M. S. (2012, January 22). Urban Local Government and Environmental Management in Bangladesh: A Study on Chunarughat Paurashava. Retrieved from https://ssrn.com/abstract=1989936

(2007). Cultural survey report of Paikgaccha Upazilla.

Das, P. (2018). An Introduction to the Concept of Environmental Management: Indian Context. International Journal of Innovation and Economic Development, 2(4), 25-34.

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S., & Akinwole, A. O. (2018). Waste production in aquaculture: Sources, components and managements in different culture systems. Aquaculture and Fisheries.

Encyclopaedia Britannica. (1998, July 20). Municipality. Retrieved from Encyclopædia Britannica: https://www.britannica.com/topic/municipality

Ghosh, A. &.-E.-S. (2003). Urban environment management : local government and community action. New Dehli: Institute of Social Sciences & Friedrich Ebert Stiftung.

Government of the Peoples' Republic of Bangladesh (GoB). (1977). The Paurashava Ordinance. Government of the Peoples' Republic of Bangladesh.

Marsh, D. (2012). Water resource management in New Zealand: Jobs or algal blooms? Journal of Environmental Management, 33-42.

School of Environment, Resources and Development. (2019). Urban Environmental Management. Retrieved from School of Environment, Resources and Development: http://serd.ait.ac.th/urban-environmental-management-2/

Shafqat, A. (2011, April). The role of the municipality in waste water management in Bahawalpur city. Management of Environmental Quality: An International Journal, 22(3), 282-291. doi:10.1108/14777831111122879

TREND ANALYSIS OF AIR QUALITY IN DHAKA CITY CONSIDERING METEOROLOGICAL PARAMETERS

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ABSTRACT

Dhaka with a population density of around 23,234 per square kilometer is experiencing major health impacts resulting from poor air quality (World population review, n.d.). The aim of this study was to understand the trend of air quality of Dhaka city considering meteorological and seasonal influences. The critical air pollutant for Dhaka city is particulate matter (PM), the primary sources of which are emission from brick kilns, vehicles, industries and re-suspension of dust. Analysis of data shows that the trend of air quality in Dhaka during the period 2012 to 2017 has a strong seasonal variation. Concentrations of both PM_{10} and $PM_{2.5}$ exceed national standard during winter by a large margin. Peak monthly average PM_{10} and $PM_{2.5}$ concentrations approach or exceed 200 µg/m^3 and 300 µg/m^3. Wind blowing from the north-western and western direction during dry season brings in pollutants from brick kiln clusters situated along northern to western periphery of the city. PM concentration decreases with the increasing of precipitation during rainy season which indicates that the water droplets settle down the ambient particulate matter. From the analysis, it is observed that the peak concentration of $PM_{2.5}$ goes slightly downward which could be due to improvement of brick kiln technologies and increasing use of CNG fuel. The concentration of $PM_{2.5}$ is slightly higher in Mirpur area possibly because of its close proximity to brick kiln clusters and ongoing infrastructure development activities.

Keywords: *PM, CAMS, Rainfall, Brick kilns, Trend*

1. INTRODUCTION

Dhaka, capital of Bangladesh, due to industrialization and urbanization processes polluted air quality. A five-year survey by the department of environment found Narayanganj has the most polluted air, followed by Dhaka. Third is Gazipur, which is followed by Rajshahi, Chattogram, Khulna, and Barisal. The air in Sylhet city, however, is cleaner. The survey was done between 2013 and 2018 with funds from the World Bank. Even though Dhaka came out second worst in the country, the World Health Organisation (WHO) in 2018 said Dhaka was the world's third worst city in terms of air pollution, behind Delhi and Cairo (Brick kiln top polluter, n.d.). Among all the criteria pollutants, Particulate Matter is of main concern as it causes several respiratory diseases such as acute respiratory distress, asthma, chronic obstructive pulmonary disease, and lung cancer. So, the parameters related to the concentration of PM need to be analyzed.

According to the data concentration of PM collected from CAMS at three location of Dhaka city, a trend can be seen over the past decade. The geographical location of Dhaka and meteorological parameters are important variables in controlling the concentration without considering the sources of PM. Due to adsorptive characteristics of rainfall, the concentration is reduced during monsoon. Wind coming from East-North direction brings PM originated most probably from brick-kilns. Sources of PM concentration are related with construction or industrial productions. Ziaul Haque, DoE director for air quality management, said that in 2017-18 fiscal year, half the air pollution in Dhaka was caused by brick kilns while construction work contributed around 25 percent and vehicle emission 10-12 percent (Brick kiln top polluter, n.d.).

A statistical analysis of concentration and meteorological parameters is a way of finding the relation among the variables and trend. A downward trend can easily be observed from the analysis at three locations of CAMS in Dhaka city. Both PM_{10} and $PM_{2.5}$ concentrations exhibit levels exceeding the World Health Organization (WHO) guidelines; they also exceed the national standards of annual PM_{10} (50 µg/m^3) and $PM_{2.5}$ (15 µg/m^3) by a factor of over two. On the basis of polluted air quality with the presence of particulate matter Dhaka is ranked as 45th among the 3000 cities of 103 countries (WHO, 2016).

2. METHODOLOGY

The trend analysis is based on the PM data collected from DoE (Department of Environment). 24-hr average concentrations of $PM_{2.5}$ and PM_{10} were measured at the CAMS and the daily and monthly data are available from April 2002 to December 2017. Data of last decade is taken to study the trend of concentration of PM. Meteorological data (Rainfall, Average temperature, Humidity, Wind direction and Wind speed) was collected from Bangladesh Meteorological Department because daily data of all the parameters are not available from DoE. The relation between PM and meteorological data are established using MS excel. The trends of PM of CAMS were obtained from plotting bar diagram using same software.

3. ASSESEMENT OF AIR QUALITY TREND IN DHAKA CITY AND EFFECTS OF METEOROLOGICAL FACTORS

Reliable air quality data is a prerequisite for air quality modelling and for development of policy options for managing air pollution and its adverse impacts. As most of the time particulate matter ($PM_{2.5}$) become “critical pollutant”, correlation of ambient PM with different meteorological parameters like rainfall, average temperature, humidity, wind speed and direction etc. have been analysed to understand their effects on ambient PM concentration.

3.1 Trend of Particulate Matter

From the monthly average PM data collected from three CAMS of Dhaka city, a regular pattern of variation of the concentration of PM with seasons was observed. Figure 1, 2 and 3 show the daily average concentration of $PM_{2.5}$ and PM_{10} from 2012 to 2017 at Sangshad Bhaban CAMS, BARC CAMS and Darussalam CAMS respectively. It shows that both $PM_{2.5}$ and PM_{10} values are well above the national standard during the dry season (November to March), while during the wet season (April to October) these concentrations comfortably meet the standards. These seasonal variations are seen in almost all the years for which data are available. From October the concentration starts to increase much and reaches peak around January. Then from February the concentration starts to decrease. From April when wet season starts the concentration become lower.

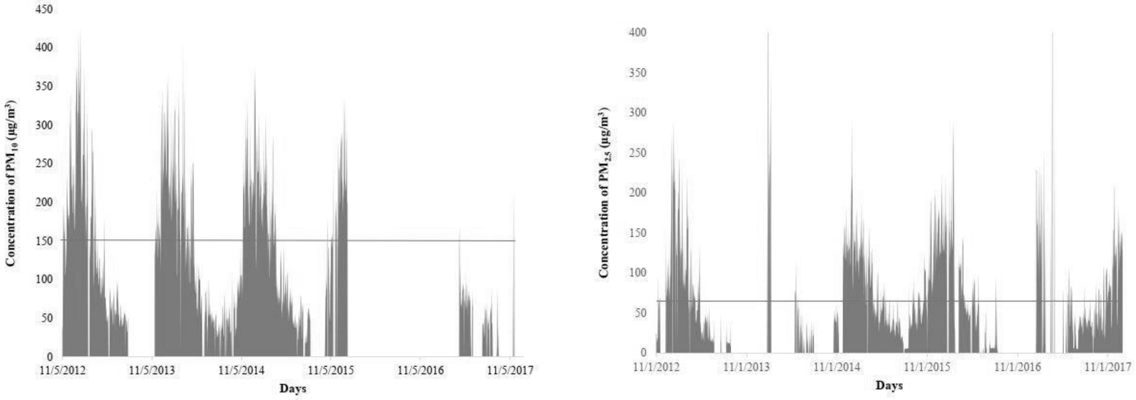

Figure 1: Daily average concentration of PM_{10} and $PM_{2.5}$ of Shangshad Bhaban CAMS

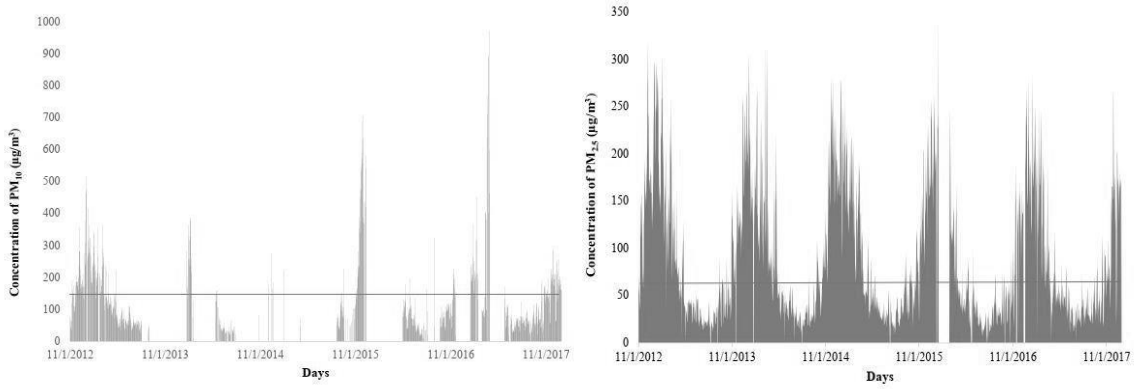

Figure 2: Daily average concentration of PM_{10} and $PM_{2.5}$ of BARC CAMS

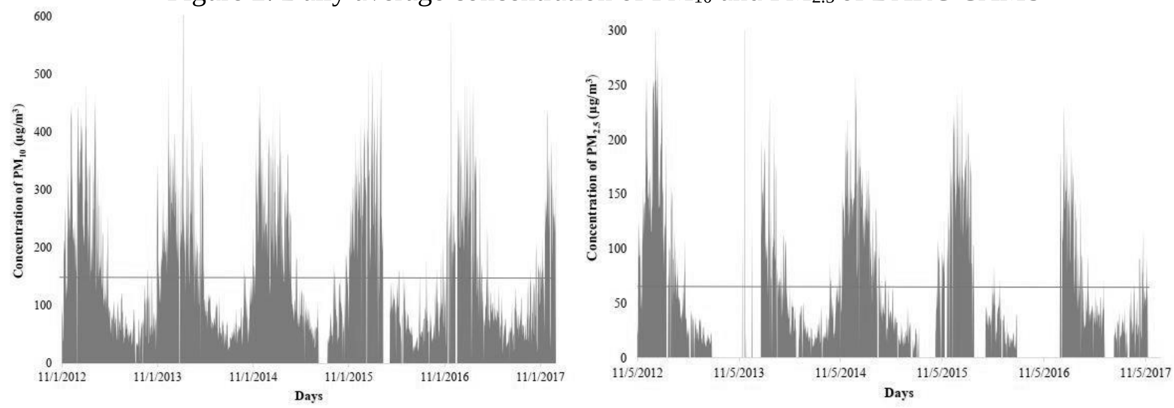

Figure 3: Daily average concentration of PM_{10} and $PM_{2.5}$ of Darussalam CAMS

3.2 Effects of Meteorological Parameters

3.2.1 Relation of PM with Precipitation

Precipitation has a significant impact on $PM_{2.5}$ and PM_{10} concentrations. From daily average concentrations of $PM_{2.5}$ and PM_{10}, we observed a huge variation of concentrations during dry season (November to March) and during wet season (April to October) (Figure 1, 2 and 3). The average concentrations of both PM are very high during dry reason relative to the wet season. One of the possible reasons behind this variation is that the water droplets settle down the ambient particulate matter in wet season.

Besides, from figure 4 a negative correlation is observed from the scattered plot of $PM_{2.5\text{-}10}$ vs rainfall. With the increase of the amount of precipitation the concentration of particulate matter decreases. It indicates that the amount of precipitation has a great impact on reducing the amount of ambient particulate matter in air. The correlation between the number of days of occurring rainfall and $PM_{2.5\text{-}10}$ are also significant (Figure 5). These two graphs show that both the amount of rainfall and number of rainy days have major impact on the decrease of particulate matter in ambient air.

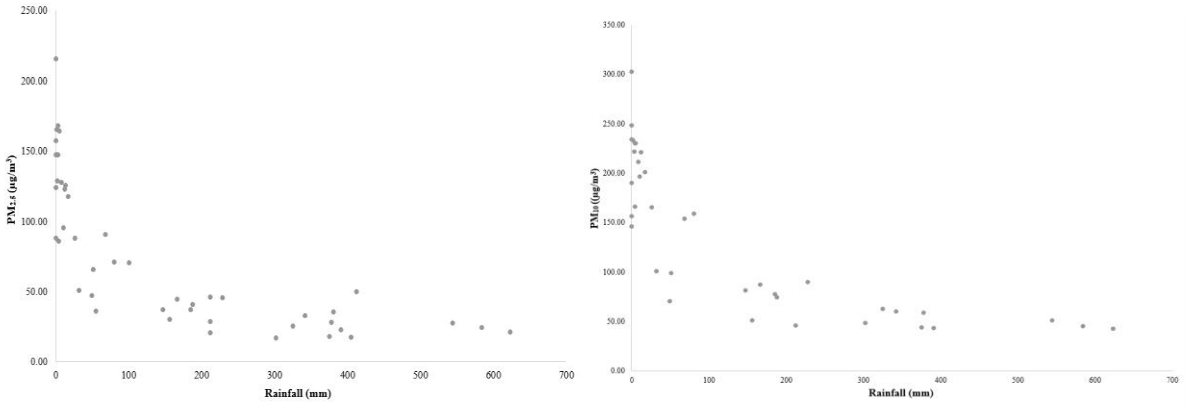

Figure 4: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against monthly average rainfall in Dhaka City

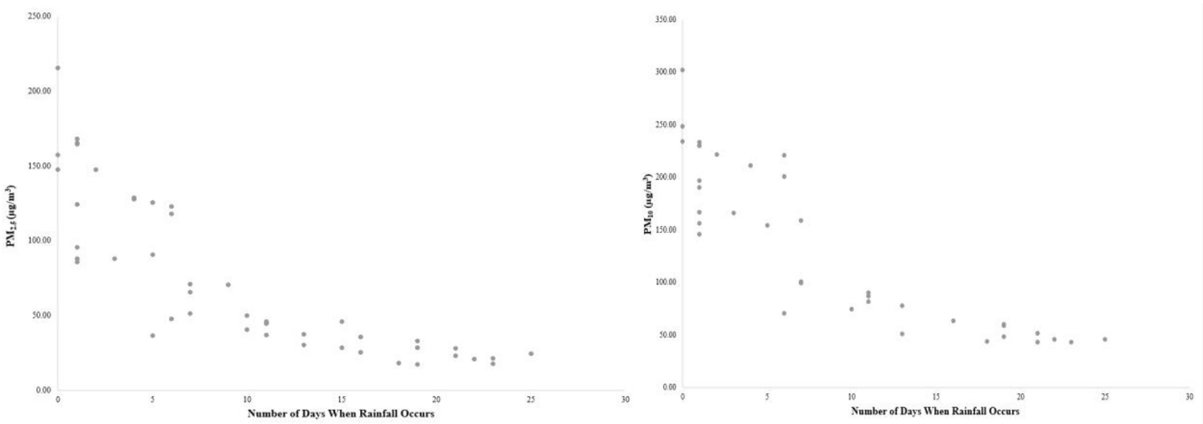

Figure 5: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against the number of rainy days in Dhaka City

3.2.2 Relation of PM with Temperature

There is a significant negative correlation of PM with average temperature. Seasonal variation is indicated by average temperature. From Figure 6 we can observe that when temperature is low, concentration of PM is high. By low temperature winter season is indicated when no rainfall occurs which helps to settle the suspended particulate matter in ambient air. Besides high concentration of PM tends to reduce atmospheric temperature due to its net negative radiative forces.

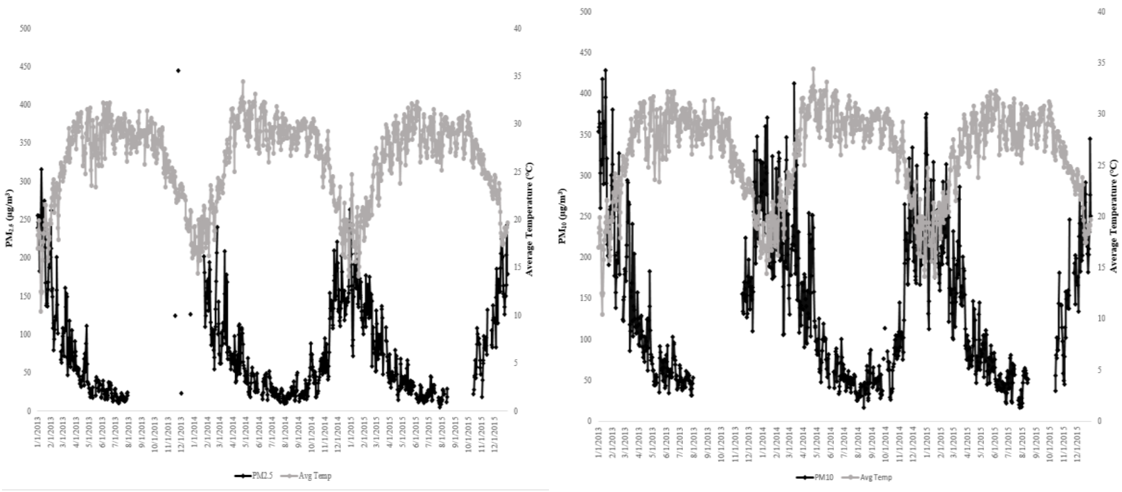

Figure 6: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against average temperature in Dhaka City

3.2.3 Relation of PM with Humidity

We can see the Relation of particulate matter with average humidity in Figure 7. There exists no significant correlation between the concentration of PM. So, we can say that humidity has no significant impact on ambient particulate matter.

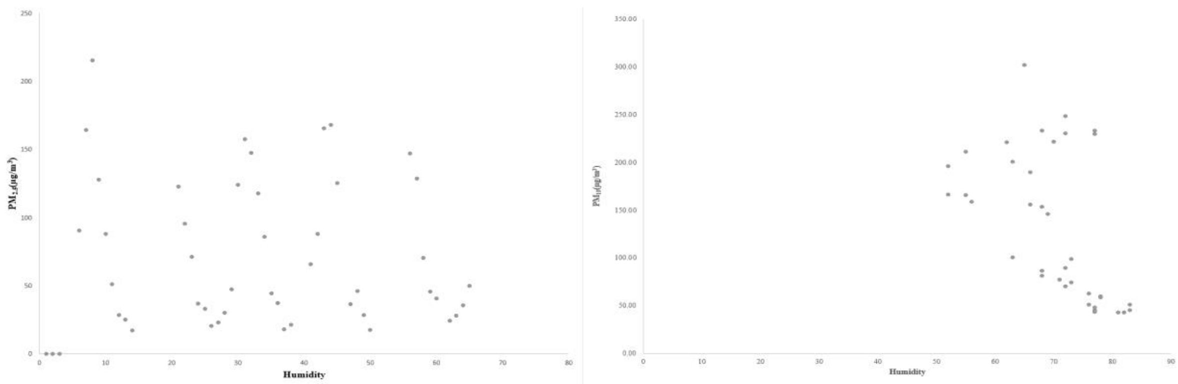

Figure 7: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against average humidity in Dhaka City

3.2.4 Relation of PM with Wind Speed and Direction

The air pollutants can get airborne from the ground surface (e.g. re-suspension of particulates due to vehicular movement in the urban environment), they can be emitted from an elevated stack (e.g. emission from a brick kiln) and they can be formed in the atmosphere (secondary PM). Their residence in the atmosphere and transport are controlled not only by the rate of emission/ formation but also by certain physical parameters such as wind speed and direction. The direction and speed of the prevailing wind may significantly affect the concentration, distribution and translocation of the particles (Giri, 2008; Van der Wal, 1996, 2000). Wind speed and direction provide real-time information on pollutant transport in a region and can be used to assess the relationships between sources and pollutant levels.

In order to understand whether wind speed has any bearing on the PM concentrations of Dhaka city, the wind speeds were plotted against the corresponding daily $PM_{2.5}$ and PM_{10} concentrations and the scatter plots are shown in Figure 8. However, this plot indicates that wind speed does not appear to have a significant influence on PM concentration in Dhaka.

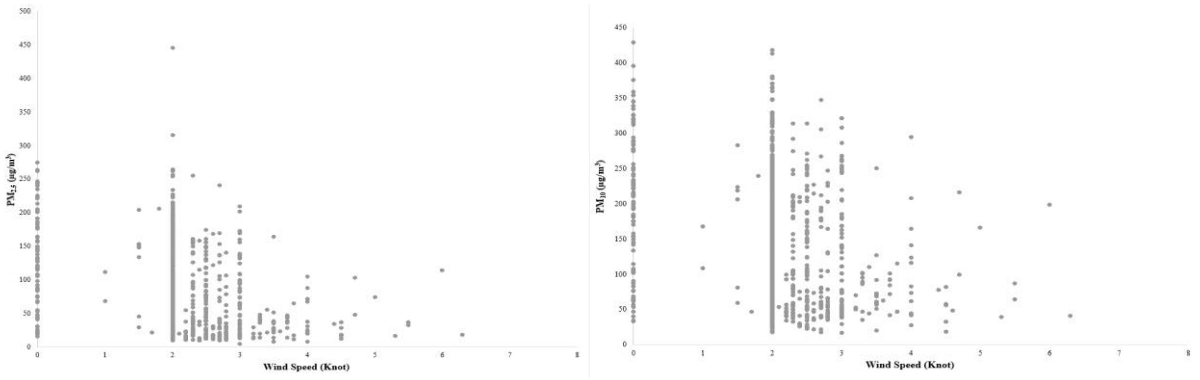

Figure 8: Scattered plot of monthly average concentration of $PM_{2.5}$ and PM_{10} against wind speed in Dhaka City

The two radar plots for Dhaka city in Figure 9 shows that the predominant wind direction for dry and wet periods are north-west (NW) and south (S) / south-east (SE) respectively. In order to study the effect of wind speed and direction on PM concentrations, the dry period dataset during 2013-2017 (from November to April) has been used. The wet period was not considered in the analysis because the major pollution sources located outside the city boundary (i.e. the brick kilns) remain closed during that period.

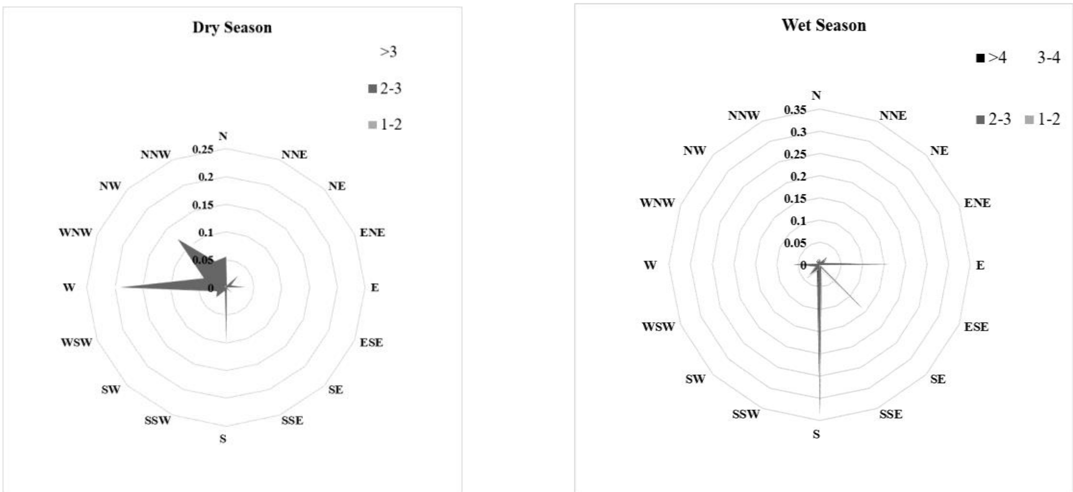

Figure 9: Radar plot of wind direction and speed of Dry season and Wet Season in Dhaka City

The radar plot in Figure 10 shows in the dry period, PM shows higher concentrations when winds come from north-west direction. This is expected as the major brick clusters of Gazipur, Savar and Dhamrai are situated along the northwestern periphery of Dhaka city (Figure 11), and wind blowing from those directions will likely carry the particulate pollution load. The strong association between wind blowing from the north and northwestern direction and PM concentrations supports the hypothesis that during the dry period brick clusters of Gazipur, Savar and Dhamrai significantly dominate the air quality of Dhaka city.

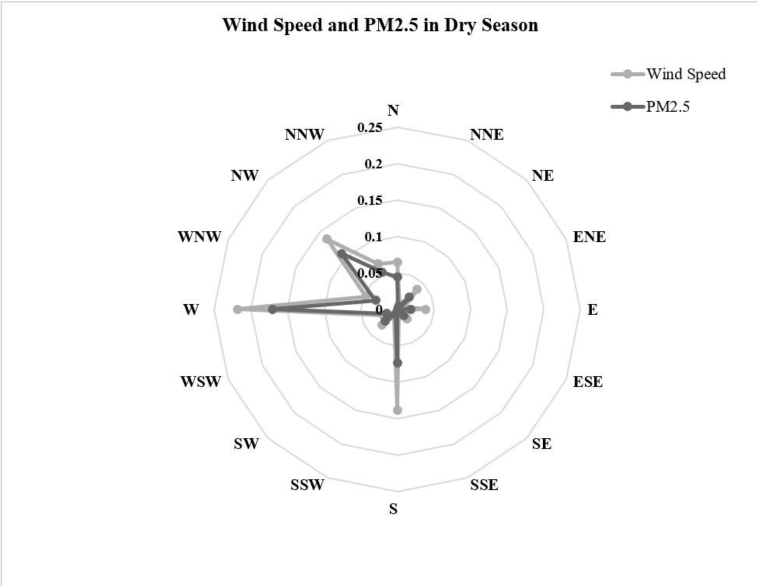

Figure 10: Radar plot of wind direction and $PM_{2.5}$ concentration of dry season in Dhaka city

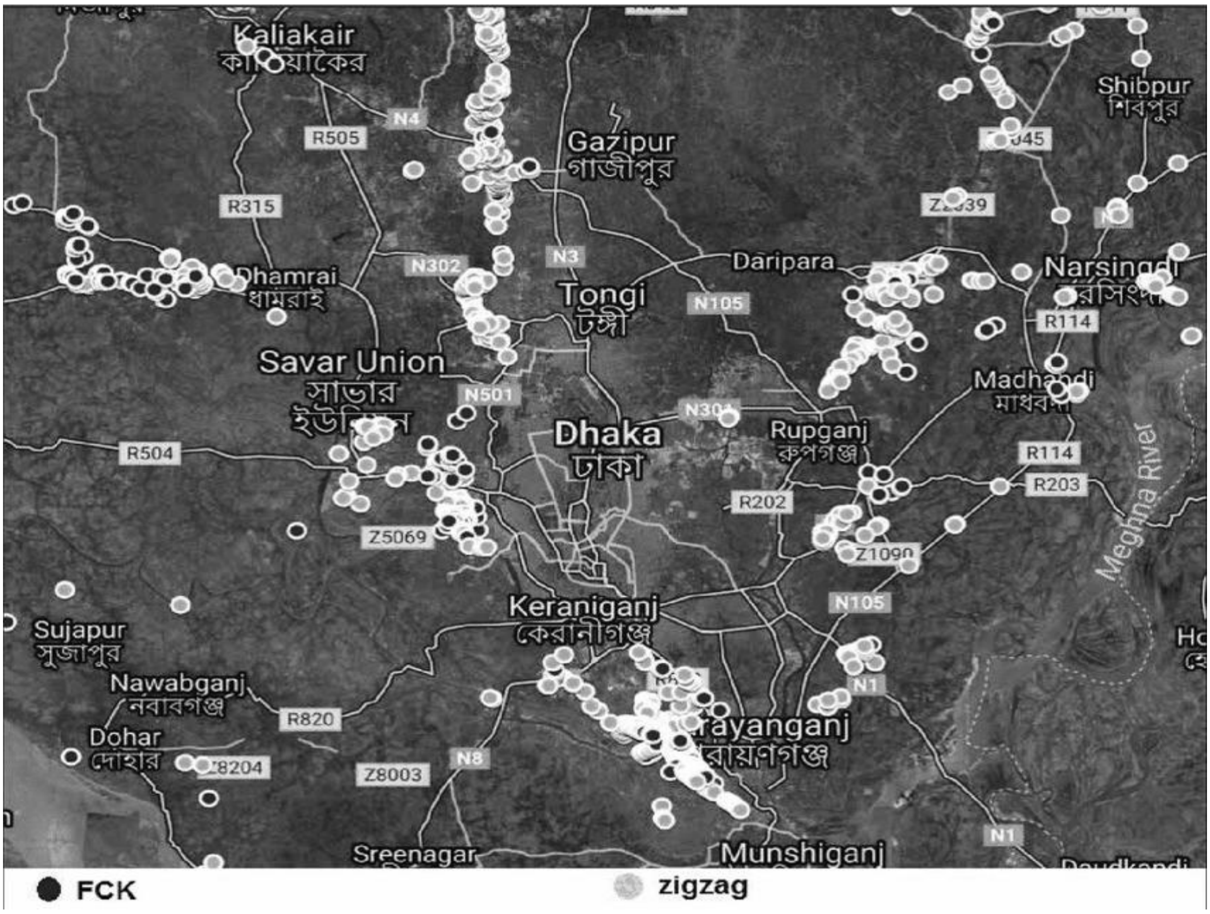

Figure 11: The brick kiln density around Dhaka city (Source: DoE)

3.3 Probable Reason Behind Observed Trend

The major cause of the increase of concentration of PM in dry season in Bangladesh is the brick kilns operated in fry season only. Operation of brick kilns starts from October and continues up to April. The concentration of PM suddenly increases significantly from November and its concentration is higher from November to March.

Though there is a periodic change of concentration of PM occurs with seasonal change but the annual peak concentration of PM shows descending pattern in spite of increasing the number of industries, brick kilns, transports etc. The probable causes behind this are the use of modern technology and equipment in industries, modernization of brick kilns, use of environment friendly fuel in transport etc. As the peak concentration of PM occurs in dry season, so we can say that modern environment friendly technology like zigzag, hybrid Hoffman, tunnel kiln, alternative technology used in brick kilns has a great significance on it.

4. CONCLUSIONS

The main target of this study was to analysis the trend of air quality in Dhaka considering the change of concentration of PM which has the concentration beyond standard and so having much effects on AQI. Major conclusions from the present study are as follows:

a. Air quality trend-
   i. The trend of the concentration of particulate matter show a sinusoidal variation, which increases beyond standard during winter season and decreases during rainy season.
   ii. The peak concentration of particulate matter shows a slightly downward slope which may occurs due to improvement of brick kiln technologies.
b. Effect of meteorological Parameters on air quality-
   i. The scattered plot of $PM_{2.5}$ and PM_{10} with precipitation indicates a negative correlation which may occur due to settlement of the suspended particulate matter by water droplets in rainy season.
   ii. The scattered plot of $PM_{2.5}$ and PM_{10} with temperature indicates the increase of $PM_{2.5\text{-}10}$ concentrations in low temperature. Low temperature indicates winter season when brick kilns are operated, which is a major source of emission of particulate matter.
   iii. The scattered plot of $PM_{2.5}$ and PM_{10} with relative humidity indicates there is no significant effect of humidity on the concentration of $PM_{2.5\text{-}10}$.
   iv. The north-western wind in dry season brings the pollutants from brick kiln clusters situated along northern to western periphery of Dhaka city.

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REFERENCES

AQMP, Department of Environment, Air Quality Data, Agargaon, 2012-2017.

AQMP, Department of Environment, Air Quality Data, Farmgate, 2012-2017.

AQMP, Department of Environment, Air Quality Data, Mirpur, 2012-2017.

DoE, Brick Kilns data up to 2018.

Brick kiln top polluter. (n.d.). Retrieved from https://www.thedailystar.net/frontpage/news/brick-kilns-top-polluter-1701871

Giri, D., Murthy, K. V., & Adhikary, P. R. (2008). The Influence of Meteorological Conditions on PM_{10} Concentrations. Kathmandu Valley. Int. J. Environ. Res., 2(1), 49-60, ISSN: 1735-6865.

Van der Wal, J. T., & Janssen, L. H. J. M. (1996). How contribute emission of PM_{10} and meteorology to concentrations of fine particles. Netherlands. J. Aerosol Sci., 27, S681–S682.

Van der Wal, J. T., & Janssen, L. H. J. M. (2000). Analysis of spatial and temporal variations of PM_{10} concentrations in using kalman filtering. Netherlands. Atmos. Environ., 34, 3675–3687.

World Health Organization (2006), WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005, Summary of Risk Assessment, World Health Organization, Geneva, Switzerland.

World Health Organization (2016), Review of Evidence on Health Aspects of Air Pollution: Final Technical Report, available at: www.euro.who.int

World population review. (n.d.). Retrieved from http://worldpopulationreview.com/world-cities/dhaka/

COMPOSTING OF TANNERY LIMED FLESHING

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ABSTRACT

Leather processing involves the conversion of putrescible hide/skin into imputrescible leather. During leather processing, huge amounts of wastes e.g., solid, liquid and gaseous air pollutants are produced. Limed fleshing is one of the major proteinaceous solid waste which is produced in fleshing operation, tannery. The generated fleshing is usually kept indiscriminately inside or outside of the industrial area which causes environmental pollution. In this study, an investigation is carried out for composting the limed fleshing with other matrixes. In the composting period, samples were regularly collected for conducting different physicochemical tests. The final composts were tested for determining nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) content. The obtained data were compared with the standard value. Results indicate that compost produce from the limed fleshing the nutrient NPK was within the standard level except for S. The compost could be used as agricultural purposes. The initiative could reduce pollution load generated through the tannery.

Keywords:*Tannery, Limed fleshing, Composting, NPKS.*

1. INTRODUCTION

The global concern of environmental changes with industrialization and agricultural development have become an important issue (Abedin, Akter & Arafin, 2015). Bangladesh is a developing country. In Bangladesh, tannery plays a vital role regarding gross output, value addition, export earnings. Tanning converts putrescible raw hide/skin into imputrescible leather (Covington, 2016). Tanning is a complex procedure comprising of several technological steps; each and every step-in leather processing generates a significant amount of solid and liquid wastes as well as gaseous air pollutants. Due to environmental pollution, the Department of Environment (DoE), Bangladesh has been categorized the tannery as 'red' category industry.

In various stages of leather processing, tanneries generate a significant amount of solid wastes.In tannery at beam house fleshing is one of the most indispensable mechanical operations where substantial amounts of inevitable solid waste (fleshings) are produced.In leather making, based on the according to the data received from the studies of several researchers, approximately 200 kg of leather is manufactured from 1 ton of wet-salted skin/hide (Veeger, 1993) andmore than 600 kg is generated as solid wastes during the transformation of raw skin/hide into leather (Boopathy, Karthikeyan, Mandal & Sekaran, 2013). It is reported that fleshings are the 50-60% of total solid wastes generated in the tanning industry (Kanagaraj,Velappan, Babu & Sadulla, 2006). In Bangladesh, yearly 33.80 thousand tons wet salted cowhide and 24.80 thousand tons wet salted goatskin are taken for leather production in which 10.3×10^3 MT fleshings from the wet salted cowhide and 9.8×10^3 MT fleshings from the wet salted goatskin are generated during fleshing operation (Hashem, Nur-A-Tomal & Mondal, 2015).Fleshing contain alkaline pH (12.3±0.2), fat 4-18%, protein 5-7%, lime 2-6%, sulphide 2-4% (Lupo, 2006).

Tannery solid waste (fleshings) management has become a major environmental issue in Bangladesh. Till today, numerous works have been done to utilize the limed fleshings. Limed fleshings waste are widely used as a fat liquor in leather processing (Nasr, 2017). Extracted fat from cowhide limed fleshings in the tannery for soap production is a significant tannery solid waste management (Hashem & Nur-A-Tomal, 2015). Also, limed fleshing is used for the production of glue and gelatine to keep the environment clean (Kanagaraj,Velappan, Babu & Sadulla, 2006). Tannery limed fleshings has been utilized to produce compost using bacteria (Ravindran & Sekaran, 2010). Till now, composting is not so much popular for the utilization of limed fleshings. At the present time, composting is the better option of solid waste management especially organic solid waste than all other options. various microorganisms break down organic matter into the simpler nutrient-rich product, which is used as a soil conditioner. It is much better than chemical fertilizer because it is not associated with any kind of risk.

In this study, the preparation of compost using cow dung and limed fleshing with different ratio ensuring anaerobic condition. Anaerobic digestion constitutes one of the most efficient biological methods by which emissions of GHG, particularly ammonia and methane (Holm-Nielsen, Seadi & Oleskowicz–Popiel, 2009) can be reduced, with the additional benefit of energy recovery through the production of biogas, a renewable fuel composed mainly of methane (50-80% volume fraction) and carbon dioxide (Tambone,Scaglia, D'Imporzano, Schievano,Orzi & Salati 2010). This gas can also be used to produce electricity or heat, or as vehicle fuel (Holm-Nielsen, Seadi&Oleskowicz-Popiel, 2009). Composting depends on the pH, moisture content and temperature.

In the present day, an attempt was made to utilize the limed fleshings for making compost at cost-effective technique ensuring environment friendly solid waste management. The main aims of this study are (i) developing environmentally solid waste management by preparing to compost from limed fleshings which is used as organic compost for the agricultural field, (ii) To contribute to the environment by means of cleaner leather production.

2. METHODOLOGY

2.1 Sample Collection

Cowhide limed fleshing were collected from the tannery at Khulna, Bangladesh. Just after fleshing operation, limed fleshing was put in a polyethylene bag and brought back to the laboratory immediately for experimentation. Cow dung was collected from the house of a local habitant of Teligati, Fulbarigate, Khulna. For the germination test, Pepper seeds, Gourd seeds, coriander seeds were collected from Doulatpur bazar, Khulna.

2.2 Sample Preparation

After the collection of limed fleshings, it was chopped into very small pieces and mixed with cow dung in anaerobic condition with the different ratio which is shown in Table 1.

Figure 1: Sample preparation using limed fleshing and cowdung

Table1: Ratio of cow dung and fleshing

ID	Composition	Ratio
CF11	Cow dung: fleshing	1:1
CF21	Cow dung: fleshing	2:1
CF31	Cow dung: fleshing	3:1
CF41	Cow dung: fleshing	4:1

Then the above-stated composition was put into the polybags and kept underground for anaerobic degradation. The compositions were withdrawn from underground after16 days and kept for rest until the smell is removed. The CF11, CF21, CF31, and CF41 seems to the proper conditions for composting.

2.3 Reagents

0.2N sulphuric acid, 4% boric acid, 40% sodium hydroxide, molybdo-vanadate, 1N ammonium hydroxide, mono-calcium phosphorus, 25% nitric acid, acetic-phosphoric acid, barium sulphate, barium chloride and gum acacia-acetic solutions were used for determining different species in this study.

2.4 Determination of Moisture Content

The moisture content of the samples was determined by the oven-dried laboratory method. A container was cleaned with lid dry it and weigh it. Then a sample was taken into the container and weighed with lid and the sample was dried to constant weight maintaining the temperature between 105°C to 110°C for a period varying with the type of sample but usually 16 to 24 hours. Finally, the constant weight was recorded for the container with the dried sample.

2.4.1Reconciliation of Moisture Content

2.4.1.1 Conditioning of CF11

Maintaining standard moisture content for compost the whole amount of CF11 sample i.e.167 g of CF11 e.g. the mixture of dried cow dung and fleshing were taken. 64 g water in the mixture of the sample was added for ensuring required moisture content. Then the sample and the water were mixed well.

2.4.1.2 Conditioning of CF21

Maintaining standard moisture content for compost the whole amount of CF21 sample i.e.167 g of CF21 e.g. the mixture of dried cow dung and fleshing were taken. 64 g water in the mixture of the sample was added for ensuring required moisture content. Then the sample and the water were mixed well.

2.4.1.3 Conditioning of CF31

Maintaining standard moisture content for compost the whole amount of CF31 sample i.e.170 g of CF31 e.g. the mixture of dried cow dung and fleshing were taken. 60 g water in the mixture of the sample was added for ensuring required moisture content. Then the sample and the water were mixed well.

2.4.1.4 Conditioning of CF41

Maintaining standard moisture content for compost the whole amount of CF41 sample i.e.140 g of CF41 e.g. the mixture of dried cow dung and fleshing were taken. 55 g water in the mixture of the sample was added for ensuring required moisture content. Then the sample and the water were mixed well.

2.5 Determination of pH

The pH of the conditioned samples (a mixture of fleshings and cow dung) was measured by using the pH (UPH-314, UNILAB, USA) meter. Before measuring the pH, the meter was calibrated with the standard buffer solution.

2.6 Determination of Nitrogen Content

Total Nitrogen content of the compost sample was estimated by the micro-Kjeldahl method as per the procedure suggested by AOAC (1995). The compost sample was digested by adding sulphuric acid in the presence of a catalyst at the temperature between 360-410°C. Then, the digested sample was heated by passing steam at a steady rate and the liberated ammonia absorbed of 4% boric acid containing mixed indicator solution kept in aconical flask with the absorption of ammonia, the pinkish colour was turned to green. Finally, the green colour distillate was titrating with 0.02N sulphuric acid and the colour changed to original shade (pinkish colour).

2.7 Determination of Phosphorus Content

Phosphorus content of the compost sample was estimated by spectrophotometric molybdo–vanadate method. For ensuring the standard value of phosphorus content, it is important to determine the P content of the compost. The compost sample solutions were mixed with molybdo–vanadate reagent was added makes up the volume with transmittance/absorbance was read at 420 mμ (blue filter). Finally,ammonium molybdate vanadate solution was added and then shaken the content and turned into the yellow colour complex.

2.8 Determination of PotassiumContent

The potassium content of the compost sample was determined by extracting the soil with neutral normal ammonium acetate solution. The compost sample solutions were taken in a different volumetric flask and 5g of the sample was added to the flasks with 25 mL 1N ammonium hydroxide.

Then the solution was shaken for 5 minutes and then filtered through Whatman No.1 filter paper. Now, the potassium extract was measured by flame photometer after calibration.

2.9 Determination of SulphurContent

Sulphur is estimated by the turbidimetric method. For ensuring the standard value of S content, it is important to determine the S content of the compost. The compost sample was mixed with monocalcium phosphorus ensuring shaken for one hour and filtrated through the Whatman No. 1 filter paper. After filtration, the filtrate mixed with nitric acid, acetic phosphorus acid and barium sulphate ensuring the precipitation of barium chloride. Then gum acacia–acetic acid solution was added and measured the colour intensity at 440 nm (blue filter).

2.10 Germination Test

Germination is the process by which an organism grows from a seed or similar structure. The most common example of germination is the sprouting of a seedling from a seed of an angiosperm or gymnosperm.The visual test of the compost was carried out by sowing seeds in compost with the soil. The soil was mixed with all the samples of compost in different ratiose.g., CF11: Soil (1:1), CF11: Soil (1:2) and CF11 (1:3) in the crocks same as for others.Approximately 5-6 pieces of pepper seeds and two pieces of gourd seeds were added in the composts which were placed 2-3 cm below from the surface with ensuring sprinkling water on the mixtures for keeping observation of germination.

3. RESULTS AND DISCUSSION

3.1 NPKS in Compost

In Figure2 depict the nutrient content of the final compost. The maximum N content (3.1%) was found in the CF31 and N content (2.1%) found in CF21 isminimum comparing other samples i.e. CF11 and CF41 whose have N content 2.3% and 2.4%, respectively. Inorganic phosphorus (P) was another important nutrient in compost which is presented in a maximum amount (2.5%) in CF41 and found minimum content (2.0%) in CF11. Also, P content in CF21 and CF31 are 2.2% and 2.4% which is gradually increased with the amount of cow dung.

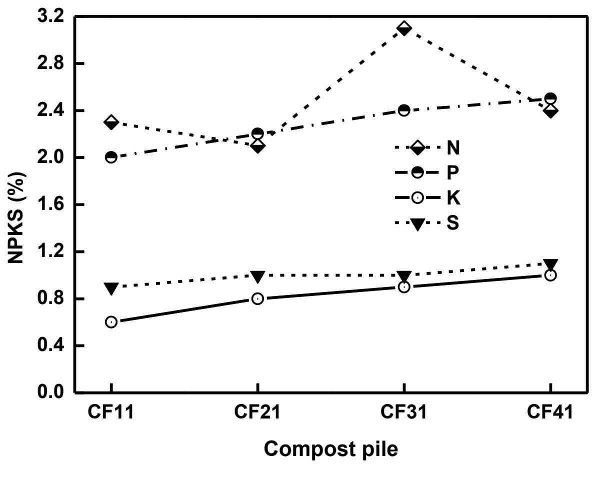

Figure 2: NPKS content of the compost

Also, Figure 2 also shows the Potassium (K) content in compost in percentage (%). The maximum K content (1.0%) present in CF41 and minimum content (0.6%) of K show in the CF11. Also, K content in other samples of compost i.e. CF21 have 0.8% and CF31 have 0.9%. Sulphur (S) is a significant nutrient for plant growth. The dotted line with triangle represents the S content in the compost. Among the different types of sample composition, the maximum S content (1.1%) was found in the CF41 and the compost sample named CF21 and CF31 both have same S content (1.0%) which is minimum.

3.2 Nutrient comparison with standard

Table 2 shows the nutrient content of the final compost. In CF11 (CD: LF=1:1), the nutrient N, P, K and S content were 2.3%, 2.0%, 0.6% and 0.9%, respectively. The three nutrients for the all ratio of CD: LF (Cow dung: limed fleshing) i.e. NPK meet the standard value (N= 0.5-4.0%; P= 0.5-3.0% and K= 0.5-3.0%) as declared by the Bangladesh Government. Although the S value was higher than the standard value (S=0.1-0.5%). It may be the reason is that limed fleshing content higher amount of sulphide. The pH for the CF11, CF21 and CF31 was 7.6, 8.4 and 8.5, respectively. Only the pH of CF41 (8.8) was at the closed margin.

Table2: Tested results of NPKS for the final compost

Parameters	**CD: LF (**1: 1)	**CD**:**LF(**2: 1)	**CD**:**LF (**3: 1)	**CD**:**LF(**4: 1)	**Standard**	**Unit**
pH	7.6	8.4	8.5	8.8	6.0-8.5	-
N	2.3	2.1	3.1	2.4	0.5-4.0	%
P	2.0	2.2	2.4	2.5	0.5-2.0	%
K	0.6	0.8	0.9	1.0	0.5-3.0	%
S	0.9	1.0	1.0	1.1	0.1-0.5	%

The nutrient (NPKS) in CF21, NPK hasthe ability to meet the standard value as the value 2.1%, 2.2% and 0.8%, respectively. But the S content (1.0%) is almost doubled than the maximum standard value (0.1-0.5%) and it is happened not only for CF21 but also for other compost sample i.e. CF31 which have S content is 1.0% and CF41 which have 1.1% S content.However, the NPK content of CF31 (N= 3.1%, P=2.4% and K=0.9%) and CF41 (N=2.4%, P=2.5% and K=1.0%) both of composts satisfy the Bangladesh standard for compost. Among four compost the maximum N content was in CF31 i.e. 3.1%. The higher amount of PKS content was in CF41. It seems that the higher amount of limed fleshing the higher thepH.As the digestion process was done by the anaerobic condition the S content remains in the compost is higher than standard which is seen in the above table. If the composting process would be carried out by aerobic digestion then the S content might be reduced which is the possible solution for high S content problem in compost and to meet the standard value.

3.3 Moisture content of final compost

As the composting process was conducted under anaerobic condition, after mixing all ingredients the moisture content was maintained between 45-55% with sprinkling water. Huge (1993) reported that in composting, moisture content should be maintainedbetween 40-60%. The composting was conducted 35 days and every 7 days the moisture was monitored. The moisture content of the final compost is depicted in Table 3.

Table 3: Moisture content of the compost

Sample ID	**Moisture content (%)**
CF11 (CD: LF=1:1)	40.03
CF21 (CD: LF=2:1)	41.02
CF31 (CD: LF=3:1)	42.07
CF41 (CD: LF=4:1)	41.90

It is clear from Table 3 that the moisture content of CF31 was 42.02% which indicatethe satisfactory level of moisture content was during compostingcompared thansamples.The lowest moisture content i.e.40.03% was in the sample of CF11. The moisture content in the sample CF21 and CF 41 was 41.02% and 41.90%, respectively. It is obvious that during composting, in all samples the moisture content was enough for composting to meet the optimum moisture content for satisfactory microbial activity.

3.4 Germination of pepper and gourd seeds

The suitability test of compost for agricultural purposes was carried out by germination of pepper seeds and gourd seeds. Among the compost samples, CF31 (CF:Soil=1:2) and CF41 (CF: Soil=1:3)have better germination as the significant growth of pepper plantwhich is shown in the Figure 3 as the NPKS content of those samples are comparatively higher than other samples i.e. CF11 (N=2.3%, P=2.0%, K=0.6% and S=0.9%) and CF21 (N=2.1%, P=2.2%, K=0.8% and S=1.0%). After 2 weeks of observation, the sample CF31: Soil=1:2 has better plant height but was not so much nourished.

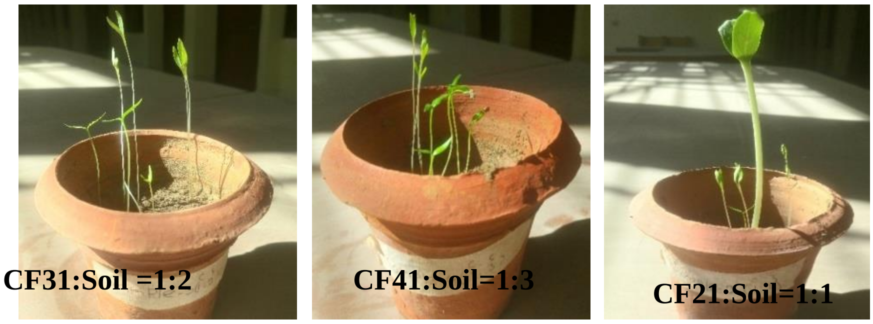

Figure 3: Germination test by sowing pepper seeds and gourd seeds

In contrast, CF41: Soil=1:3 was the most nourished with less plant height of pepper plants. Moreover, the sample CF21 (CF21: Soil=1:1) represents the better germination results in terms of the growth of gourd plants which is also shown in Fig.3. The indiscrimination in the growth of the plants in terms of plant height and nourishment due to the variation in the amount of soil and uneven nutrient i.e. some of the nutrients contribute to plant height and some other contribute to plant nourishment.

4. CONCLUSIONS

Fleshing has a negative effect on the environment. This study is an approach of preparing compost from limed fleshing which could be a solution to manage the solid waste in the tannery. Compost is used as a very effective natural fertilizer without environmental disturbance. hazards. Compostprepared from their respective organic wastes possessed considerably higher levels of major nutrients-NPK except S. The composting process could be optimized in reducingSulphur content at the standard level.

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REFERENCES

Abedin, J.M., Akter, S., &Arafin, S.A.K. (2015). Chromium toxicity in soil around tannery area, Hazaribagh, Dhaka, Bangladesh, and its impacts on environment as well as human health.International Journal of Innovative Research in Advanced Engineering, 2, 119-122.

AOAC, Official Methods of Analysis.16th edition, Association of Official Analytical Chemists, Washington, DC, 1995.

Boopathy, R., Karthikeyan, S., Mandal, A.B, &Sekaran, G. (2013). Characterization and recovery of sodium chloride from salt-laden solid waste generated from leather industry. Clean Technologies and Environmental Policy, 15, 117-124.

Covington, A.D. (2016). Tanning Chemistry: The Science of Leather, Royal Society of Chemistry, Cambridge, Northampton, UK.

Hashem, M.A., Nur-A-Tomal, M.S., &Mondal, B.K. (2015). Generation of fleshings at beam house in tannery and its environmental impact assessment: Bangladesh perspective. Bangladesh Journal of Scientific Industrial Research, 50, 227-232.

Haug, R. T. (1993). Process kinetics and product stability.In: The Practical Handbook of Compost Engineering. Lewis Publishers, Boca Raton, FL, USA.335-83.

Holm-Nielsen, J.B., &Seadi, Al. T., &Oleskowicz-Popiel, P. (2009).The future of anaerobic digestion and biogas utilization.Bioresource Technology,100(22), 5478-84.

Kanagaraj, J., Velappan, K.C., Babu, N.K.C,&Sadulla, S. (2006). Solid wastes generation in the leather industry and its utilization for cleaner environment-A review.Journal of Scientific Industrial Research,65, 541-54.

Lupo, R. (2006). Fleshing treatment and compacting. Proc. II. Eurocongress, IULTCS, Istanbul, Turkey.

Nasr, A.I. (2017). Reusing limed fleshings wastes as a fat liquor in leather processing. Egyptian Journal of Chemistry,60, 919-928.

Ravindran, B., &Sekaran, G. (2010). Bacterial composting of animal fleshing generated from tannery industries. Waste management, 30, 2622-2630.

Tambone, F., Scaglia, B., D'Imporzano, G., Schievano, A., Orzi, V.,& Salati, S. (2010). Assessing amendment and fertilizing properties of digestates from anaerobic digestion through a comparative study with digested sludge and compost. Chemosphere, 81 (5), 577-83.

Veeger, L. (1993). Ecological procedure to solve the tannery waste problems.Journal of the American Leather Chemists Association, 88(9), 326-29.

COMPOSTING OF LEATHER SHAVING DUST: WASTE TO WEALTH APPROACH IN TANNERY

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ABSTRACT

Leather industries play a vital role in the economic growth of Bangladesh. Leather processing consists of a series of chemical and mechanical operations. Each and every operation produces a substantial amount of wastes. Shaving is one of the indispensable mechanical operations where a significant amount of solid waste solid is produced known as ‘shaving dust’. This study is focused on the composting of shaving dust with cow dung and chicken manure. The leather shaving dust was mixed with the cow dung, chicken manure in different ratio maintaining carbon to nitrogen ratio 25-30:1(C/N=25-30:1) and observed for 60 days in aerobic (open-air) condition. To evaluate composting, samples were collected in different interval conducting physicochemical tests. The final composts were tested for the quantitative analysis nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) content. The obtained data were compared with the standard. Results indicate that compost produce from the leather shaving dust could be used as a soil conditioner.

Keywords: *Leather shaving dust, composting, NPKS.*

1. INTRODUCTION

Every day in Bangladesh, the leather industry generate a large amount of solid waste one of which is chrome saving dust that is the by-product during leather processing. It is a matter of regret that the tanneries of Bangladesh are discharging their processing wastewater and solid waste into the green environment prior to proper treatment (Zahid, Balke, Hasan & Fleger, 2006). Solid waste from the leather industry is chrome saving dust, buffing dust, lime fleshing, raw skin trimming (Kanagaraj, Velappan, Chandra Babu & Sadulla, 2006). Leaching of toxic chemical and heavy metals from chrome saving dust affects the surrounding environments, groundwater as well as soil. So it is the major concern all over Bangladesh in the tannery sector, disposal of chrome saving dust without environment pollution as an environment-friendly substance.

Microorganisms (fungi and bacteria) and smaller animals (many types of worms, including earthworms, nematodes, beetles and other insects) turn waste materials into mature compost. Initial carbon to nitrogen ratio in the raw waste mixture is one of the important factors for microbial activity that helps in decomposition (Bertoldi, Vallini & Pera, 1983). It is suggested that an initial carbon to nitrogen ratio of 25-30 is appropriate for composting (Mathava, Yan-Liang & Jih-Gaw Lin, 2010). Composting helps to reduce the volume and moisture content, minimize potential odour, decrease pathogenic bacteria and increase potential nutrients of solid waste (Hasan, Sarker, Alamgir, Bari & Haedrich, 2012). Compost that can be applied to a cultivate land to improve the organic matter content in the soil, which will release nutrients upon decomposition and increase soil structure and cation exchange capacity (Contreras-Ramos, Alvarez-Bernal, Trujillo-Tapia & Dendooven, (2004). During composting various chemical reactions happened within the mixing raw waste material. At the period of composting, organic and inorganic compounds are transferred into more stable and complex organic substance by the successive activities of different kind of microbes (Ravindran & Sekaran, 2010). The end time and also quality of the compost differ according to the composition of the initial waste mixture being processed (Kaur, Singh, Vig, Dhaliwal & Rup, 2010).

Despite the huge potential to convert a significant portion of municipal solid waste of Bangladesh into compost, this sector suffers several setbacks. With the view of objectives, a suitable composting technology for the country, an aerobic compost plant was built. At the end of composting various physical and chemical properties of the final compost has been studied.

The main objective of this study is to make compost from leather shaving dust to reduce the tannery solid waste. The essential parameters e.g., temperature and moisture were monitored during compost. The nutrient of the compost is compared with standard.

2. MATERIALS AND METHODS

2.1 Sample collection

Chrome shaving dust was collected from SAF Industries Ltd, Nowapara, Khulna, Bangladesh just after the shaving operation in a sack and brought back to the laboratory immediately. Cow dung and chicken manure were collected from the local respective firm, Khulna, Bangladesh.

2.2 Mixing of composting ingredients

First of all, the moisture content of each ingredient was determined in order to make a homogenous mixture relative to its moisture content. The pH of the ingredients was determined using a pH (UPH-314, UNILAB, USA) meter. Table 1 shows the moisture content and pH of leather shaving dust, cow dung, and chicken manure.

Table 1: Initial moisture content and pH of ingredients

Ingredients	Moisture content (%)	pH
Leather shaving dust	38.67	3.6
Cow dung	79.11	7.2
Chicken manure	62.97	7.3

Figure 1: Mixed ingredients of leather shaving dust, cow dung and chicken manure

Figure 1 shows a mixed ingredient of composting material. The leather shaving dust (LSD), cow dung (CD) and chicken manure (CM) were mixed manually with a distinct ratio to maintain the carbon to nitrogen ratio (C/N=25-30:1) between 25-30 composting. Table 2 shows the amount of the LSD, cow CD and CM for each pile.

Table 2: Amount (kg) of ingredients of piles

Piles	LSD	CD	CM	Total Weight (kg)
Pile # 1	5	12	16	33
Pile # 2	5	15	10	30
Pile # 3	5	12	11	28

2.3 Determination of Moisture Content

About 5 g sample was weight in a conditioned crucible and placed in the drying oven at 105±5°C for 16 to 24 h. The sample was cooled in a desiccator and weighed. The procedure was repeated for extra 1 h or more until the mass of the sample remains constant. Using thermostatically controlled drying oven capable of operating to 105±3°C the sample was dried to constant weight.

2.4 Determination of pH

The pH of the sample was determined by using the pH (UPH-314, UNILAB, USA) meter. Before measuring pH, the meter was calibrated with the standard solutions.

2.5 Determination of compost nutrient

The nutrient in the compost e.g., nitrogen (N), phosphorus (P), potassium (K), and sulphur (S) test was carried out by the help of the Soil Resource Development Institute, Regional Laboratory, Daulatpur, Khulna, Bangladesh. The micro-Kjeldahl method was used for the estimation of total nitrogen content in the sample as per the procedure suggested by AOAC (1995). The P content of the compost sample was estimated by a spectrophotometric molybdo-vanadate method. The K content in the compost was determined by extracting from the compost with neutral normal ammonium acetate solution and the S was estimated by the turbidimetric method.

2.6 Determination of Conductivity, Salinity, Total Dissolved Solids

The electrical conductivity (EC), salinity and total dissolved solids (TDS) were determined using the conductivity meter (CT-676, BOECEO, Germany). Before measuring, the meter was calibrated with the standard solution.

2.7 Pilling

After the homogeneous mixture of ingredients according to their ratio of the total of three piles were set up. Piles were covered with polythene sheet in order to protect piles from rainfall maintaining a necessary gap for sufficient aeration. With the aim of maintaining aerobic (open-air) condition during the process, the piles were turned manually every 7 days.

Table 3: Pile size of composting

Piles	Length× Width× Height (cm^3)
Pile#1	33×28×18
Pile#2	31×28×18
Pile#3	28×28×28

3. RESULTS AND DISCUSSION

3.1 Temperature of compost piles

The temperature of the compost piles was monitored regularly at the centre of the compost reactor with the help of digital thermometer. Figure 2 shows the compost piles temperature during composting. The heat is generated during the composting period due to the metabolic activity of the microbes. At a different range of temperature different types of microbes present.

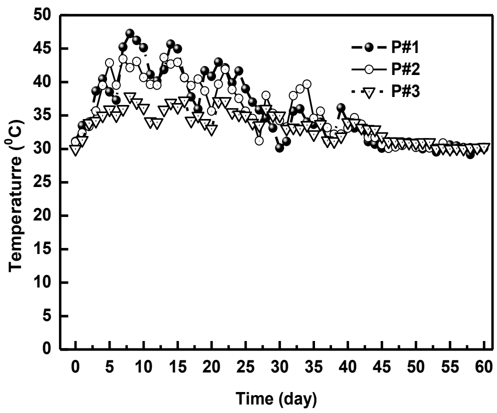

Figure 2: Change of temperature during the composting period

The temperature that carries the chemical reaction makes the remaining organic matter more stable and suitable for use as an organic fertilizer. The maximum temperature found in pile #1, pile #2 and pile #3 was 47.25°C, 43.66°C, 37.85°C on 8^{th}, 13^{th} and 8^{th} days of composting, respectively. At the beginning of the compost, the temperature is almost equal to the day temperature. After a few days when sufficient microbes grew result in an increase in the temperature of the compost. From the beginning phase to intermediate phase when falling down the temperature, turning the pile usually increase the temperate of the compost. When decomposition is over, turning the pile can't increase the compost temperature. At the end of the 44^{th}, 45^{th} and 48^{th} days of composting pile #1, pile #2 and pile #3 respectively balance the compost temperature with the place temperature.

3.2 Moisture of compost piles

The moisture of the sample was monitored every 10 days and measured during the following day that is depicted in Figure 2. During composting, the moisture content was adjusted with the help to sprinkling the tap water. Shyamala and Belagali (2012) reported that standard moisture content is 45%-65%. Because in composting period moisture is an important parameter for quicker degradation of organic materials, which turn into final compost. The initial moisture content in pile #1, pile #2 and pile #3 were 60.11%, 62.12% and 58.68%, respectively. It seems that gradually volume of the piles and moisture were reduced. On the 60th day, the moisture content in pile #1, pile #2 and pile #3 was 48.91%, 50.12% and 49.51% in, respectively.

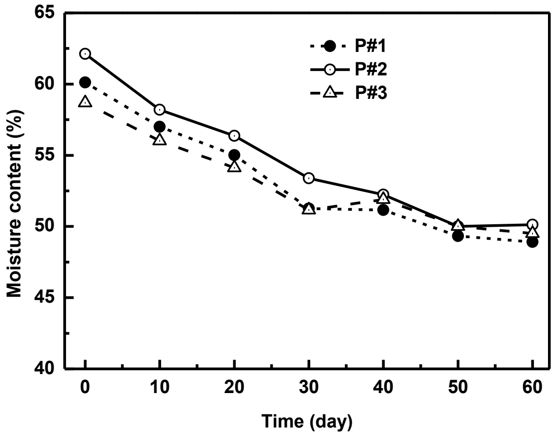

Figure 1: Moisture content during the composting period

All three final compost moisture content notify the compost standard level. If the moisture content is very low during composting that imply early dehydration of pile happened which inhibits the bacterial activity giving a physical stable but biologically unstable compost. Whereas the too high moisture content interface with the aeration by clogging the pores (Bertoldi, Vallini & Pera, 1983).

3.3 Characteristics of compost

Table 4 shows the nutrient content of the final compost in pile#1 as the nutrient N, P, K and S content were 0.50, 0.80%, 0.70% and 0.20%, respectively. All the nutrients for the pile#1 (compost ratio, LSD: CD: CM= 5:12:16) i.e. NPKS meet the standard value (N= 0.5-4.0%; P= 0.5-3.0%; K= 0.5-3.0% and S=0.1-0.5%) as declared by the Bangladesh Govt. Standard, 2013. The nutrient (NPKS) in pile#2, NPKS has ability to meet the standard value, as the values were 0.50%, 0.50%, 0.70% and 0.10%, respectively. However, the NPKS content of the pile#3 (N= 1.1%, P=1.1%, K=0.60% and S= 0.10%) compost satisfy the Bangladesh Govt. Standard, 2013 for compost. Among the three compost, the maximum N and P content were in pile#3 i.e. 1.1% and 1.1% respectively. The maximum NP content in pile#1 due to higher amount of chicken manure (CM) that is a rich source of NP content. The higher amount of S content was in pile#1. The higher the amount of P content in pile#3 and maximum amount of K content in pile#1 and pile#2.

Table 4: Physiochemical characteristics of the compost

Parameters	Pile#1	Pile#2	Pile#3	Standard	Unit
pH	7.13±0.21	6.86±0.4	6.76±0.7	6.0-8.5	-
Moisture Content	48.91±1.7	50.12±2.01	49.51±1.6	-	%
Temperature	30.56±1.8	29.94±1.5	29.41±1.2	-	°C
Conductivity	4.40±0.7	4.38±0.9	4.64±1.1	-	mS/cm
Salinity	2.56±0.6	2.46±0.7	2.53±0.4	-	Ppt
Total Dissolved Solids	2.31±0.3	2.31±0.2	2.22±0.6	-	g/L
Nitrogen (N)	0.50	0.50	1.1	0.5-4.0	%
Phosphorus (P_2O_5)	0.80	0.50	1.1	0.5-2.0	%
Potassium (K_2O)	0.70	0.70	0.60	0.5-3.0	%
Sulphur (S)	0.20	0.10	0.10	0.1-0.5	%

It might be the reason is that releasing of available P and K during decomposition of high content P and K organic substances. The minimum amount of N content was in the pile#1 and pile# 2 as the value of 0.50%. This decrease of nitrogen content might be due to the volatilization of gaseous ammonia during composting process proceeds. The earthworms known as the farmer's friend can't grow in a high range of pH (>9) even in the lower range of pH (<5). The optimum pH value was in the range of 6.00-9.00 (David, Roy, Edward & Michael, 1980). The pH for the pile#1, pile#2 and pile#31 was 7.13, 6.86 and 6.76 respectively. All the compost are suitable for growing earthworms.

3.1 NPKS assessment with standard

Table 4 depicts the NPKS content of the final compost. The NPKS values for the composts meet the standard value as declared by the Bangladesh Govt. Standard, 2013. The pH of the composts was within the standard level (6.0-8.5). The compost from leather shaving dust could be used as a soil conditioner.

4. CONCLUSIONS

This work is an initiative to use leather shaving dust as compost, which could be a solution to manage the solid waste in the tannery. It could be used as alternative chemical fertilizers avoiding any environmental interference. Prepared compost content the standard level of major nutrient NPKS, which is very important for plant growth. The tannery owner could take initiative to manage the leather shaving dust through to reduce the environmental load from the tannery.

REFERENCES

AOAC, Official Methods of Analysis. 16th edition, Association of Official Analytical Chemists, Washington, DC, 1995.

Bertoldi, M., Vallini, G., & Pera, A. (1983). The biology of composting: A Review. Waste Management Research, 1, 157-176.

Contreras-Ramos, S.M., Alvarez-Bernal, D., Trujillo-Tapia, N., & Dendooven, L. (2004). Composting of tannery effluent with cow manure and wheat straw. Bioresource Technology, 94, 223-228.

David, L.K., Roy, H., Edward, F.N., & Michael, R.M. (1980). Physicochemical requirements in the environment of the earthworm Eisenia foetida. Soil Biology and Biochemistry, 12, 347-352.

Hasan, K.M.M., Sarker, G., Alamgir, M., Bari, Q.H., & Haedrich, G. (2012). Study on the quality and stability of compost through a Demo Compost Plant. Waste Management, 32, 2046-2055.

Kanagaraj, J., Velappan, K.C., Chandra Babu, N.K., & Sadulla, S. (2006). Solid wastes generation in the leather industry and its utilization for cleaner environment-A review. Journal of Scientific & Industrial Research, 65, 541-54.

Kaur, A., Singh, J., Vig, A.P., Dhaliwal, S.S., & Rup, P.J. (2010). Cocomposting with and without Ei Eisenia fetida for conversion of toxic paper mill sludge into soil conditioner. Bioresource Technology, 101, 8192-8198.

Kumar, M., Ou, Y-Li., & Lin, J-G. (2010). Co-composting of green waste and food waste at low C/N ratio. Waste Management, 30, 602-609

Ravindran, B., & Sekaran, G. (2010). Bacterial composting of animal fleshing generated from tannery industries. Waste management, 30, 2622-2630.

Shyamala, D.C., & Belagali, S.L. (2012). Studies on variations in physico-chemical and biological characteristics at different maturity stages of municipal solid waste compost. International Journal of Environmental Science, 2, 1994-1997.

Zahid, A., Balke, K.-D., Hasan, M.Q., & Fleger, M. (2006). Evaluation of aquifer environment under Hazaribagh leather processing zone of Dhaka city. Environmental Geology, 50, 495-504.

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WATER QUALITY ASSESSMENT OF TONGI KHAL (CANAL) DURING DRY SEASON

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ABSTRACT

Ecosystem health of the peripheral rivers of Dhaka, the capital city of Bangladesh, has degraded significantly over the last few decades. Though some of these peripheral rivers are marked as Ecologically Critical Area (ECA) by the Government, there is no system in place for monitoring of water quality and ecosystem health of the rivers. In this study, water quality of Tongi khal (canal), one of the heavily polluted surface water system in Dhaka, was monitored during the dry (low flow) season. During dry season, aquatic ecosystem remains in critical state due to lack of precipiatation and low upstream flows that reduce the pollution level by dilution. Four seperate sampling campaigns (two in pre-monsoon and two in winter) were carried out to collect water samples from four distinct points of Tongi khal. The water samples were analyzed, both in-situ and in the laboratory, for a range of water quality parameters. Results of the water quality analysis shows that Tongi khal is heavily polluted by discharges from both industrial and domestic sources. Anoxic condition has been identified in the river during the dry season, with very low dissolved oxygen (~ 0.2 mg/L), negative ORP (redox potential) and high sulfide concentrations (as much as 177.5 µg/L) in the river water. Dry period water quality of Tongi khal is characterized by high concentrations of organic matter (highest BOD_5 91.9 mg/L, COD 212 mg/L), ammonia (highest concentration 25.2 mg/L), phosphate (up to 8.31 mg/L), and sulfate (as high as 295 mg/L). Most of those parameters (except pH) do not meet the Bangladesh National Standard. Moreover, this study reveals significant spatial and temporal variation of dry season water quality of Tongi khal. Water quality of Tongi khal becomes worse at the end of the dry season i.e., March-April. During this pre-monsoon period, highest BOD_5, COD and ammonia concentration in Tongi khal water were 91.9 mg/L, 212 mg/L and 25.2 mg/L, respectively; the corresponding values for the samples collected during December-January (i.e., winter) are 62.5 mg/L, 146 mg/L and 13.75 mg/L, respectively. Furthermore, water quality of Tongi khal deteriorates as one moves from upstream of the industrial locations to downstream (towards Balu River), due to the discharge of industrial (as well as domestic) effluents from industrial establishments. The highest values of BOD_5, COD, and ammonia were identified at sampling points downstream of the industrial locations.. Bangladesh government has plans to resuscitate the peripheral rivers of Dhaka. This study provides a baseline scenario of pollution of Tongi khal during the dry season. This will help to plan and execute a successful restoration program for this surface water system.

Keywords: *Peripheral river, Pollution, Tongi khal, Water quality.*

1. INTRODUCTION

The peripheral river systems (Turag, Tongikhal, Balu, Shityalakhya, Buriganga river) of Dhaka, the capital city of Bangladesh, are highly polluted by unregulated industrial and land developments (Bird et al., 2018). The pollution of the rivers has reached such a state that the Bangladesh Government has declared the peripheral river systems as Ecologically Critical Area in 2009 (DoE, 2015). Proper assessment of the ecosystem health for such ecologically sensitive surface water systems require regular monitoring, based on which corrective measures are to be adopted. However, no systematic monitoring of the river system is currently in place.

Tongi khal (canal) is a surface water system that connects Turag river with Balu river. Tongi khal is reported to be polluted by the nearby Tongi industrial cluster. This cluster is located to the east of Dhaka city and industries in this cluster are concentrated in the Tongi BSCIC area, Tongi industrial area, Cherag Ali, Ershad Nagar, Vhadam, Gazipura, Sataish and Nimtoli areas. Polluting industries in this cluster include textile-dyeing, chemical-pharmaceutical, printing-packaging, glass-ceramic factories, foods, and other miscellaneous industries (MoEF, 2010).

Several studies (e.g., Bhuiyan et al., 2011; Rahman et al., 2012; Mobin et al., 2014; Ahmed et al., 2016; Sarkar et al., 2016; Sikder et al., 2016; Zakir et al., 2016; Hafizur et al., 2017, Tahmina et al., 2018, Islam et al., 2018) have been carried out over the years to assess the surface water quality of Tongi khal. However, most of those studies are based on assessment of water quality by collection of water samples at a single time and analysis of the samples for limited number of water quality parameters. The Department of Environment (DoE) measures only few water quality parameters (pH, DO, BOD, COD, TDS, SS, Chloride, Alkalinity, Total Coliform, Fecal Coliform) in Tongi khal on a monthly basis. Moreover, laboratory assessment studies (Das and Ali., 2018; Das et al., 2019) have reported presence of highly contaminated sediment in Tongi khal which has a direct influence in the surface water chemistry.

Recently Bangladesh government has started an initiative to restore many of the major river systems of Bangladesh including Tongi khal (canal). Before starting any restoration activity, it is important to assess the baseline pollution scenario. For assessment of pollution, the dry season is the most critical period when there is virtually no precipitation and upstream flow reaches its minimum. This study aims to provide a baseline scenario of pollution of Tongi khal during the dry season by systematic sampling and analysis of water samples throughout the dry season (December to April) over a critical stretch of the khal (canal).

2. MATERIALS AND METHODS

2.1 Collection of surface water samples:

Since the water quality of Tongi khal becomes strained during the dry season compared to wet season, sampling was done during dry season (pre-monsoon and winter). Surface water sampling was performed twice during pre-monsoon season (March 2017, April 2017) and twice during winter season (December 2017, January 2018). Four distinct points were selected for carrying out the surface water sampling (shown in Fig. 1). The four-sampling location are: S1: Near Iztema field, S2 and S3: Near Industrial establishments, and S4: Just before the confluence of Tongi khal with Balu river.

Table 1: GPS locations of sampling points

Sampling Location	Latitude	Longitude
S1	23°53'9.79"N	90°23'33.39"E
S2	23°53'18.18"N	90°25'20.66"E
S3	23°53'36.19"N	90°25'41.17"E
S4	23°53'57.24"N	90°26'34.61"E

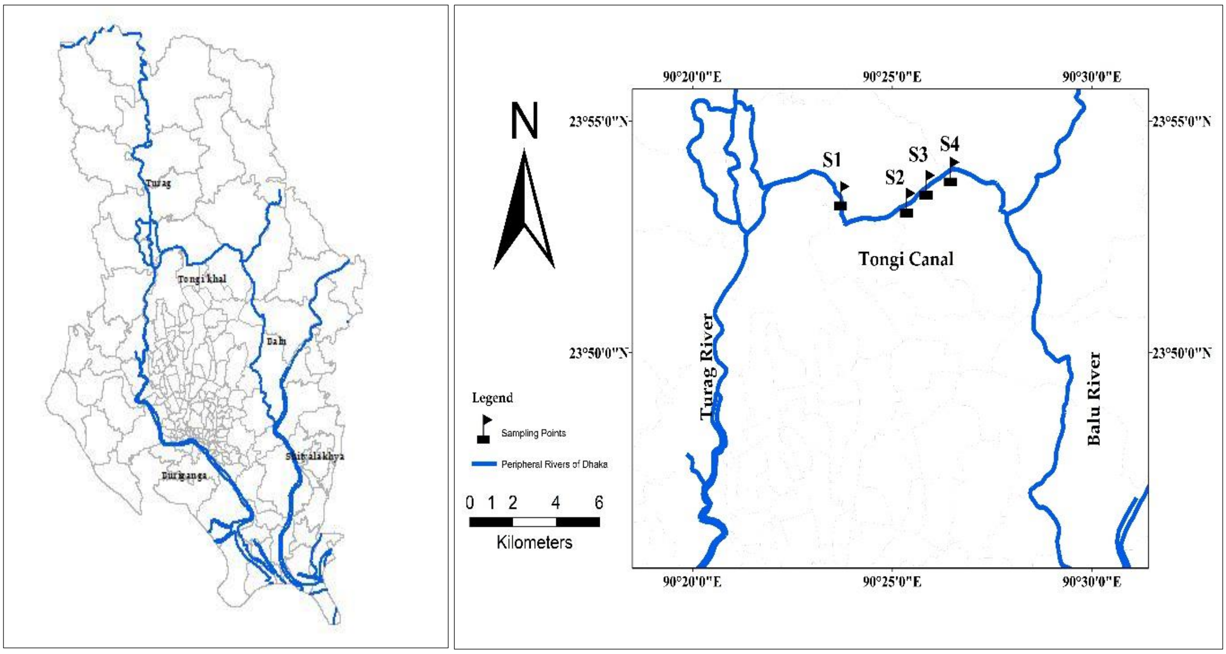

Figure 1: (a) Peripheral river system of Dhaka city (b) Sampling points along Tongi Khal

The water sampling was done following APHA standard protocol (APHA, 1989). Grab sampling at those four distinct locations was employed to collect water samples using an automatic water sampler. The depth of collection of water was two feet below the surface to avoid floating debris. Properly acid washed plastic containers were used as sample containers. From each sampling point around two liters of sample was collected. Then the sample containers were sealed properly and brought to the laboratory for analysis, placing them surrounded with ice box.

2.2 Water quality parameters assessment

The Collected water samples were tested for several physical, chemical and biochemical parameters. Water quality parameters were measured both in in-situ and in the laboratory. The pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), electrical conductivity (EC), total dissolved solids (TDS) and temperature were measured in-situ with HACH HQ 40d multi-parameter meter. In laboratory, color was measured with a spectrophotometer, ammonia (NH_3-N) was measured by the Nessler method, nitrate (NO_3-N) by the cadmium reduction method, nitrite (NO_2-N) by the USEPA Diazotization method, phosphate (PO_4^{3-}) by the ascorbic acid method, sulfate (SO_4^{2-}) by the SulfaVer 4 method, and sulphide (S^{2-}) by the methylene blue method, using a spectrophotometer (Hach, Model DR6000). Other parameters were measured following Standard Methods (APHA, AWWA).

3. RESULTS AND DISCUSSIONS

Surface water of Tongi khal has been found to be heavily polluted during both pre-monsoon and winter season, and the water quality resembles that of untreated domestic sewage. Dry period water quality in Tongi khal exhibits significant spatial and temporal variation. In general, the water quality of Tongi khal is characterized by high concentration of organic matter (BOD_5, COD), ammonia, phosphate, sulfate and sulphide. Very low concentration of dissolved oxygen (DO), low ORP (redox potential) and high sulfide concentrations indicate anoxic condition in the river. The summary of the water quality parameters is presented in Table 1. Very high COD (up to about 212 mg/L) and BOD_5 (over 90 mg/L) was recorded in water samples of Tongi khal near the industrial establishments (location S2 and S3); very high color (over 500 Pt.-Co. unit), sulfide (up to 176 μg/L) and ammonia (over 25 mg/L) concentrations, and low DO (as low as 0.16 mg/L) and ORP (redox potential, -333 mV) were also recorded at these locations. High concentration of dissolved solids (TDS up to 766 mg/L, EC up to 1579 µS/cm) and suspended solids (up to 166 mg/L) were found in the surface water of Tongi khal.

Comparison of water quality of Tongi khal with Bangladesh National Standard (ECR 1997) shows that most of the water quality parameters (except pH) do not meet the standards. Measured dissolved oxygen (DO) remained below 1 mg/L during the dry period at four different measurements along the Tongi khal, which is well below the limit of 5 mg/L set in ECR 1997.

Table 1: Physiochemical characteristics of water samples collected Tongi khal

Parameters	Pre-Monsoon Season	Winter Season
pH	7.5 ~ 8.4	7.6 ~ 8.2
Temperature (^{0}C)	25.4 ~ 32.1	22.3 ~ 25.8
ORP	(-218) ~ (-333)	(-249) ~ (+53.2)
DO (mg/L)	0.17 ~ 0.25	0.16 ~ 0.91
EC (µS/cm)	1122 ~ 1579	587 ~ 1220
TSS (mg/L)	81 ~ 166	26 ~ 103
Color (Pt-Co Unit)	144.5 ~ 464	208.5 ~ 521.5
Ammonia, NH_3-N (mg/L)	9.99 ~ 25.2	1.65 ~ 13.8
Nitrate, NO_3^-N (mg/L)	0.2 ~ 1.4	0.6 ~ 3.2
Nitrite, NO_2^-N(mg/L)	0.0108 ~ 0.4	0.0019 ~ 0.0218
Phosphate, PO_4^{3-} (mg/L)	0.75 ~ 8.3	2.2 ~ 7.2
Sulfate, SO_4^{2-} (mg/L)	108 ~ 198.5	89 ~ 295
Sulfide, S^{2-} (µg/L)	62.5 ~ 177.5	0.0275 ~ 30
Chloride, Cl^-(mg/L)	96.1 ~ 186.2	46.1 ~ 108.1
Alkalinity (mg/L as $CaCO_3$)	298.3 ~ 400.4	167.2 ~ 361.3
COD (mg/L)	79 ~ 212	33 ~ 146
BOD_5 (mg/L)	7.5 ~ 91.9	5.6 ~ 62.5

All water samples from Tongi khal have BOD_5 values, well above the standard of 2 mg/L or less, set in ECR 1997. Most of the water samples also contained high concentrations of ammonia, exceeing the the maximum limit of 1.2 mg/L (considering water used for pisiculture) in ECR 1997.

3.1 Spatial variation Tongi khal water quality during dry period

Figure 2 through 4 shows water quality characteristics of Tongi khal during the sampling period. Data presented in Figure 2 to Figure 4 clearly show that water quality of Tongi khal deteriorates as one moves from upstream to downstream. This is clearly due to the discharge of industrial as well as domestic effluents from establishments close to sampling locations S2 and S3. For example, at sampling location S1, BOD_5 in March 2017 was around 7.5 mg/L; at that time, BOD_5 at S2, S3 and S4 locations were around 30, 40, 40 mg/L, respectively. Similar trend was observed in April 2017, December 2017 and January 2018. For a particular sampling time, BOD_5 values at S3 location was 1.4 to 5.3 times higher than those at S1 location. A similar trend was observed for COD. For example, COD value of water at S1 location in March 2017 was 118 mg/L; the value was 212 mg/L at S2, 171 mg/L at S3 and 206 mg/L at S4 location. In January 2018, the COD values at S1, S2, S3 and S4 locations were 59, 111, 123 and 146 mg/L, respectively.

Ammonia (NH_3-N) concentration in Tongi khal also shows strong temporal variation throughout the sampling period. In March and April (2017), ammonia concentration increased significantly in the downstream locations; for example, at S1 location, ammonia concentration in March and April were around 10.5 and 10 mg/L, respectively; while at S4 location corresponding concentrations were 25.2 and 24.6 mg/L, respectively. In January 2018, ammonia concentration at S3 and S4 locations were lower compared to that at S2 location. This could be due to algal uptake of ammonia and conversion of ammonia to nitrate. Similar spatial trend (i.e., increasing concentration of pollutant downstream) was observed for color, sulfide and phosphate. No particular trend was observed for pH, ORP, TDS and EC. Recorded DO values were very low (~ 0.2 mg/L) throughout the sampling period, except in December, when relatively higher values (0.4 to 0.9 mg/L) of DO were recorded.

Figures 2, 3 and 4 illustrate the spatial and temporal variation of the measured physical, inorganic nutrients and miscellaneous water quality parameters, respectively at four distinct monitoring points during March 2017, April 2017, December 2017 and January 2018.

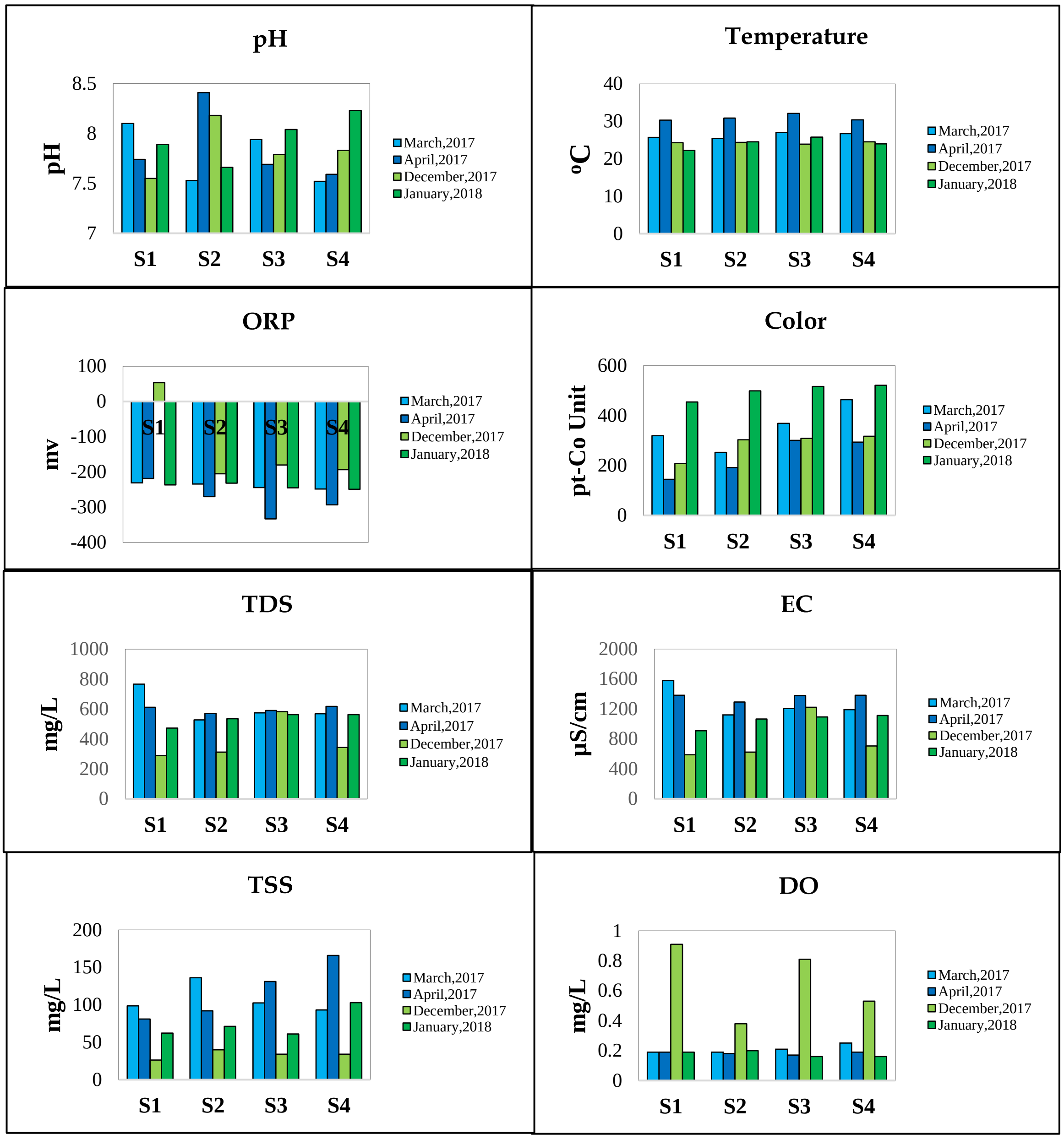

Figure 2: Spatial and temporal variation of physical water quality parameters of Tongi khal during dry season.

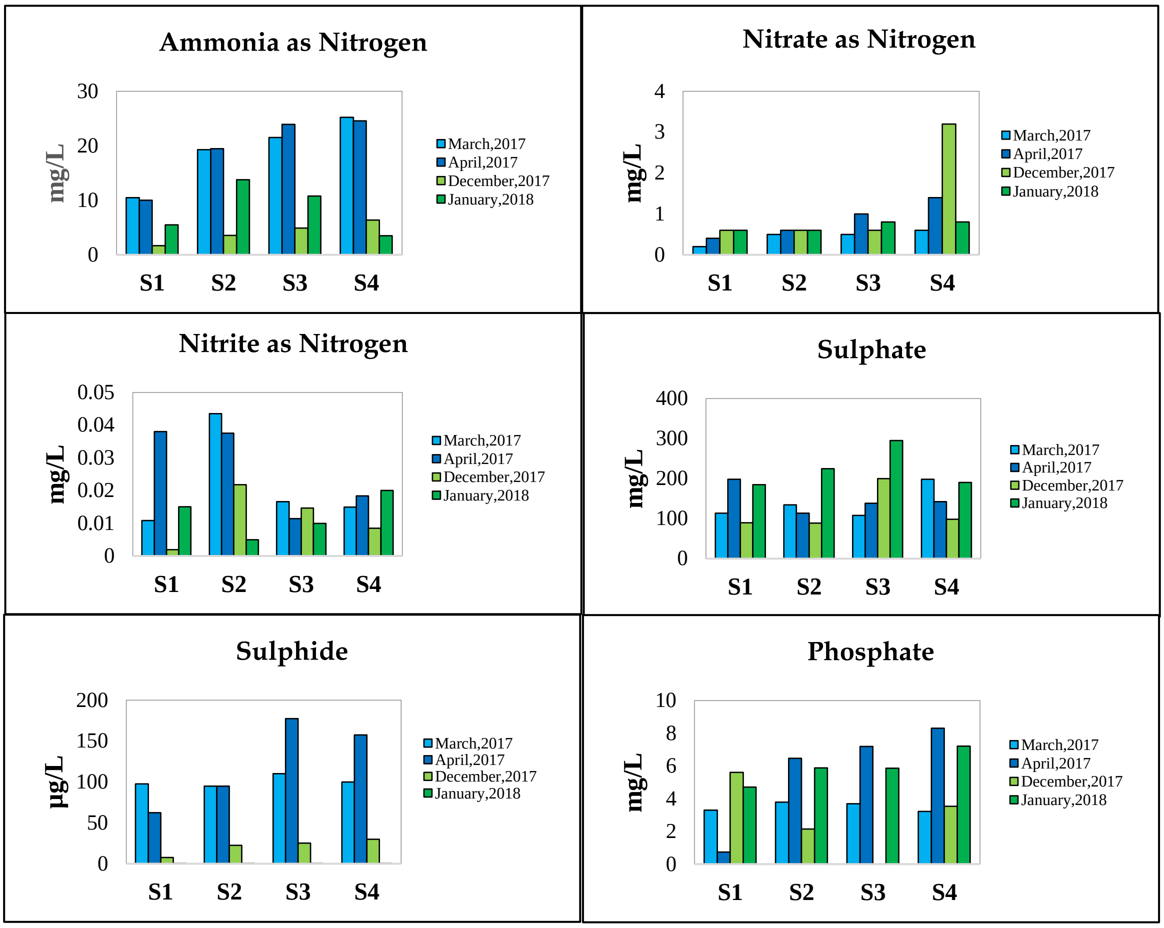

Figure 3: Spatial and temporal variation of inorganic nutrients in Tongikhal water during dry season.

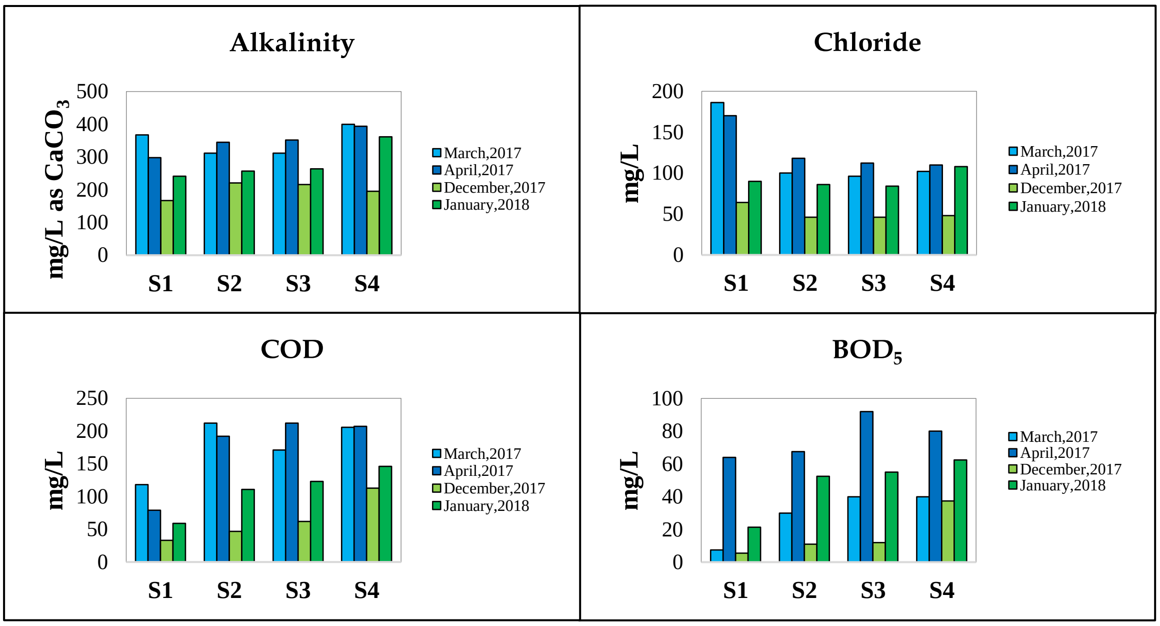

Figure 4: Spatial and temporal variation of Alkalinity, Chloride, COD and BOD_5 in Tongi khal water during dry season.

3.2 Temporal variation Tongi khal water quality during dry period

The water quality data of Tongi khal presented in Table 1 shows significant temporal variation of water quality within the dry season. In Bangladesh, November-December marks the beginning of the dry season, while March-April marks the end of the dry season. Analysis of the water quality data suggests that water quality of Tongi khal becomes worse (with respect to most parameters considered in this study) at the end of the dry season (i.e., March-April). During March-April (i.e., pre-monsoon), highest BOD_5, COD and ammonia concentration in Tongi khal water were 91.9 mg/L, 212 mg/L and 25.2 mg/L, respectively; the corresponding values for the samples collected during December-January (i.e., winter) are 62.5 mg/L, 146 mg/L and 13.75 mg/L, respectively. Sulfide and TSS concentrations were also found to be higher in March-April. However, higher values of color and sulfate was recorded for samples collected during winter (i.e., November-December).

4. CONCLUSIONS

The major findings of this study are-

- The Tongi khal becomes highly polluted during the dry season by both the industrial and domestic wastes. Due to drying up of surface water and relatively low flow situation, the pollution becomes more intense in this period of time. The concetrations of some of the water quality parameters reach those commonly found in untreated domestic and industrial wastewater. During the dry season, the water quality appears to reach a critical state (e.g. highly anoxic) that is unlikely to support any aquatic organism.

- Bangladesh government is planning to restore the peripheral rivers of Dhaka.This program includes dredging of the rivers to ease the navigability as well as augmenting flow during the dry season. However, to make this program effective and successful, the baseline pollution scenario needs to be assessed. Only then an effective restoration program could be designed. This study provides a baseline surface water quality of Tongi khal during dry season.

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REFERENCES

Ahmed, K. S., Rahman, A. K. M. L., Sarkar, M., Islam, J. B., Jahan, I. A., Moniruzzaman, M., Saha, B. & Bhoumik, N. C. (2016). Assessment on the level of contamination of Turag river at Tongi area in Dhaka. Bangladesh Journal of Scientific and Industrial Research, 51(3), 193-202.

American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation. (1915). Standard methods for the examination of water and wastewater (Vol. 2). American Public Health Association..

Bird, J., Li, Y., Rahman, H. Z., Rama, M., & Venables, A. J. (2018). Toward Great Dhaka: A New Urban Development Paradigm Eastward. The World Bank.

Bhuiyan, M. A., Rakib, M. A., Dampare, S. B., Ganyaglo, S., & Suzuki, S. (2011). Surface water quality assessment in the central part of Bangladesh using multivariate analysis. KSCE Journal of Civil Engineering, 15(6), 995-1003.

Das, P. and Ali, M.A. (2018). "Assessment of Sediment Oxygen Demand (SOD) of heavily polluted Tongi khal (Canal)." Proceedings of the 4th International Conference on Advances in Civil Engineering (ICACE), Chittagong, Bangladesh., 1-6.

Das, P., Ali, M.A. & Fattah, K.P. (2019). Assessment of contaminant flux from heavily polluted benthic sediment of Tongi khal (canal): An ex-situ approach. Desalination and Water Treatment journal, Manuscript ID TDWT-2019-1077.R1 (accepted).

DoE (2015) Community based ecosystem conservation and adaptation in ecologically critical areas of Bangladesh: Responding to nature and changing climate. Department of Environment, Ministry of Environment and Forests (MoEF), Department of Environment, Dhaka, Bangladesh, ISBN: 978-984-34-0337-7

Hafizur, R. M., Nuralam, H. M., & Rumainul, I. M. (2017). Investigation of physicochemical parameter, heavy metal in Turag river water and adjacent industrial effluent in Bangladesh. Journal of Science, Technology and Environment Informatics, 5(1), 347-360.

Islam, J. B., Akter, S., Bhowmick, A. C., Uddin, M. N., & Sarkar, M. (2018). Hydro-environmental pollution of Turag river in Bangladesh. Bangladesh Journal of Scientific and Industrial Research, 53(3), 161-168.

Mobin, M. N., Islam, M. S., Mia, M. Y., & Bakali, B. (2014). Analysis of physicochemical properties of the Turag River water, Tongi, Gazipur in Bangladesh. Journal of Environmental Science and Natural Resources, 7(1), 27-33.

MoEF (2010) Pollution Abatement Strategies for Rivers and Wetlands in and Around Dhaka City 2010. Government of Bangladesh, Ministry of Environment & Forests, Dhaka.

Rahman, A. L., Islam, M., Hossain, M. Z., & Ahsan, M. A. (2012). Study of the seasonal variations in Turag river water quality parameters. African Journal of Pure and Applied Chemistry, 6(10), 144-148.

Sarkar, M., Islam, J. B., & Akter, S. (2016). Pollution and ecological risk assessment for the environmentally impacted Turag River, Bangladesh. Journal of Materials and Environmental Science, 7(7), 2295-2304.

Sikder, M. N. A., Huq, S. M. S., Mamun, M. A. A., Hoque, K. A., Bhuyan, M. S., & Bakar, M. A. (2016). Assessment of physicochemical parameters with its effects on human and aquatic animals giving special preference to effective management of Turag River. J of Environ. Sci. Toxico. Food Tech, 10, 41-51.

Tahmina, B., Sujan, D., Karabi, R., Hena, M.K.A., Amin, K.R. and Sharmin, S. (2018). Assessment of Surface Water Quality of the Turag River in Bangladesh. Research Journal of Chemistry and Environment, 22, 2.

Zakir, H. M., Islam, M. M., & Hossain, M. S. (2016). Impact of urbanization and industrialization on irrigation water quality of a canal-a case study of Tongi canal, Bangladesh. Adv Environ Res, 5(2), 109-123.

OCCURRENCE AND QUANTIFICATION OF MICROPLASTICS IN THE SELECTED WATERBODIES OF DHAKA CITY

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ABSTRACT

Today a world without plastics is unimaginable. But their non-biodegradability poses serious threat to the ecosystem, especially to the aquatic environment. Probable adverse effects of microplastics include adsorption of persistent organic pollutants, bio-accumulation, and death of various aquatic organisms, which eventually leads to loss of biodiversity. Though freshwater environment is closely associated with the origin microplastics and their transfer to the seas and oceans, limited studies have been conducted on freshwater ecosystem compared to the marine environment. There is virtually no data on microplastics for the waterbodies in Bangladesh. This study was aimed at assessment of the occurrence of microplastics and determination of their quantity in five selected waterbodies of Dhaka city. Concentration of microplastics was determined by wet sieving where 4.75-mm and 0.3-mm sieves were used to isolate the solid material of appropriate size, then wet peroxide oxidation was done using hydrogen peroxide (H_2O_2) to digest labile organic matter while the plastic debris remained unchanged. Then density separation was done using sodium chloride (NaCl) solution to isolate the plastic debris through flotation. The floating solids was then separated from the denser undigested mineral components using a 0.3 mm filter, air dried and weighed. Finally, microplastics were detected using a magnifying glass. The quantity of microplastics in water samples from five water bodies of Dhaka City varied from 0.49% (in Dhanmondi Lake) to 9.48% (in Turag River) of total solids. Quantity of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake) have been found to be relatively low, compared to those found in the two peripheral rivers – Buriganga and Turag. Hatirjheel, which receives storm water mixed with domestic sewage, also contains relatively high concentration of microplastics. This study gives an idea about the degree of microplastics pollution in different water bodies of Dhaka city. It also provides insight into the possible sources of microplastics.

Keywords: *Microplastic, Water body, Eco-system, Organic Pollutants.*

1. INTRODUCTION

Plastics are synthetic organic polymers, which are formed from the polymerization of monomers extracted from oil or gas (Derraik et al, 2002; Rios et al., 2007; Thompson et al., 2009). The common forms of plastics used in modern days include polyethylene terephthalate (PETE or PET), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), polylactic acid (PLA), polycarbonate (PC), acrylic (PMMA), etc. They can be molded into shape while soft, and then set into a stiff or slightly elastic form. They are lightweight, durable, inert and corrosion-resistant. About 260 million tons of plastics are produced each year globally, about 10 percent of these ends up in the Ocean, (Greenpeace, 2006). The possibility that microplastics pose a threat to biota, as they are increasingly found in marine organisms, is of increasing scientific concern (Barnes et al., 2009; Derraik et al, 2002; Fendall and Sewell, 2009; Lozano & Mouat, 2009; Ng & Obbard, 2006; Thompson et al., 2004). Exposure of freshwater organisms to microplastics has been found to cause mortality, neurotoxicity, oxidative stress and damage, decrease of individual and population fitness, and several other adverse effects (Au et al., 2015; Bhattacharya et al., 2014; Lagarde et al., 2016). Microplastics and nanoplastic have been found to cause a wide range of adverse effects, such as immobilization, mortality, feeding inhibition, decreased reproductive fitness, among others (Besseling et al., 2014; Jemec et al., 2016; Nasser and Lynch, 2015; Ogonowski et al., 2016; Rehse et al., 2016; Frydkjær et al., 2017).

Although presence of microplastics in the marine environment received most attention, in recent years, presence of microplastics in inland water bodies (e.g. lakes and rivers) is becoming a major concern. There is virtually no data on the occurrence and quantity of microplastics in water bodies in Bangladesh. It is therefore important to assess occurrence of microplastics in the waterbodies in Bangladesh, and quantify the concentration of microplastics, as the first step in understanding the adverse impacts of this pollutant on the aquatic ecosystem. The overall objective of this study is to quantify microplastics in five selected water bodies (Dhanmondi lake, Ramna lake, Hatirjheel, Buriganga and Turag Rivers) within and around Dhaka City.

2. METHODOLOGY

2.1 Sample Collection

In this study, five water bodies were selected for collection of samples for analysis of Microplastics. These included 3 water bodies (lakes) within Dhaka city and two peripheral rivers. The inland water bodies included: (a) Dhanmondi Lake, (b) Ramna Lake, and (c) Hatirjheel. The peripheral water bodies included: (a) Buriganga River, and (b) Turag River.

A sampling net prepared using a piece of cotton cloth (similar to Manta net) was used for collection of water samples from the water bodies. Sample from Dhanmondi Lake was collected from the area surrounding the Number 8 Bridge. From Ramna Lake, water samples were collected from a location near a sewage outlet. Sample from Hatirjheel was collected from a stagnant area. Water samples from Buriganga River and Turag River were collected using a boat. All water samples were collected during November-December, 2018.

2.2 Analysis for Microplastics

The standard method for analysis of Microplastics involves filtration of the collected solids through 5.6-mm and/or 0.3-mm sieves to separate the solid material of the appropriate size. But due to unavailability of sieves with this particular opening, the collected samples were sieved through #4 (4.75-mm) and #50 (0.3-mm) sieves. First the sample was poured through a stacked arrangement of 4.75-mm (No. 4) and 0.3-mm (No. 50) stainless steel mesh sieves and rinsed with a squirt bottle filled with distilled water to transfer all residual solids to the sieves. Sieves were rinsed thoroughly using distilled water ensuring all material been well washed, drained, and sorted. Then materials retained on 4.75-mm sieve was discarded.

A clean and dry 500-mL beaker was weighted to the nearest 0.1 mg. The solids collected in the 0.3-mm sieve was then transferred to the tared beaker using a spatula and minimal rinsing with a squirt bottle containing distilled water ensuring all solids are transferred into the beaker. The beaker was then placed in 90° C drying oven for 24 hours or longer to sample dryness. The mass of the beaker with dried solids was determined using an analytical balance to the nearest 0.1 mg. The mass of the tared beaker was subtracted to provide the mass of total solids collected in the sieve. This was the mass of all Microplastics and natural materials.

For wet peroxide oxidation, 20 ml of aqueous 0.05 M Fe (II) solution was added to the beaker containing the 0.3 mm size fraction of the collected solids. Then 20 ml of 30% hydrogen peroxide was added. Then the mixture was allowed to stand on a lab bench at room temperature for five minutes prior to proceeding to the next step. A stir bar was added to the beaker and covered with aluminum foil. Thereafter, it was heated to 75°C on a hotplate. As soon as gas foams/bubbles were observed at the surface, the beaker was removed from the hotplate. If reaction appeared to have the potential to overflow the beaker, distilled water was added to slow the reaction, then continued to heat to 75° C for an additional 30 minutes. The process was repeated until no natural organic material was visible. The WPO mixture was then subjected to density separation in NaCl (aq) to isolate the plastic debris through flotation. About 6 g of salt (NaCl) per 20 ml of sample was added to increase the density of the aqueous solution (~5 M NaCl) and again the mixture was heated to 75° C until the salt dissolved. This mixture is highly reactive and can boil violently if heated >75°C. So proper laboratory safety practices were followed for handling this mixture before completing this analysis.

The WPO solution was transferred for density separation. The WPO beaker was rinsed with distilled water to transfer all remaining solids to the beaker and covered loosely with aluminum foil. The solids were then allowed to settle overnight. The settled solids were inspected visually for any Microplastics. If any were present, then the Microplastics were removed using forceps and the residuals was discarded. Floating solids were collected in a clean 0.3-mm custom sieve. The beaker was rinsed several times with distilled water to transfer all solids to the 0.3-mm sieve and the sieve was allowed to air dry while loosely covered with aluminum foil for 24 hours. A clean and dry 4-mL vial was weighed. Under a magnifying glass, identifiable Microplastics were collected from the 0.3-mm sieve and were transferred to the tared vial. The mass of the vial and Microplastics were weighted to the nearest 0.1 mg. The mass of the tared vial was subtracted to provide the mass of Microplastics collected in the sieve.

3. RESULTS AND DISCUSSION

Microplastics were identified in varying quantities in the water samples collected from the 5 water bodies in and around Dhaka City. Figure 1 shows the photographs of microplastics collected from the 5 water bodies. Figure 2 shows the quantity of microplastics (expressed as % of total solids) found in different water bodies. It clearly shows that the quantities of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake) are relatively low. On the other hand, much higher quantity of microplastics was detected in the two peripheral rivers – Buriganga River and Turag River. Hatirjheel, which receive storm water mixed with domestic sewage, also contains relatively high concentration of microplastics.

The percentage of microplastics in Dhanmondi Lake has been found to be only 0.49% of total solids, which is not a very significant amount. Since Dhanmondi Lake is located in a residential area, the probable sources of microplastics pollution are degradation and abrasion of larger plastic products. Uncontrolled dumping of plastic products into the lake which includes ice cream packets, chips packets, and polythene could be a major reason for the formation of microplastics. Primary Microplastics resulting from micro beads intentionally incorporated into the personal care products could be another reason for the microplastic pollution in Dhanmondi Lake. The microplastics in this Lake were primarily low density plastics since most of them were obtained from the floating material during the laboratory work. Low density plastic is a thermoplastic made from the monomer ethylene. Low density plastic is very flexible, translucent with high impact strength and has a density value of 0.91gm/cm^3. It should be noted that after the renovation work in the recent past, Dhanmondi Lake does not receive any domestic sewage directly through sewer outfall. Therefore, the source of microplastics is most likely direct disposal of plastic materials (e.g., by people visiting the Lake area) and from storm runoff.

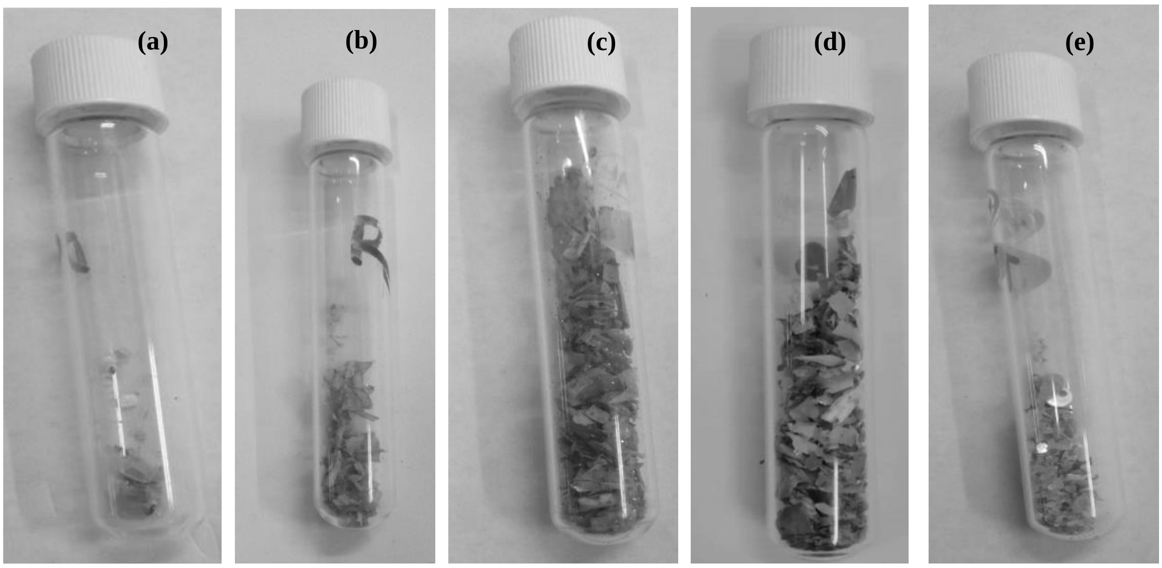

Figure 1: Microplastics extracted from water samples collected from 5 water bodies in and around Dhaka City: (a) Dhanmondi lake; (b) Rahman lake; (c) Hatirjheel; (d) Buriganga River; (e) Turag River.

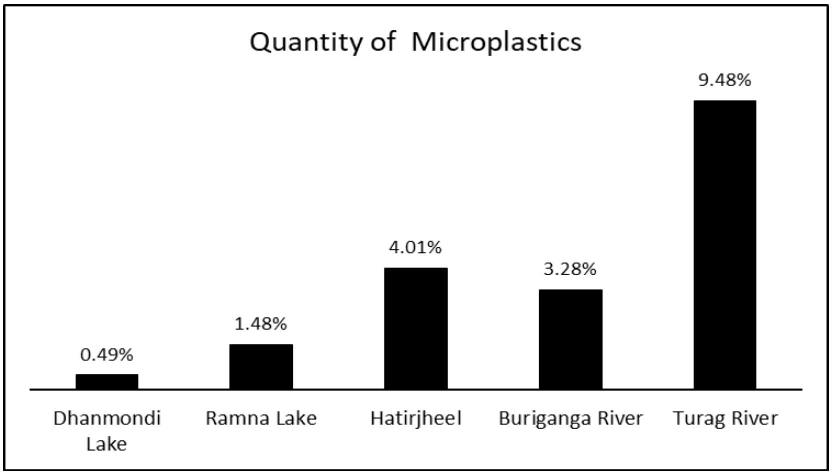

Figure 2: Quantity of microplastics in different water bodies in and surrounding Dhaka city

The percentage of microplastics in the Ramna Lake has been found to be about 1.48% of total solids. The microplastics found here were not colourful (see Fig. 1). The sample was collected from a location close to a sewage outlet. Like in Dhanmondi Lake, the fragmentation of larger plastic products such as chips packets, polythene bags, toys, tapes and ice-cream packets might have resulted in the formation of Microplastics. The microplastics were mostly high-density plastic since most of the Microplastics were obtained from the sediment during the laboratory work. High density plastics are thermoplastic polymer produced from the monomer ethylene.

The percentage of microplastics obtained from Hatirjheel is 4.01% of total solids. The amount is quite significant when compared to the percentage of microplastics found in the other two Lakes. The microplastics were not very colourful (see Fig. 1). It should be noted that Hatirjheel receives huge amount of storm water mixed with domestic sewage (especially during the wet season). This is a potential source of microplastics in Hatirjheel. Besides, since Geobags have been placed to protect banks from soil erosion, plastic fibers found in the sample could have resulted from these Geobags. Hatirjheel is a recreational place where many visitors come to the place every day to view the scenic landscape. Unfortunately, most of the visitors do not apply civic sense when they go to the area. They carry with them plastic bottles, chips packets, polythene filled with ground nut, biscuits and newspapers and leave there those after use. These could eventually contribute to the pollution of the water body with plastic products. These larger plastics then fragment to form the smaller pieces of Microplastics which pose serious hazard to the aquatic lives present in the water body. Most of the Microplastics were found from the floating materials so this indicates that the Microplastics were mostly low-density plastics.

Buriganga River is one of the most polluted rivers in Bangladesh. The microplastics obtained from Buriganga River is 3.28% of total solids. From visual inspection it was seen that the microplastics of Buriganga River is very colourful (see Fig. 1). This indicates microplastics in this river have resulted from a wide variety of sources. Household plastic products such as plastic buckets, plastic bottles, and polythene might have degraded to form the smaller pieces of microplastics. Since the Dhaka City dwellers have been dumping domestic waste into the Buriganga River, amount of plastic waste found here is significantly high. A lot of sewer outlets dump domestic and industrial wastewater in the river resulting in presence of a huge amount of primary microplastics. It is also suspected that the dumping of plastic waste by the nearby slum people such as ice cream packets, chips packets, and plastic bottle caps could be a major reason for the formation of microplastics. The amount of microplastics obtained is comparatively lower than from some of the water bodies even though visually it seems to be quite a significant. The possible reason is that the plastics are LDP (low density plastic).

The microplastics found from Turag River is 9.48% of total solids, which is highest amongst all the values. Even though from visual appearance it might not seem a very significant amount (see Fig. 1), but the weight of the microplastics is higher because the microplastics might be originated from the degradation of hard plastics which may include feeders, plastic containers for milk, shampoos and conditioners, detergents and bleaches. Glitters were found profoundly in this sample. One of the reasons could be that glitters, plastic embroidery works from the clothing might have drained into the river. At some point sewage outlet connected to domestic sources is seen and slum dwellers without proper drainage facilities discharge their sewage water into the river; so primary plastics used in personal care products might be present in our sample. Since many industries including pharmaceutical industries, dyeing industry, textile industry, etc. are located in the vicinity of the river, there are variety of sources which might have resulted in microplastics in the river.

4. CONCLUSIONS

Microplastics have been detected in all 5 water bodies from which samples were collected and analyzed in this study. The quantities of microplastics in inland water bodies (Dhanmondi Lake and Ramna Lake, Hatirjheel) are relatively low. Hatirjheel, which receives storm water mixed with domestic sewage also contains relatively high concentration of microplastics. Relatively higher quantity of microplastics was detected in the two peripheral rivers – Buriganga River and Turag River. Turag is most polluted with microplastics especially high density microplastics. The quantities of microplastics (as percentage of total solids) also depend on composition of microplastics (e.g., density of materials). This study gives an idea about the degree of microplastics pollution in the different water bodies of Dhaka city. This study also gives insight into the possible sources of microplastics. More studies are needed for identification and characterization of microplastics in freshwater environmnet and their possible impact on the environment and ecosystem.

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REFERENCES

Au, S.Y., Bruce, T.F., Bridges, W.C., Klaine, S.J. (2015). Responses of Hyalella azteca to acute and chronic microplastic exposures. Environmental Toxicology and Chemistry, 34(11), 2564-2572.

Bajracharya, R.M., Manalo, A.C., Karunasena, W., Lau, K-T., (2014). An overview of mechanical properties and durability of glass-fibre reinforced recycled mixed plastic waste composites. Materials & Design, 62, 98-112.
doi:10.1016/j.matdes.2014.04.081.

Barnes, D.K., Galgani, F., Thompson, R.C., (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 364, 1985–1998.

Besseling, E., Wang, B., Lurling, M., Koelmans, A.A. (2014). Nanoplastic Affects Growth of S. obliquus and Reproduction of D. magna. Environmental Science & Technology, 48(20), 12336-43.
doi: 10.1021/es503001d.

Derraik, J.G.B., (2002). The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin, 44, 842–852.
doi: 10.1016/S0025-326X(02)00220-5.

Fendall, L.S., Sewell, M.A., (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. Marine Pollution Bulletin, 58, 1225–1228. doi:10.1016/j.marpolbul.2009.04.025.

Frydkjær, C., Iversen, N., Roslev, P., (2017). Ingestion and Egestion of Microplastics by the Cladoceran Daphnia magna: Effects of Regular and Irregular Shaped Plastic and Sorbed Phenanthrene. Bulletin of Environmental Contamination and Toxicology, 99. 655-661.
doi: 10.1007/s00128-017-2186-3.

Greenpeace (2006), Plastic Debris in the World's Oceans, Greenpeace International, Ottho Heldringstraat 5, 1066 AZ Amsterdam, Netherlands

Jemec, A., Horvat, P., Kunej, U., Bele, M., Kržan, A., (2016). Uptake and effects of microplastic textile fibers on freshwater crustacean Daphnia magna. Environmental Pollution, 219. 201-209.
doi: 10.1016/j.envpol.2016.10.037.

Lagarde, F., Olivier, O., Zanella, M., Daniel, P., Hiard, S., Caruso, A., (2016). Microplastic interactions with freshwater microalgae: Hetero-aggregation and changes in plastic density appear strongly dependent on polymer type. Environmental Pollution, 215, 331-339.
doi: 10.1016/j.envpol.2016.05.006.

Lozano, R.L., Mouat, J., (2009). Marine Litter in the North-East Atlantic Region: Assessment and Priorities for Response. KIMO International, 127.

Nasser, F., Lynch, I., (2015). Secreted protein eco-corona mediates uptake and impacts of polystyrene nanoparticles on Daphnia magna. Journal of Proteomics, 137, 45-51.
doi: 10.1016/j.jprot.2015.09.005.

Ng, K & Obbard, Jeff. (2006). Prevalence of microplastics in Singapore's coastal marine environment. Marine pollution bulletin, 52(7), 761-767.
doi: 10.1016/j.marpolbul.2005.11.017.

Ogonowski, M., & Schur, C., Jarsen, A., Gorokhova, E., (2016). The Effects of Natural and Anthropogenic Microparticles on Individual Fitness in Daphnia magna. PloS One, 11(5), e0155063.
doi: 10.1371/journal.pone.0155063.

Rehse, S., Kloas, W., Zarfl, C., (2016). Short-term exposure with high concentrations of pristine microplastic particles leads to immobilisation of Daphnia magna. Chemosphere. 153. 91-99.
doi: 10.1016/j.chemosphere.2016.02.133.

Rios, L.M., Moore, C., Jones, P.R., (2007). Persistent organic pollutants carried by synthetic polymers in the ocean environment. Marine Pollution Bulletin, 54(8), 1230–1237. doi:10.1016/j.marpolbul.2007.03.022.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D.,Russell, A.E., (2004). Lost at sea: where is all the plastic? Science, 304(5672), 838–838. doi:10.1126/science.1094559.

Thompson, R.C., Moore, C.J., Vom Saal, F.S., Swan, S.H., (2009). Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153–2166. doi: 10.1098/rstb.2009.0053.

COMPARATIVE STUDY OF RAINWATER QUALITY AT CUET CAMPUS AREA, HARVESTED FROM ROOFTOP AND OPEN SPACE

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ABSTRACT

Currently, Rainwater Harvesting System (RWS) is considered as one of the most important sustainable drinking water source. But there are so many factors that affect the rainwater quality, roof surface is one of them. This study is focused to compare the rainwater quality in between harvested from Rooftop and Open Space. Rainwater samples were collected from July 2018 to January 2019 by 500 ml polypropylene bottle. In almost every sample, the concentration of different physiochemical (pH, Temperature, Conductivity, Total Dissolved Solids, Turbidity, Alkalinity, Hardness, Carbon dioxide, Sulfate (SO_4^{2-}) and Nitrate (NO_3^-)) and trace metals (Fe, Pb, Zn, Mn, Cd, Cr, Cu) parameters were found higher in rooftop harvested rain water than the open space harvesting. For evaluating the water quality of harvested rainwater with time, both water (one collected from rooftop another directly from open space) is stored for long time (July 2018 to January 2019) and tested that water at regular interval. From the tested result it is revealed that for both conditions the physico-chemical parameters are not changed but the bacteriological parameters changed with time.

Keywords: *Rainwater quality, Rooftop, Open space, Physico-chemical parameters; Bacteriological parameters.*

1. INTRODUCTION

Water is a key commodity which is necessary for all living beings to grow and reproduce (Ahmed, 2010; Al-Khatib, Daoud, Rasmawi, Wa'rra & Kassabry, 2005). Sustainable development is based on clean water (Ezbakhe, 2018). The Sustainable Development Goals tackle this problem in Objective 6, which seeks to: "Ensure accessibility and sustainable water and sanitation management for all." Target 6.1 sets out: "Achieving universal and equitable access for all to secure and affordable drinking water by 2030" and significantly improving global recycling and secure reuse. But, now-a-days drinking water scarcity is one of the most significant environmental issues in developing countries (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016). Whereas, Water scarcity impacts all industries of society and the economy and threats the sustainability of natural resources (Mancosu, Snyder, Kyriakakis, & Spano, 2015). Most developing countries go through industrialization and population growth so fast that the drinking water supply cannot keep up with the demand. The rapid development of cities and consequent population explosion in urban areas has led to depletion of surface water resources as well as ground water resources (Perilla, Gomez, Diaz, & Cortezon, 2012). In this condition Rainwater Harvesting System (RWS) is considered as one of the most important sustainable drinking water source. But rainwater may pollute by several things. Factors that influence the quality of harvested rainwater include: roof geometry (size, exposure, and inclination), roof material (chemical characteristics, roughness, surface coating, age, and weather ability), location of the roof (proximity of pollution sources), maintenance history of the roof, rainfall events (wind speed, intensity, and pollutant concentration), other meteorological factors (seasons, weather characteristics, and antecedent dry period), and concentration of substances in the atmosphere (transport, emission, half-life, and phase distribution) (Abbasi & Abbasi, 2011).

Several research were done in Bangladesh about the potentiality of harvested rainwater(Akter & Ahmed 2015; Ashraful & Islam 2015; Rahman, Khan, Akib, Din, Biswas, & Shirazi, 2014; Dakua, Akhter, Biswas, Siddique, & Shihab, 2014; Islam, Chou, Kabir, & Liaw, 2010). Islam et al., 2011, studied about the feasibility and acceptability of rainwater for Dhaka city, Akter & Ahmed 2015, studied about the potentiality of rainwater harvesting in chittagong city and Alam et al., 2012, caried out a study about the feasibility of rainwaterv harvesting for Sylhet city. This paper is mainly focused on the comparison between rooftop and open space harvested rainwater-quality parameters and also evaluate the stored water quality of harvested rainwater with time.

2. METHODOLOGY

2.1 Instrument- Setup

The roof size for rooftop rainwater collection is (20′ × 10′) with 15˚ inclination and 12′ height. A 500-liter storage tank is used for storing the rainwater. For collecting rainwater from open space, a frame like Figure 1 is used. The frame is placed in the top of the civil engineering building at CUET campus. The frame is consist of two step, in upper step a 50 litre water bucket is placed for collecting rainwater directly from space and in lower step there are two 5 litre container, the left side one is for first flash rainwater collecting and the right side one is for after first flash rainwater collecting.

Rooftop Harvesting

Open Space Harvesting

Figure 1: Instrument setup for rainwater collection.

2.2 Rainwater Sampling

The sampling of rainwater from rooftop and open space were performed 16 times with 500 mL polypropylene bottles for a period July 2018 to December 2018. At the time of collection of sampling, always tried to take samples as per sampling guideline. Rainwater from Open space harvested and Rooftop harvested is stored separately in 50-litre tank for evaluating the water quality of harvested rainwater with time.

2.3 Laboratory Analysis

It has assembled around 60 different samples and tested for different physiochemical (pH, Temperature, Conductivity, Total Dissolved Solids, Turbidity, Alkalinity, Hardness, Carbon dioxide, Sulfate (SO_4^{2-}) and Nitrate (NO_3^-)), trace metals (Fe, Pb, Zn, Mn, Cd, Cr, Cu) and microbiological (TC) characteristics. The testing methods and standard of WHO & Bangladesh is shown in Table 1.

Table 1: Testing methods and standards (WHO & Bangladesh) of different water quality parameters

Water Quality Parameters	Bangladesh Standards (mg/L)	WHO Guide Line	Methods/ Equipment
pH	6.5-8.5	6.5-8.5	pH Meter
Electrical Conductivity	-µs/cm	-	Multi-meter
Total Dissolved Solid	1000	-	Multi-meter
Turbidity	10 NTU	-	Turbidity meter
Alkalinity as CaCO3	-	-	Titrimetric
Hardness as CaCO3	200-500	-	Titrimetric
Carbon dioxide (CO_2)	-	-	Titrimetric
Nitrate	10	50.0 as N	UV-VIS
Sulfate (SO_4^{2-})			UV-VIS
Iron	0.3-1.0	-	UV-VIS
Copper	1	2	UV-VIS
Lead	0.05	0.01	AAS
Zinc	5	-	UV-VIS
Manganese	0.1	-	UV-VIS
Chromium	0.05	0.05(P)	UV-VIS
Cadmium	0.005	0.003	AAS
TC	0 CFU (N/100mL)	0	Membrane Filtration Method

3. RESULT & DISCUSSION

3.1 Open Space Harvesting

Descriptive statistics for selected parameters of open space harvested rainwater were presented in Table 2 both for first flash and after first flash rainwater. The statistical analysis showed no statistically significant difference in the concentration of pH of the first flush and the corresponding the rainwater of after first flash (Table 2). The mean concentration of pH in first flash tank is slightly higher than the tank of after first flash. The mean value of pH at all sampling points was in the acidic range and fluctuated between 4.52 and 7.01. Mean EC values of first flash and after first were 14.97 µS/cm and 12 µS/cm respectively which is very much lower than the threshold set by Bangladesh Standard for drinking water. The statistical difference in between first flash and after first flash for TDS concentration were found same as EC. The mean concentration of alkalinity values for first flash and after first flash rainwater were found 5.79 mg/l and 5.46 mg/l respectively. Mean hardness values of first flash and after first flash rainwater were 51.79 and 38.4 (mg $CaCO_3$/L), respectively (Table 2), i.e., hardness exhibited higher mean values in waters (first-flush) and was around 26 times greater than the concentrations in after first flash water tanks. The concentration of sulfate and nitrate were found higher in the first flash tank than the after first flash tank. The reasons behind the higher concentration of sulfate and nitrate in first flash tank is, generally the pollutants SO_x and NO_x present in air accumulates in initial rainfall. There is no statistically significant difference in the concentration of all trace metals (Fe, Cu, Zn, Mn, and Cr) of the first flush and the corresponding the rainwater of after first flash (Table 2). The concentration of lead and cadmium were not found within the minimum detection limit.

Table 2: Descriptive Statistics of Open Space Harvested Rainwater

Parameters	First Flash	After First Flash
pH	5.85 ± 0.80	5.7 ± 0.78
Conductivity (µS)	14.97 ± 5.62	12 ± 6.04
TDS (mg/l)	9.94 ± 3.16	8.2 ± 3.35
Turbidity (NTU)	1.5 ± 0.78	1.4 ± 0.38
Alkalinity as CaCO3 (mg/l)	5.79 ± 1.08	5.46 ± 0.95
Hardness as CaCO3 (mg/l)	51.79 ± 18.36	38.4 ± 14.2
Sulfate (SO_4^{2-}) (mg/l)	0.43 ± 0.65	0.23 ± 0.18
Nitrate (NO_3^-) (mg/l)	0.22 ± 0.27	0.13 ± 0.16
Iron	0.07 ± 0.11	0.06 ± 0.09
Copper	0.018 ± 0.01	0.02 ± 0.012
Zinc	0.19 ± 0.019	0.14 ± 0.023
lead	0	0
Manganese	.0013 ± .0006	.0003 ± .0005
Chromium	0.0074 ± 0.0086	0.002 ± 0.001
Cadmium	0	0

3.2 Comparisons in Between Open Space and Rooftop Harvested Rainwater

In almost every sample, the concentration of selected parameters found higher in rooftop harvested rain water than the open space harvesting (Table 3). Especially for the concentration of pH, Iron and Zn, the variation was considerable. The concentration of pH value for open space harvesting found in between 4.52 to 7.68, whereas for rooftop harvesting it is found 6.85 to 8.66. Same for Iron concentration, for open space harvesting found in between 0.01 - 0.11 mg/l, whereas for rooftop harvesting it is found 0.03 - 0.32 mg/l. Zinc concentration for rooftop harvested rainwater was found 0.18 - 0.37 mg/l but for open space harvesting it was in the range of 0.06 -0.23 mg/l.

Table 3: Comparison of CUET Campus Rainwater Quality between Open space harvesting and Roof top harvesting

Parameters	Open Space Harvesting		Rooftop Harvesting	
	Median	Range	Median	Range
pH	5.76	4.52 - 7.68	7.2	6.85 - 8.66
Conductivity (µS)	13.89	8.39 -26.6	54.9	27.1 - 63
TDS (mg/l)	9.51	5.95 -16.6	38.2	19.7 - 41.8
Turbidity (NTU)	1.16	0.6 - 3.48	1.3	0.41 - 2.19
Alkalinity as CaCO3 (mg/l)	6	4.0 - 8.0	23	20 - 25
Hardness as CaCO3 (mg/l)	50	15 - 80	60	35 - 90
Sulfate (SO_4^{2-}) (mg/l)	0.5	0 - 2	1	0 -11
Nitrate (NO_3^-) (mg/l)	0.22	0 – 0.89	0.47	0 – 0.88
Nitrite (NO_2^-)	0.14	0 - 2	0.5	0 -2
Iron (mg/l)	0.03	0.01 - 0.11	0.06	0.03 - 0.32
Copper (mg/l)	0.02	0.01 - 0.04	0.03	0.01 - 0.08
Zinc (mg/l)	0.19	0.06 -0.23	0.23	0.18 - 0.37
lead (mg/l)	0	0	0	0
Manganese (mg/l)	0.001	0.001 - 0.003	0.004	0.001 - 0.007

Parameters	Open Space Harvesting		Rooftop Harvesting	
	Median	Range	Median	Range
Chromium (mg/l)	0.004	0.001 - 0.022	0.007	0.002 - 0.011
Cadmium (mg/l)	0	0	0	0
Total Coliform (TC) (N/100mL)	4	0 - 12	1	0 - 4

3.3 Stored Rainwater Quality

For comparison both water (one collected from rooftop another directly from open space) was stored for several months and tested that water frequently. From the tested result it is revealed that for both conditions the physicochemical parameters are not changed but the bacteriological parameters changed. The variation of physicochemical parameters with storage period for open space harvested and rooftop harvested rainwater are shown in Figure 2 and Figure 3. For both cases the concentration of Hardness varies more than other parameters. Initially the concentration of Hardness for rooftop harvested rainwater was 60 mg/l. After reaching the concentration to 40 mg/l, the curve for Hardness was being flat till the final sampling date. For the case of open space harvested rainwater, the concentration of Hardness initially was 55 mg/l, after reaching to 70 mg/l for some sampling dates the concentration falls to 40 mg/l finally.

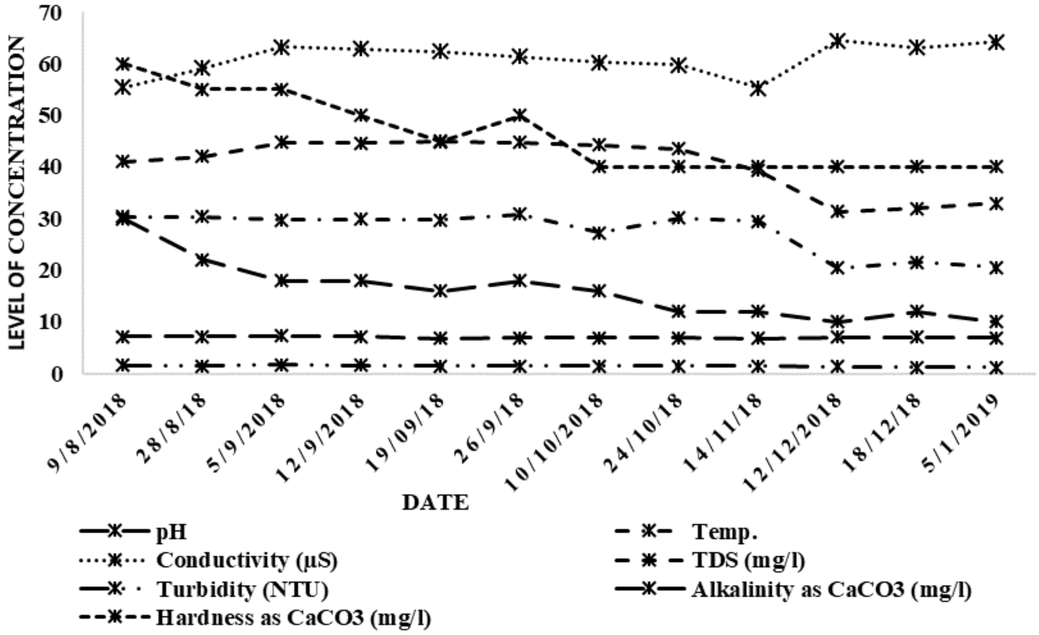

Figure 2: Variation of Physicochemical- Parameters due long-time storage (Roof Top Harvested)

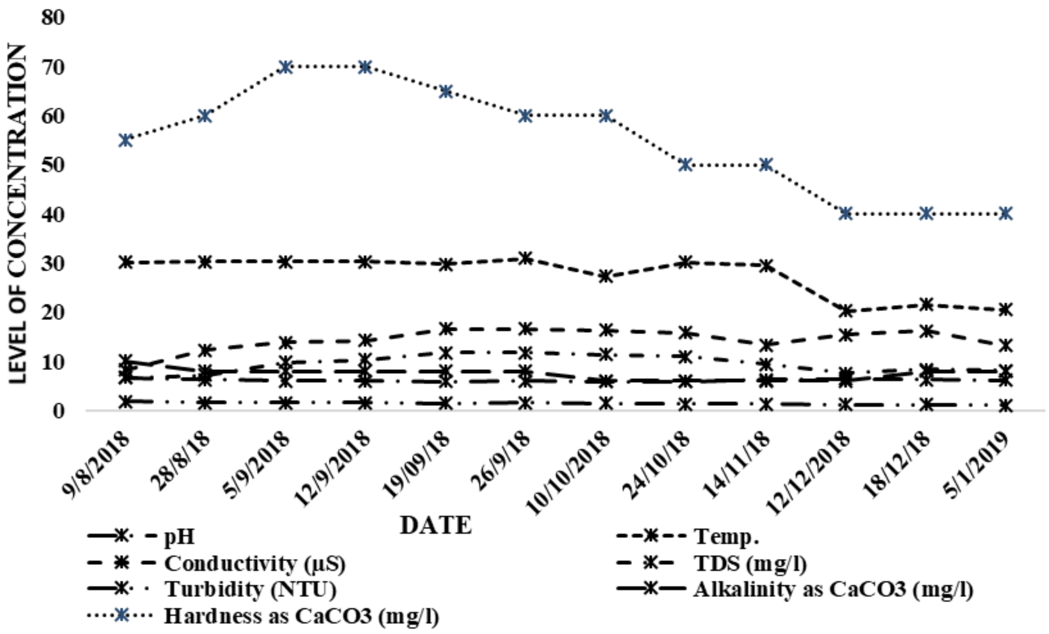

Figure 3: Variation of Physicochemical- Parameters due long-time storage (Open Space Harvested)

For rooftop harvested rainwater, initially the amount of total coliform was found per 100 ml water around 25 which is reduced to 4 (Figure 4). And for open space harvested rainwater, initially the amount of total coliform was found per 100 ml water around 140 which was reduced to 10 (Figure 5).

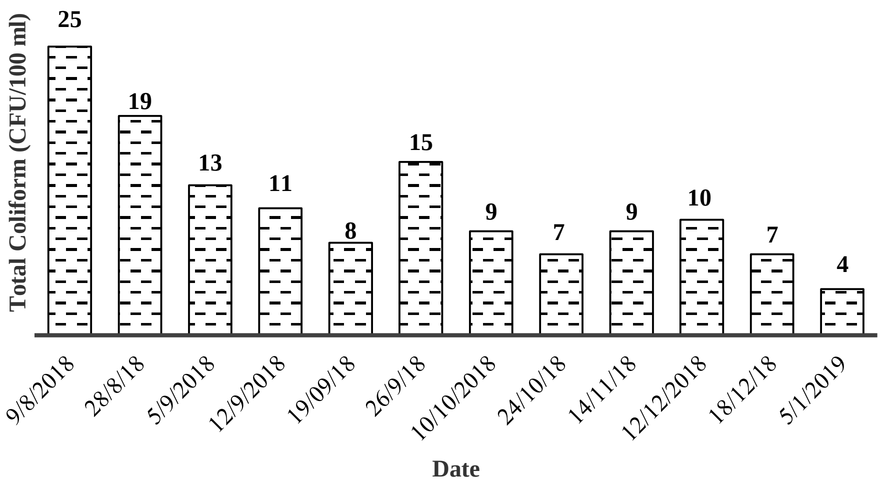

Figure 4: Trend of Coliform in Stored Rainwater collected from rooftop

The materials of storage tank were same throughout the storage period, moreover the temperature difference from the first date of storage period to last date was not high. So, the variation of number of coliforms may be due to lack of food for the survival.

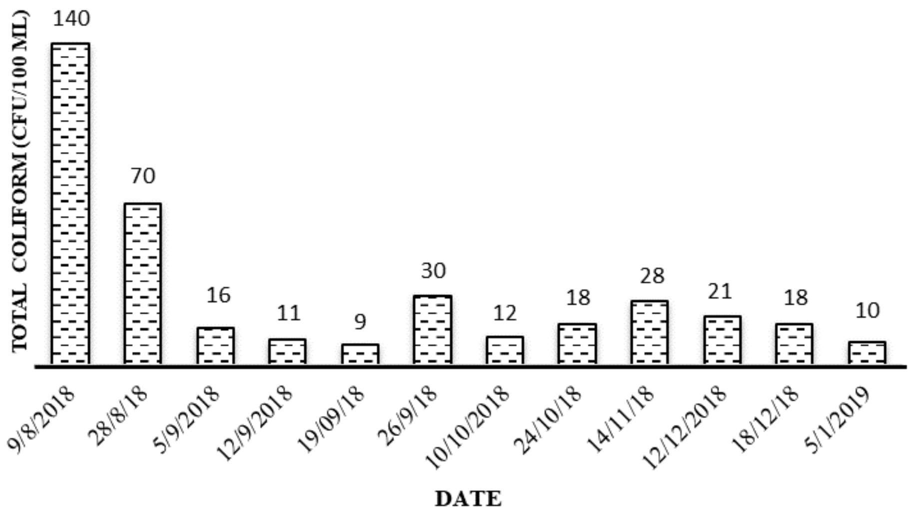

Figure 5: Trend of Coliform in Stored Rainwater collected from Open Space

4. CONCLUSIONS

In this study, the quality of harvested rainwater was assessed for different catchment type from July 2018 to January 2018. The difference between the quality of first flash and the after first flash rainwater was also exmined. The rainwaters were also stored from August 2018 to January 2019 and tested them at regular interval. Analysis of rainwater samples revealed that the concentrations of all measured parameters were within the permissible limit for drinking purpose according to Bangladesh Standard. But, the concentrations of all parameters were found higher for first flash rainwater than the rainwater after first flash. In almost every sample, the concentration of selected parameters found higher in rooftop harvested rain water than the open space harvesting. Especially for the concentration of pH, Iron and Zn, the variation was considerable. For stored rainwater, it is revealed that for both conditions (open space and rooftop harvested) the physico-chemical parameters are not changed but the bacteriological parameters changed with time. The reason behind the change of bacteriological parameters may be due to lack of food for the survival of coliform.

ACKNOWLEDGEMENTS

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REFERENCES

Abbasi, T., & Abbasi, S. A. (2011). Sources of pollution in rooftop rainwater harvesting systems and their control. Critical Reviews in Environmental Science and Technology, 41, 2097–2167.

Ahmed, R. (2010), Drinking Water Contamination and Its Effects on Human Health. MPHP 429: Introduction to Environmental Health.

Akter, A., & Ahmed, S. (2015). Potentiality of rainwater harvesting for an urban community in Bangladesh. Journal of Hydrology, 528, 84-93.

Alam, R., Munna, G., Chowdhury, M. A. I., Sarkar, M. S. K. A., Ahmed, M., Rahman, M. T., ... & Toimoor, M. A. (2012). Feasibility study of rainwater harvesting system in Sylhet City. Environmental monitoring and assessment, 184(1), 573-580.

Al-Khatib,I. A., Daoud, F.,Rasmawi, F.,Wa'rra, S.,Kassabry., M. (2005) Seasonal Variation of Bacteriological and Chemical Quality of Drinking Water: A Case, Study in a Palestinian District. Journal of the Chartered Institution of Water and Environmental Management, 3(19).

Ashraful, A. M., & Islam, M. M. (2015). A Study on Rain Water Harvesting and Comparative Cost Analysis with Withdrawal of Underground Water around Gazipur City. Journal of Environmental Science and Natural Resources, 8(1), 91-94.

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). Nature-based solutions to address global societal challenges. IUCN, Gland, Switzerland, 97.

Dakua, M., Akhter, F., Biswas, P. P., Siddique, M. L. R., & Shihab, R. M. (2014). Potential of rainwater harvesting in buildings to reduce over extraction of groundwater in urban areas of Bangladesh. European Scientific Journal, ESJ, 9(10).

Ezbakhe, F. (2018). Addressing Water Pollution as a means to achieving the sustainable development goals. J Water Pollut Control, 1(1), 6.

Islam, M. M., Chou, F. F., Kabir, M. R., & Liaw, C. H. (2010). Rainwater: A potential alternative source for scarce safe drinking and arsenic contaminated water in Bangladesh. Water resources management, 24(14), 3987-4008.

Islam, M. M., Chou, F. F., & Kabir, M. R. (2011). Feasibility and acceptability study of rainwater use to the acute water shortage areas in Dhaka City, Bangladesh. Natural hazards, 56(1), 93-111.

Mancosu, N., Snyder, R., Kyriakakis, G., & Spano, D. (2015). Water scarcity and future challenges for food production. Water, 7(3), 975-992.

Rahman, S., Khan, M. T. R., Akib, S., Din, N. B. C., Biswas, S. K., & Shirazi, S. M. (2014). Sustainability of rainwater harvesting system in terms of water quality. The Scientific World Journal, 2014.

Usaquen Perilla, O.L.; Garcia Gomez, A.; Garcia Gomez, A.; Alvarez Diaz, C.; Revilla Cortezon, J.A. 2012. Methodology to assess sustainable management of water resources in coastal lagoons with agricultural uses: An application to the Albufera lagoon of Valencia (Eastern Spain). Ecol. Indic. 13, 129–143.

SPATIAL & TEMPORAL ASSESSMENT OF GROUNDWATER QUALITY OF CENTRAL DHAKA FOR DRINKING PURPOSE

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ABSTRACT

Dhaka, the capital of Bangladesh is the most densely populated city of the country. Major part of its supply water is abstracted from groundwater. Due to heavy extraction of groundwater, dispose of industrial waste, municipal waste, infiltration of polluted surface water in shallow aquifer, groundwater quality is changing and degrading day by day. So groundwater quality assessment is essential. Physio-chemical analysis reveals whether the water is suitable for drinking purposes. In specifying the quality characteristics of groundwater, chemical, physical & biological analysis is required. Properties of groundwater evaluated in the Physical analysis include temperature, color, turbidity, taste. Important Chemical constituent present in groundwater are Na, Ca, Mg, K, Cl, Nitrate, Sulfate, Carbon Di-Oxide, As, Fe etc. Biological analysis includes test to detect the presence of coliform bacteria. For classifying the water quality parameters Piper diagram were used & USSI classification were used. Spatial Analysis using data from lab tests shows that most of the physical & chemical parameters are within the acceptable limit to WHO standard & Bangladesh Standard except Iron , Silica m Manganese were observed quiet equal & in some cases exceeding the limiting value. Again the samples were less susceptible to bacteria. So the water is quiet suitable for drinking purpose. The groundwater of Dhaka city falls into C2-S1 category in USSI classification & into Calcium & Bi-carbonate dominant type in Piper diagram. Temporal analysis shows that values of pH , Temperature, TDS , Calcium , Carbon Dioxide , Bi-carbonate has been increasing while value of Sodium, Magnesium , Chlorine , Iron , Nitrate has been falling in last 20-25yrs. DRI analysis states that groundwater of Dhaka city contributes very little to amount of intake recommended for an individual per day. From the analyses, it is hoped that this study will be of immense help for the groundwater quality development and would serve as a guide for taking necessary measures for improving the water quality and availability to people. Furthermore this study will help us to predict the groundwater quality based on these correlation equations which can be used for any other location.

Keywords: *Groundwater, Parameters, Laboratory tests, ArcGIS, Dhaka.*

1. INTRODUCTION

Dhaka city mainly depends on the groundwater for its supply. More than 400pumping stations are set to abstract the groundwater by DhakaWASA. Due to heavy abstraction of groundwater the water table is declining alarmingly every year. Groundwater quality issue gets more importance due to rapid increase of population, rapid industrialization, and flow of pollution from surface water through infiltration and much use of fertilizer and pesticides in agriculture. So investigation of groundwater quality for drinking uses is a compulsory task. Groundwater generally contains Fe, Ca, Mg, Silica, arsenic, phosphate, sulphate, chloride, Mn, Na, K, Mg in dissolve state the presence of which above certain limits also affect the body system.

In Bangladesh, water extracted from shallow aquifer is the primary source of drinking and cooking for most of its population of over 150 million. Not only the rural supply but also the urban water supply heavily depends on groundwater. About 70% of irrigation water and around 83% of supply water are supplied by groundwater. Shahidullah et al. (2000) attempted to asses the groundwater quality in a selected area of Bangladesh. Their results suggested that there was neither salinity nor toxicity problem of irrigation water, so that groundwater can safely be used for long-term irrigation. All the research so far completed on groundwater quality of different areas of Bangladesh is based on physicochemical analyses. A few numbers of studies are available regarding the analysis of groundwater quality data using regression techniques for prediction purposes.Joarder et al. (2008) studied groundwater quality of Sunamganj district, Bangladesh using regression techniques. No attempt has yet been made to predict groundwater quality of Dhaka district using this regression technique. In the present study an attempt has been made to study groundwater quality of Dhaka district and to find correlation among different quality parameters. Zahid & Bodruddoha(2018) presented the current situation of groundwater quality in Hazaribag tannery area in Dhaka & observed trace elements being present in groundwater. Bodruddoha (2019) investigated the existence & amount of trace elements in Dhaka found little trace elements in majority of locations. Zahid & khan (2016) assessed the impact of mega city pumping on groundwater quality, how this overexploiting groundwater pumping is affecting the quality of groundwater beneath soil.

2. OBJETIVE

The main aim of this work is to analyze the groundwater quality parameter of Dhaka city using both primary & secondary data for drinking purpose.

For evaluating the groundwater quality parameters, water samples were collected from different zones of the study area & then tested on laboratory to find out the current status of groundwater quality. It was then represented with the help of ArcGIS. And to assess the changing pattern of various groundwater quality parameters, groundwater quality data of previous 35years were collected to check the changing pattern of these parameters all over the years.

3. STUDY AREA

Dhaka, the capital of Bangladesh is bounded by a network of 3rivers; the Buriganga on South-West, the Turag on West & the Balu on East. In addition to surrounded rivers, the city has a number of medium & small khals, with hydrologic functions of draining & detaining storm-sewer water of the city. The city lies on the lower reaches of the Ganges Delta & covers a total area of 360sq.kilometers.It consists of mainly 24thanas, 130wards& 725mohallas. Tropical vegetation & moist soil are the characteristics of the land, which is flat & close to sea level. Dhaka experiences a hot, wet, humid tropical climate. Annual average temperature of the city is around 26-28°C having maximum 35.5°C and minimum 18.5°C temperatures. Average annual rainfall is 1854mm.

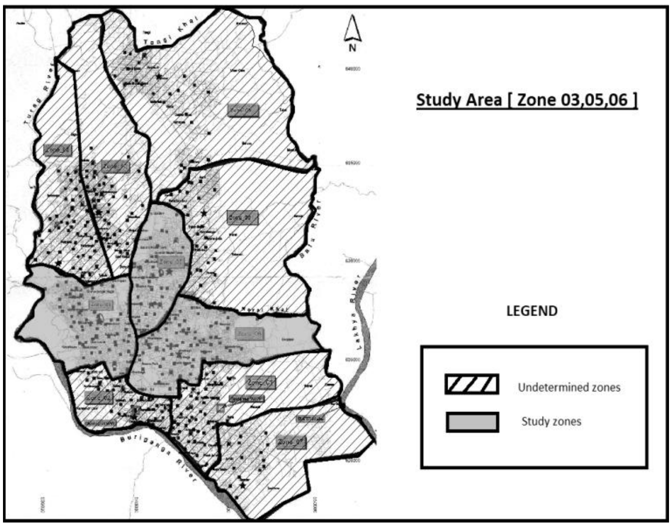

Figure 1: Location of Study Area (Central Dhaka)

4. METHODOLGY

4.1 Data & Sample Collection

The groundwater quality data of Dhaka city were collected from the Groundwater Hydrology Department of Bangladesh Water Development Board for the year 1985 to 2017 of several parameters of Dhaka city for investigating the temporal variation of groundwater quality.

Water samples were collected from 3 Dhaka WASA mod zones (Tejkunipara water pump, Lalmatia water tank, Fakirapool water tank) of Dhaka city for investigating the suitability & vulnerability of groundwater quality of various locations among Dhaka city. Samples were collected in bottles (one normal bottle & other one acidified) provided by Department of Public Health & Engineering laboratory.

Photo 1: (a) Sample collecting bottles; (b)Tejkunipara water pump ; (c)Lalmatia water tank.

4.2 Water Sample Investigation

Water samples that were collected was submitted in the laboratory of Department of Public Health & Engineering & was then examined. Table 1 shows the water quality lab tests that were conducted (APHA 1985).

Table 1: Water Sample Parameters Tests

Parameters	Analysis Method	Unit
pH	pH meter	
TDS	Multimeter	mg/L
Sodium	AAS	mg/L
Potassium	AAS	mg/L
Calcium	AAS	mg/L
Magnesium	AAS	mg/L
Iron	AAS	mg/L
Arsenic	AAS	mg/L
Chloride	Titrimetric	mg/L
Coliform	MFM	N/100mL
Silica	UVS	mg/L
Nitrogen	UVS	mg/L
Sulphate	UVS	mg/L

4.3 Classification Based on Piper Diagram

The piper diagram is suitable for comparing the ionic composition of a set of water samples, but does not lend itself to spatial comparisons. The cations and anions are shown by separate ternary plots (Piper, 1953).

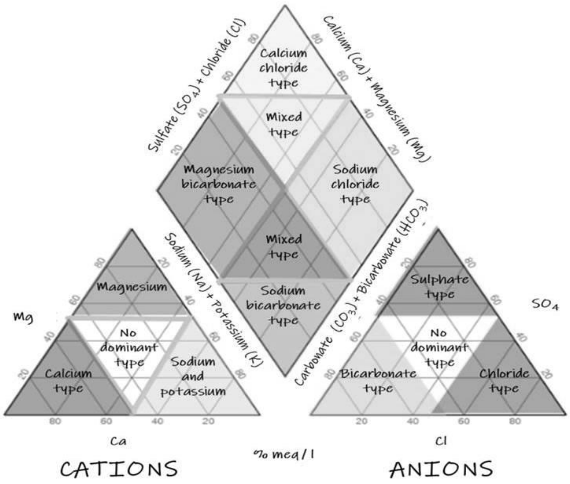

Figure 2: Piper Diagram

4.4 Dietary Reference Intake Analysis

Dietary reference intakes (DRI) are a set of reference values for vitamins, minerals, and other nutrients important to human health. DRIs provide guidance about the appropriate amount & safe upper limit intake of each nutrient. DRIs are specific to age group, gender, and for women, reproductive-status (Lawrence Appel, 2004).

Table 2: Dietary Reference Intake values for Sodium , Potassium , Chloride , Water

Nutrients	Intake(g/day)
Sodium	1.5
Potassium	4.7
Chloride	2.3
Water	3

5. RESULTS

5.1 Comparison with WHO , BS guidelines

Table 3 shows the comparison of the water sample tests & datas with the values of WHO guidelines & BS limits. The parameters which were found above the guideline values were identified.

Table 3:Statistics of Water Quality Parameters

	Unit	WHO	BS limit	MOHAKHALI Sample	MOTIJHEEL Sample	MOHAMMADPUR Sample
Temperature	°C			28.6	29	29
pH		6.5-8.5	6.5-8.5	7.5	7.2	7.8
Arsenic	mg/L	0.01	0.05	0.001	0.001	0.001
Calcium	mg/L	75	75	20	50	40

	Unit	WHO	BS limit	MOHAKHALI Sample	MOTIJHEEL Sample	MOHAMMADPUR Sample
Sodium	mg/L	200	200	23	35	29.8
Potassium	mg/L	50	12	1	2.63	1
Magnesium	mg/L	50	30-35	10	19.23	23
Chloride	mg/L	250	150-600	12	6.35	35
Sulphate	mg/L	250	400	1	2.26	6
TDS	mg/L	1000	1000	158	290	358
Silica	mg/L	10	50	65.1	25.1	48
Iron	mg/L	0.3	0.3-1.00	1.08	0.28	0.5
Nitrogen	mg/L	50	10	1.4	2	2.2
Coliform	N/100mL	0	0	48	65	74
HCO3	mg/L			185	189	240
CO2	mg/L			45	58	90
Manganese	mg/L	0.05-0.1	0.1	0.1	0.15	0.06

5.2 Changing Trends of Water Quality Parameters (Temporal Analysis)

In order to observe the trends of groundwater quality parameters in last 40yrs, secondary data were collected from BWDB of Mohammadpur , Motijheel area of Dhaka city which were available in Dhaka region.

Value of **Total Dissolved Solids** seemed to remain quiet same for Motijheel area while it tends to increase a bit for Mohammadpur area. **pH value** seemed to fall slowly in last 20yrs. **Temperature** is increasing slowly in last 20yrs. Value of **Sodium** seemed to fall in last 40yrs in both areas. **Potassium** had some unusual high values but it remained quite same otherwise. In both areas, value of **Calcium** has been increasing since 1980s. **Magnesium** value has fallen in Motijheel area although it remain quite same in Mohammadpur in last 40yrs. Change in **Chloride** value is different in 2areas. In Mohammadpur it has decreased in amount in last 40yrs but in Motijheel it increased in first 20yrs & then decreasing in last 20yrs. **Carbon Dioxide** is increasing in both areas significantly. **Flouride** value is falling at a very slow rate. Value of **Manganese** is falling in Mohammadpur area but it's remained quiet same for Motijheel in last 20yrs. Amount of **Silica** seemed to remain quiet same in last 40yrs in both areas. In both areas, amount of **Iron** was observed very high in the 1980s but it falled significantly to such low amount in 1990s which is started to increase at a very slow rate in last 10yrs. Change of values of **Sulphate** was found to be unusual in both areas. In both areas , Value of **Nitrate** was obvserved to high in early 1980s then it started to decrease in late 1990s which has began to increase again in last 20yrs. Amount of **Bi-Carbonate** is increasing at a very slow rate in last 40yrs in both areas.

Major results that were obtained from temporal analysis are represented in fig 3(a-h) :

Changing Patterns of Parameters Shown in Graphs

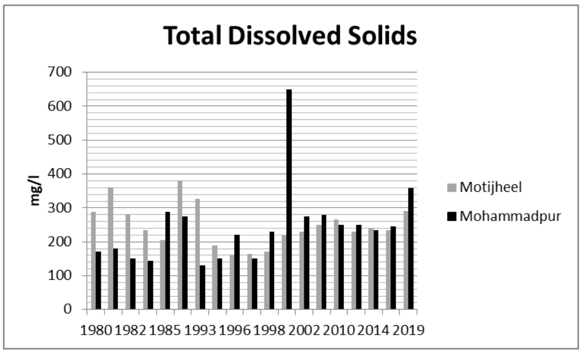

Figure 3(a): Temporal variation of TDS

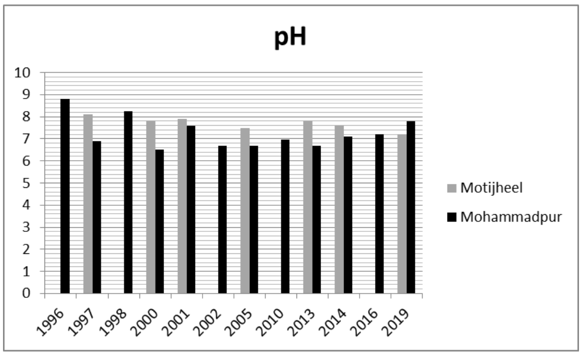

Figure 3(b): Temporal variation of pH

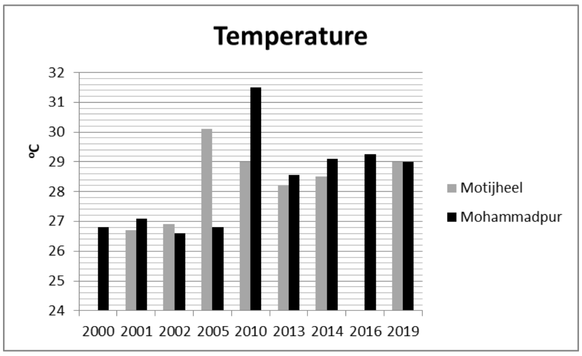

Figure 3(c): Temporal variation of Temperature

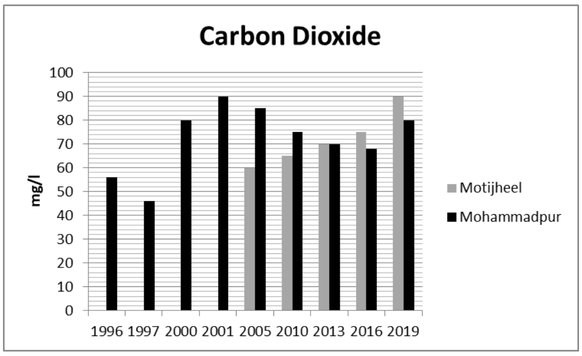

Figure 3(d): Temporal variation of Carbon Dioxide

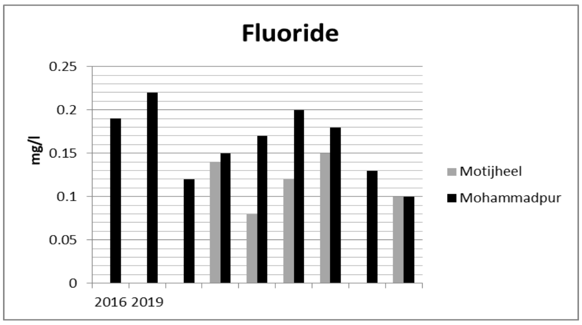

Figure 3(e): Temporal variation of Fluoride

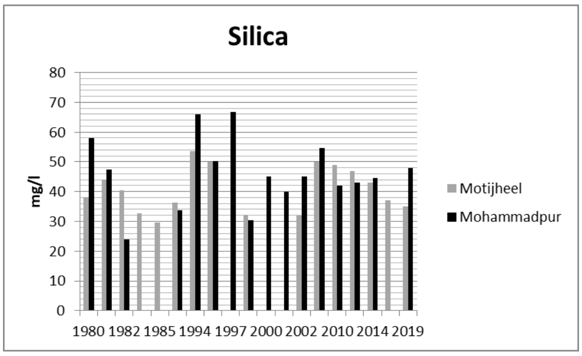

Figure 3(f): Temporal variation of Silica

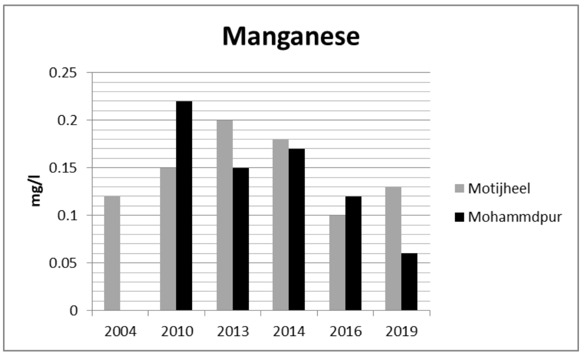

Figure 3(g): Temporal variation of Manganese

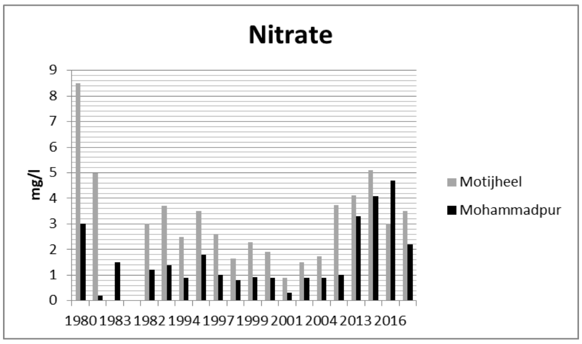

Figure 3(h): Temporal variation of Nitrate

4.3 Comparing Present Groundwater Condition with WHO, BS values (Spatial Analysis)

In order to compare water quality with BS values groundwater samples were collected from Tejkunipara , Mohammadpur , Motijheel area of Dhaka city which cover almost the central Dhaka.
Coliform bacteria was found in number of 48 , 65 , 75 in Tejkunipara, Motijheel , Mohammadpur groundwater respectively. The presence of these bacteria indicates that groundwater is contaminated with feces or sewage, and it has the potential to cause disease. **pH** values were observed in nominal range (6.5-8.5) in Tejkuniapra , Motijheel, Mohammadpur groundwater. Values of **Sodium**, **Calcium**, **Potassium**, **Magnesium** were observed well below the BS value. **Silica** present in groundwater of Tejkunipara (65.1mg/L) is exceeding the BS value. Value of **Iron** in groundwater of Tejkunipara (1.08mg/L) is just above BS value. **Arsenic** is in negligible amount (.001mg/L) in Tejkunipara, Motijheel, Mohammadpur. **Sulphate**, **Nitrate**, **Chloride** were found in amount which is much lower than their BS limiting values. The value of **Manganese** was found to be quiet equal to its BS limiting value in Tejkunipara & Mohammadpur while it exceeds in Motijheel. In previous studies, no heavy metal were reported in significant amount in all around Dhaka city but a few were traced in location of Hazaribag Tanneries. Severe contamination of groundwater wasn't observed except for tannery area.

Major results that were obtained from spatial analysis are represented in fig 4(a-g) :

Variation of Parameters Shown in ArcGIS Map:

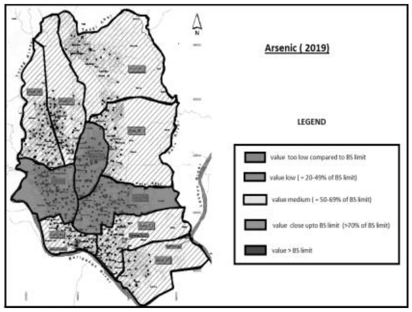

Figure 4(a): Spatial variation of Arsenic

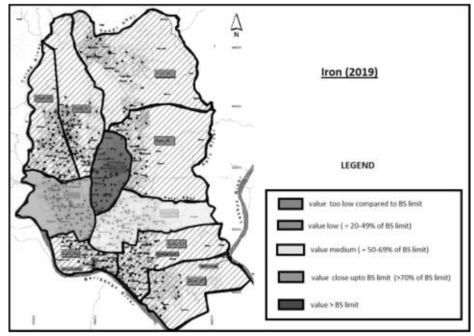

Fig 4(c): Spatial variation of Iron

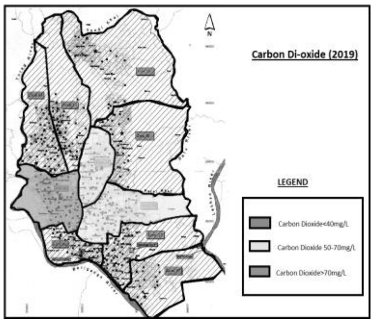

Fig 4(b): Spatial variation of CO_2

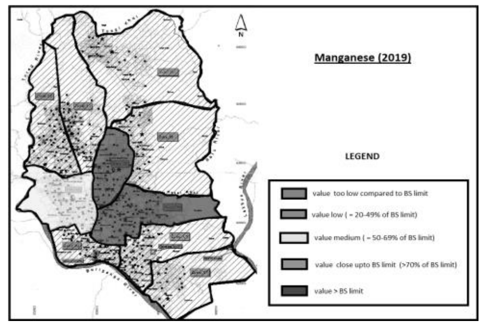

Fig 4(d): Spatial variation of Mn

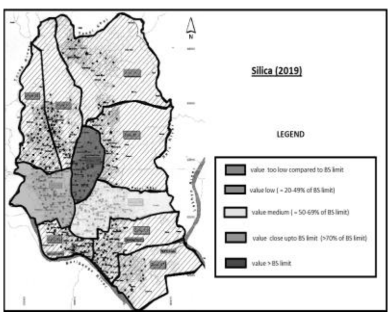

Fig 4(e): Spatial variation of SiO_2

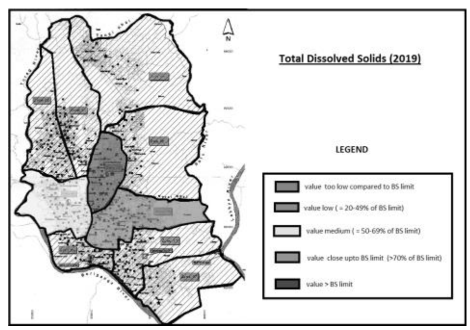

Fig 4(f): Spatial variation of TDS

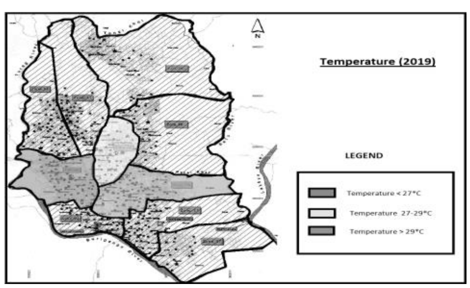

Fig 4(g): Spatial variation of Temperat

4.4 Piper Diagram Analysis

Tejkunipara – **Na** & **HCO_3^-** dominant type
Mohammadpur – **Ca** & **HCO_3^-** dominant type
Motijheel – **Ca** & **HCO_3^-** dominant type

4.5 DRI Analysis

Sodium: Groundwater samples contribute **6-10%** of the total intake recommended.
Potassium: Groundwater samples contribute **1-3%** of the total intake recommended.
Chloride: Groundwater samples contribute **2-6%** of the total intake recommended.
Sulphate: Groundwater samples contribute upto **1%** of the total intake recommended.

5. CONCLUSION

The major objective of this study was to monitor the groundwater quality of Dhaka city to compare the present water quality with WHO, Bangladesh Standards values & to show the trends of physical & chemical parameters using previous data. The major findings obtained from the study were –

- Most of the parameters are within nominal range of BS limiting value.
- Mn , Fe , Si – these parameters exceed the BS limiting value.
- Heavy metals weren't observed in Dhaka except in Hazaribag Tannery areas. (previous study)
- Mineral intake level is much lower than the required intake level for an individual.
- Arsenic is in negligible amount all around Dhaka city(.001mg/L).
- Severe contamination of groundwater wasn't observed except for tannery area.(previous study)
- Temperature, Carbon Di-oxide is increasing while pH is decreasing.
- Coliform bacteria were found in the samples of central Dhaka in significant amount.

REFERENCES

Academies, I. o. (• Lawrence Appel, Chair. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate.). Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate.

Association., A. P. (1985). Standard Method for the Examination of Water and Wastewater. Washington DC.

BodrudDoza, M. B. (2019). Delineation of trace metals contamination in groundwater using geostatistical techniques: A study on Dhaka City of Bangladesh. Groundwater for Sustainable Development 9.

(n.d.). Disolved Minerals, Mineral Sources & Significance. . National Ground Water Association.

Hem, J. (1985). Study & Intepretation of the Chemical Characteristics of Natural Water. USGS Water Supply Paper.

Joarder, M. R. (Summer 2008). Regression Analysis of Groundwater Quality Data of Sunamganj District. Int. J. Environ. Res. 2(3)., 291-296.

Piper, A. (1953). A Graphic Procedure in the Geochemical Interpretation of Water Analysis. Washington D.C.: United States Geological Survey.

Shahidullah, S., Hakim, M., Alam, M., & Shamsuddoha, A. (February 2000). Assessment of Groundwater Quality in a Selected Area of Bangladesh. Pakistan journal of Bilogial Sciences. February 2000.

Shahidullah, S., Hakim, M., Alam, M., & Shamsuddoha, A. (February 2000). Assessment of Groundwater Quality in a Selected Area of Bangladesh. Pakistan journal of Bilogial Sciences.

Todd, D. (1980). Groundwater Hydrology. New York.: Wiley.

World Health Organization. (2005). Nutrients in drinking water. World Health Organization.
Zahid, A. ,. (September 2016). Megacity Pumping and Preferential Flow Threaten Groundwater Quality. Nature Communications 7:12833 ·.
Zahid, A. A. (2018, November). Hydrogeochemical evaluation and statistical analysis of groundwater of Sylhet, north-eastern Bangladesh. Acta Geochimica · .
Zahid, A. (October 2017). Hydrogeology and Groundwater Model of the South East Bengal Delta. . Scholar's Press, Omniscriptum GmbH and Co. KG.
Zahid, A. (October 2017). Impact of Tanneries on Groundwater Environment of Dhaka City. LAP LAMBERT Academic Publishing.

ASSESSMENT OF WATER QUALITY AT CONSUMER LEVEL AND AT SOURCE IN DHAKA CITY

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ABSTRACT

The present study focuses on monitoring the chemical water quality at household level supplied by Dhaka WASA. In this study, five areas (Kallyanpur, Rampura, Malibagh, Baridhara and Uttara) have been selected to assess the water quality over a four-month period (October 2018 to February 2019). The water samples were analyzed for pH, EC, hardness, alkalinity, ammonia, nitrate, phosphate, total chlorine, free chlorine, and chloramines (mono-, di- and tri-chloramines). In order to assess surface water quality at source, data on treated water quality at the Saidabad Water Treatment Plant (SWTP) were collected for the year 2017. In order to assess groundwater quality at source, water samples collected from three deep tubewell (DTW) pump stations located at Bijaynagar, BUET West Palashi Campus and Rampura were analyzed. This study shows that characteristics of water received at consumer-level in different areas of Dhaka city vary significantly, primarily due to variation in the characteristics of DTW water and water supplied from the SWTP. The water samples collected from Rampura and Kallyanpur contained relatively high concentrations of ammonia, free and total chlorine, and chloramines; and concentration of these parameters increased with the progress of dry season (from October to February). This variation closely matches the characteristics of treated water as STWP. The water samples collected from Baridhara, Uttara and Malibagh shows similar chemical characteristics that did not vary significantly with time; groundwater appears to be the predominant source of supply in these areas. Complete lack of chlorine in supplied water in these areas is a concern.

Keywords: *Water quality, Dhaka WASA, Chemical characteristics, Ammonia, Chloramines.*

1. INTRODUCTION

Supply of safe water for drinking and other purposes in Dhaka city appears to be a major challenge nowadays due to escalated pollution of surface water and lowering of ground water level. At present, total population of the Dhaka city is around 18.24 million. This huge population needs a large volume of water for the purpose of drinking and domestic uses. The whole water supply system including collection, treatment and distribution of water is done by Dhaka WASA. The water supplied by Dhaka WASA comprises of both groundwater and treated surface water (primarily from Saidabad Water Treatment Plant, SWTP). Groundwater extracted from deep tubewells (DTW) and treated surface water are fed to the same distribution network that carries it to the consumers. The service area of Dhaka WASA covers more than 360 square km. At present, the service area of Dhaka WASA extends to Mirpur and Uttara in the North and to Narayanganj in the South. For better operation, maintenance, and customer care, the total service area of Dhaka WASA is divided into 11 geographic zones, which includes 10 zones in Dhaka city and 1 zone in Narayanganj. Depending on location, some consumers therefore receive primarily ground water, some receive predominantly groundwater, while others receive mixture of surface and groundwater. The quality of treated surface water at the SWTP depends on the quality of raw water drawn from the Sitalakhya rivers, which varies seasonally. The raw water quality deteriorates significantly in dry season, with very high concentrations of organic matter, ammonia, and dissolved solids. Chlorination carried out at the SWTP are likely to form chloramine due to reaction of chlorine with ammonia. Studies have demonstrated that excessive levels of free chlorine cause a negative impact on human health (Zheng, C. He & Q. He, 2015). Chloramines may cause immune system problem, respiratory problem, skin problem, digestive and gastric problem. That is why it is necessary to monitor the water quality at consumer level as well as at source. A variety of physical, chemical and biological transformations can happen once the water travels through a distribution system.

The overall objective of this study was to assess the quality of potable water at consumer level and at sources in Dhaka city. The specific objectives included: (i) Collection of the water samples from consumers in five different locations distributed over Dhaka city, and analysis of the water samples for selected parameters; (ii) Collection and analysis of groundwater samples from selected DWASA deep tubewell pumps in Dhaka; and (iii) Collection and analysis of water quality data from the Saidabad Water Treatment Plant (SWTP).

2. METHODOLOGY

2.1 The study area

In this study, water samples were collected from 5 different areas of Dhaka City, as listed in Table 1, and shown in Figure 1. These points were selected considering their location with respect to the Saidabad Water Treatment Plant (SWTP). Kallyanpur, Rampura and Malibagh were selected considering that these are located close to the SWTP and the water supplied to these areas are likely to have a significant fraction of water from the SWTP. Baridhara and Uttara were selected considering that these two areas are located away from the SWTP, and are likely to receive water primarily from local DTWs. Ground water samples were collected from 3 different Deep Tube wells in Dhaka City, as listed in Table 2.

Table 1: Location of Water sample collection zones

Collection point	Location	Address
1	Baridhara	Road#05, Baridhara, Diplomatic Zone, Dhaka
2	Uttara	Sector 14, Road 16, Uttara, Dhaka
3	Kallyanpur	Road#01, Kallyanpur, Dhaka
4	Malibagh	D.I.T Road, Malibagh, Dhaka.
5	Rampura	East Rampura Road, Dhaka

Table 2: Location of Deep Tubewell

DTW Identification	Location
1	Bijoynagar
2	BUET West Polashi Campus
3	Rampura

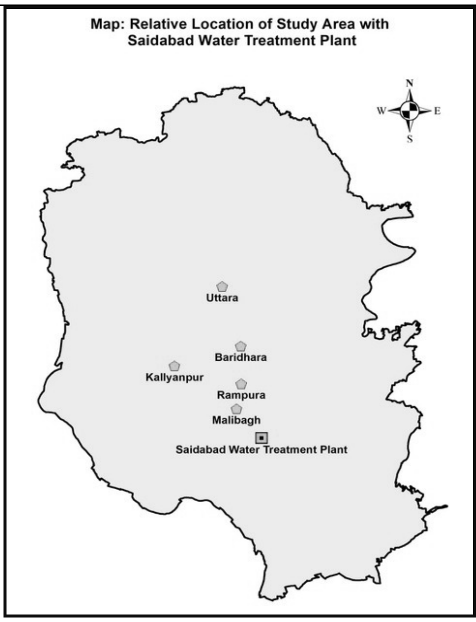


Figure 1: Study areas showing locations of sampling points and location of SWTP

2.2 Collection and Analysis of Water Samples

Water samples were collected from the five areas of Dhaka city roughly at one-week interval in order to monitor the water quality in a continuous manner. Table 3 shows the sampling schedule. All collected samples were transported to the laboratoy within 3 hours of collection, and tested immediately.

Table 3: Sampling and Testing schedule

Sampling cycle	Collection Point	Date of Sampling
1	Baridhara, Kallyanpur, Rampura	09 October, 2018
2	Baridhara, Uttara, Kallyanpur, Rampura	05 November, 2018
3	Baridhara, Uttara, Kallyanpur, Rampura	19 November, 2018
4	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	28 November, 2018
5	Baridhara, Kallyanpur, Malibagh, Rampura	12 December, 2018
6	Baridhara, Kallyanpur, Malibagh, Rampura	09 January, 2019
7	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	16 January, 2019
8	Baridhara, Malibagh, Rampura	23 January, 2019
9	Baridhara, Uttara, Kallyanpur, Malibagh, Rampura	12 February, 2019

All collected water samples were analyzed for a range of chemical parameters, including pH, electrical conductivity, alkalinity, hardness, ammonia, free chlorine and total chlorine, chloramines (mono, di and tri-chloramine), nitrate and phosphate. pH and EC were measured with a pH meter

(Hach) and EC meter (WTW), respecively. Ammonia was measured by the Nessler method, nitrate by the cadmium reduction method, phosphate by the molybdenum blue method using a spectrophotometer (Hach, DR 6000U). Free chlorine and mono-, di-, tri-chloramines were measured by DPD titrimetric method, following Standard Methods. N, N-diethyl-p-phenylenediamine (DPD) is used as an indicator in the titrimetric procedure with ferrous ammonium sulfate (FAS).All other parameters were measured followoing Standard Methods.

3. RESULTS AND DISCUSSION

3.1 Water Quality at Source

3.1.1 Saidabad water treatment plant (SWTP)

Dhaka WASA supplies 17% of its total supplied water from the SWTP. To evaluate the quality of treated water at SWTP, sever parameters – pH, electrical conductivity (EC), alkalinity, ammonia nitrate, and phosphate - were analyzed based on water quality data collected from Dhaka WASA for the year 2017. This section briefly describes the treated water quality at the SWTP.

The pH of the treated water at the SWTP varied over a narrow range. The maximum value was 7.65, while the minimum was 6.84. The EC measured at SWTP showed a seasonal variation. Relatively higher values were recorded from January to May, i.e., during the peak dry period. The recorded values exceed 1,000 μS/cm during February to April. Higher values of alkalinity were measured in January to mid of April (i.e. the dry season). The maximum alkalinity was recorded in March and the minimum alkalinity was recorded in November.

Figure 2 shows variation of ammonia concentration in treated water at the SWTP in 2017. The treated water contains high concentration of ammonia during the peak dry season (January to April). The maximum value, 12.8 mg/l, was recorded in February. Previous studies showed that the duration of ammonia contamination of the Sitalakhya River is extended and continues from December to April (Serajuddin, 2017). Ammonia concentrations recorded during January to March exceed the Bangladesh drinking water quality standard (0.5 mg/l) by a large margin. The elevated ammonia concentration in the treated water during the dry season coincides with high ammonium concentration in the water of the river Sitalakhya River (Mahbub, Nahar and Ahmed, 2011). Ammonia concentration in both raw water (from Sitalakhya River) and treated water at the SWTP drops sharply with the commencement of wet season.

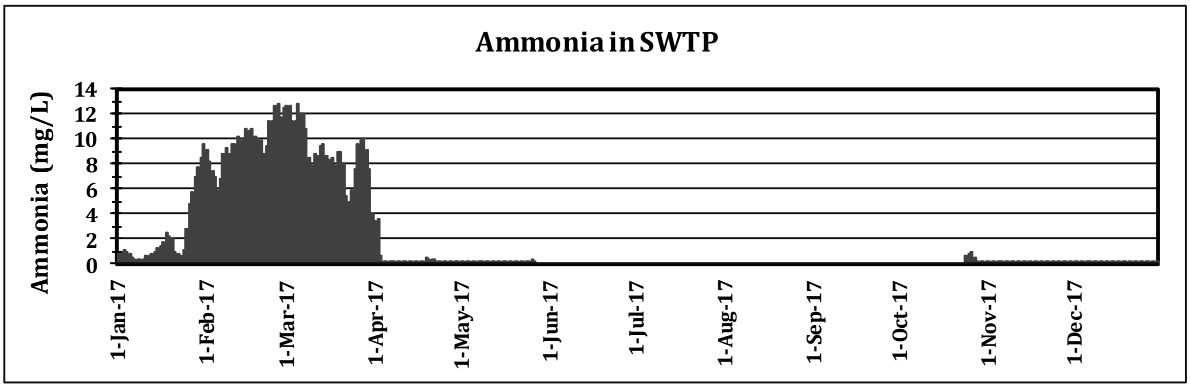


Figure 2: Variation of ammonia in treated water at SWTP in 2017

Higher nitrate concentrations were recorded in treated water as the SWTP from January to May (i.e., during dry season), followed by lower concentration during the wet season (June to October). Concentration of nitrate began to increase again from November, with the commencement of dry season. Nitrate concentration exceeded the Bangladesh standard (10 mg/l) in March 2017. Microbial activities can get increased due to the presence of Ammonia and Nitrate (Rajala et al., 2015). Elevated concentration of ammonia can affect influenced turbidity, colour, taste, odor, alkalinity, TDS, etc. which are the aesthetic properties of treated water (Hossain, Begum, Fakhruddin & Khan, 2006). Phosphate concentration in treated water follows a trend similar to that of nitrate. High phosphate concentration exceeding the Bangladesh drinking water standard of 6 mg/l was recorded in February and March.

3.1.2 Deep Tube well Pump Stations

The pH value of the three groundwater samples were similar; pH ranged from 6.5 to 7.1. The TDS values lie in a narrow range (230 to 450 mg/l). The alkalinity of the groundwater samples ranged between 140 to 200 mg/l as $CaCO_3$. This values are significantly lower than the alkalinity values of treated water at the SWTP during the dry season. Hardness of the groundwater samples ranged from 104 mg/l (as $CaCO_3$) for the Rampura DTW to 264 mg/l (as $CaCO_3$) for the BUET Campus DTW. Chloride concentration of the groundwater samples ranged from 6 mg/l for the Rampura DTW to 80 mg/l for the BUET Campus DTW. Ammonia concentration ranged from 0.06 mg/l for the Rampura DTW to 0.26 mg/l for the BUET Campus DTW. Nitrate concentration ranged from 0.20 mg/l for the Rampura DTW to 1.4 mg/l for the Bijoynagar DTW, while phosphate concentration ranged from 0.40 mg/l for the BUET Campus DTW to 3.10 mg/l for Rampura DTW. Arsenic concentration in the groundwater samples were all below 2 ppb, well below the Bangladesh standard of 50 ppb. Iron concentrations in all groundwater samples were below the Bangladesh standard of 1.0 mg/l; only the Mn concentration of BUET DTW water exceed the Bangladesh standard of 0.1 mg/l. Very low chlorine (total) concentration, varying from 0.02 to 0.03 mg/l, was detected in the groundwater samples.

3.2 Water Quality at Consumers Level

As treated water from the SWTP gets mixed with extracted groundwater from DTW pump stations in the distribution network, water quality varies significantly at consumer level. Contamination of water may take place in the distribution system and/or in water tanks or reservoirs at household level (Mahbub et al. 2012). Among the areas from where water samples were collected, Rampura, Malibagh and Kallyanpur are located closer to the SWTP, and are likely to receive part of the water supply from the SWTP. On the other hand, Baridhara and Uttara are located far away from the STWO and receive water supply primarily from DTWs. The following section describes the water quality at consumer level, based on the results of analysis of the collected water samples.

pH: pH of water samples collected from Baridhara and Uttara lied in the range 6.8-7.55 and did not vary considerably over the study period. The peak pH was observed in January in both these areas. The average pH value of water samples collected from Kallyanpur frequently exceeded 7; the maximum value was recorded in November in this area. The pH of water samples collected from Rampura area varied over a wider range (6.8-7.84). Peak pH is recorded in the month of December.

Electrical Conductivity: The EC of water samples collected from Baridhara ranged between 293-342 μS/cm and increased slightly with the approach of dry season. The EC of water samples from Uttara remained within a very narrow range of 248-253 μS/cm throughout the study period. In the water samples collected from Kallyanpur, the EC showed a distinct elevation as the dry season approached, with a peak value of 926 μS/cm in February. In Malibagh, EC remained within a narrow range of 311-370 μS/cm. Similar to Kallyanpur, the EC showed an increasing trend from October to February for water samples from Rampura.

Alkalinity: The alkalinity values of water samples from Baridhara and Uttara were similar to those recorded for the DTW water samples. Also, the values were less than the average alkalinity (200 mg/L as $CaCO_3$) of treated water at SWTP. The alkalinity of water samples from Kallyanpur and Malibagh ranged between 150-200 mg/l as $CaCO_3$. The alkalinity of water samples from Rampura showed an increasing trend as dry season progressed from October (48 mg/l as $CaCO_3$) to February

(222 mg/l as$CaCO_3$). This variation shows a strong resemblance with the alkalinity values recorded at SWTP.

Hardness: The hardness of water samples of Baridhara ranges between 50-150 mg/l as $CaCO_3$ in 9 cycles of test; hardness of water samples collected from Uttara varied from 76 to 112 mg/l as $CaCO_3$. For water samples collected from Malibagh, hardness varied over a narrow range of 104 to 130 mg/l as $CaCO_3$. Hardness of water samples from Kallyanpur was a bit higher, and varied from 140 to 230 mg/l as $CaCO_3$. The hardness of water samples collected from Rampur varied from 82 to 296 mg/l as $CaCO_3$; it showed an increasing trend as dry season progressed from October to February.

Ammonia: Ammonia measured in Baridhara water samples were negligible, except for the two samples collected in November and December (see Fig. 3). In Uttara, ammonia concentration exceeded the drinking water quality standard (0.5 mg/l) in November; however, ammonia concentration became negligible (0.02 mg/l) during January-February. In the water samples from Kallyanpur, ammonia concentration was elevated drastically in February, reaching a value of 13 mg/l. A similar trend was observed for Rampura, where ammonia concentration reached a peak value of 12 mg/l in February. These peak values (at Kallyanpur and Rampura) are significantly higher than the groundwater ammonia concentration recorded in this study. On the other hand, these values are comparable to the high ammonia concentration in treated water at SWTP. This suggests that Kallyanpur and Rampura receive water mainly from the SWTP. The presence of ammonia induces objectionable odor at consumer level.

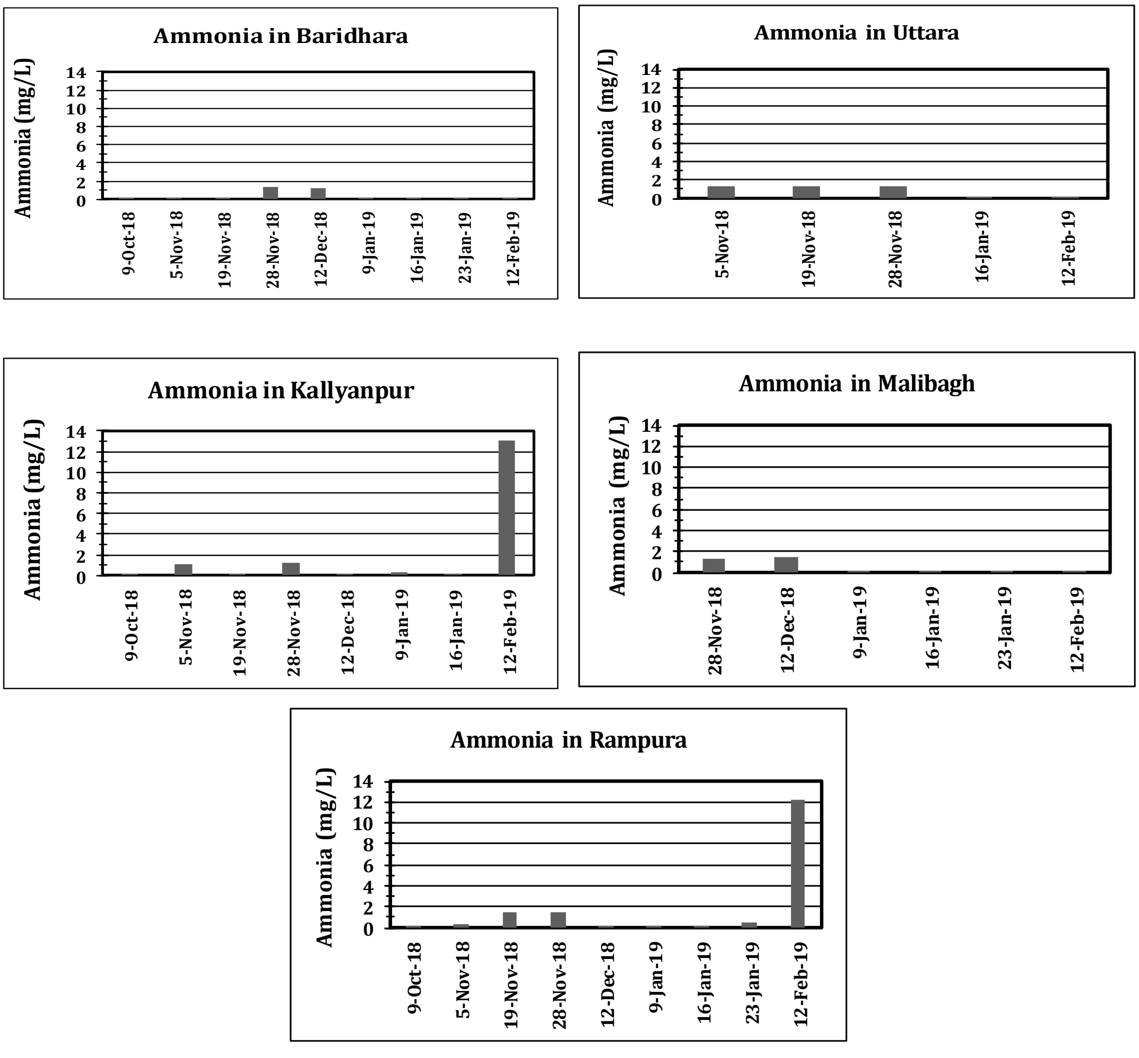


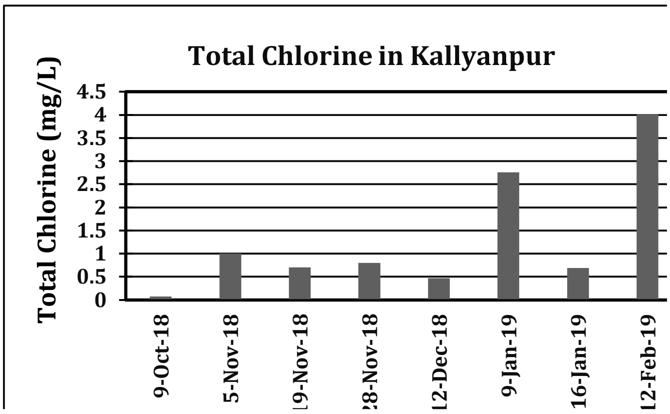
Figure 3: Variation of ammonia concentration in water samples collected from households in Baridhara, Uttara, Kallyanpur, Malibagh and Rampura

Nitrate: The nitrate concentration remained almost constant over test cycles in water samples collected from Baridhara, Uttara and Malibagh, ranging from 0.2 to 0.6 mg/l. Nitrate concentrations were relatively higher in water samples collected from Kallyanpur and Rampura. The highest concentration recorded for Kallyanpur was 4.4 mg/l. Nitrate concentrations varied from 2.5 to 3.8 mg/l for the water samples collected from Rampura.

Phosphate: Phosphate concentration in water samples from Baridhara varied over a narrow range of 4.0 to 4.5 mg/l, while in Uttara it varied from 4.3 to 10.5 mg/l. In Malibagh, phosphate concentrations in water samples varied over a wide range of 1.5 to 11.2 mg/l, while for water samples from Kallyanpur, it varied from 3.1 to 7.25 mg/l. Phosphate concentrations of Rampura water samples ranges from 0.05 to 5.9 mg/l during October to January; while in February, a very high concentration of 13.9 mg/ was recorded.

Free Chlorine: Virtually No free chlorine was detected in the water samples from Baridhara, Uttara and Malibagh. Free chlorine was detected in water samples from Kallyanpur and Rampura, areas that appear to receive water from the SWTP. Significant free chlorine was detected in the water samples collected from Kallyanpur, where it varied from below detection limit (in October) to 2.0 mg/l in January. In Rampura, free chlorine concentration varied from less than detection limit to 3.0 mg/l.

Total Chlorine: Like free chlorine, total chlorine concentration was low in water samples from Baridhara, Uttara and Malibagh; while it was higher for water samples collected from Kallyanpur and Rampura. In Kallyanpur, total chlorine varied from 0.07 to 4.02 mg/l; while in Rampura, it varied from less than detection limit to 3.0 mg/l.



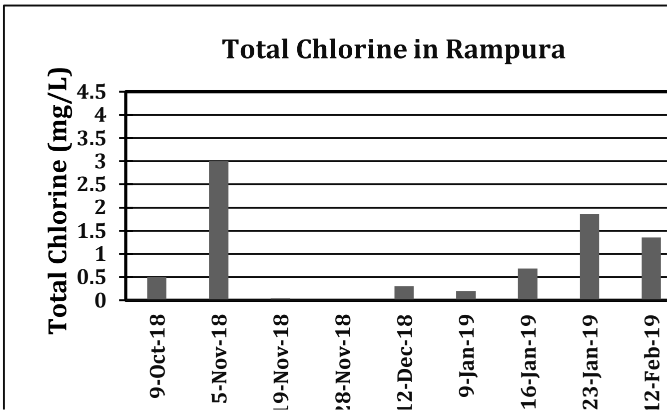


Figure 4: Variation of total chlorine in water samples collected from Kallyanpur and Rampura

Chloramines: Figure 5 shows chloramines concentration in water samples collected from households in different areas of Dhaka. Relatively low concentrations of chloramines were detected in water samples from Baridhara and Uttara. Higher concentrations of chloramines were detected in water samples from Malibagh, Kallyanpur and Rampura. However, mono-chloramine, the species with strong disinfection power was detected in low concentrations in most water samples. In Malibagh, mono-chloramine was detected in three out of six water samples, and the concentration varied from 0.2 to 0.3 mg/l. In Kallyanpur water samples, mono-chloramine was detected in four test cycles; but high concentration (3.0 mg/l) was detected only in the water sample collected in February; in the other three samples chloramines varied from 0.05 to 0.20 mg/l. In Rampura, mono-chloramine was detected in three out of nine water samples, and the concentration varied from 0.05 mg/l (in October) to 1.5 mg/l (in February). It appears that chloramines concentrations increase with the increase in ammonia concentration in raw and treated water at the SWTP as dry season progresses.

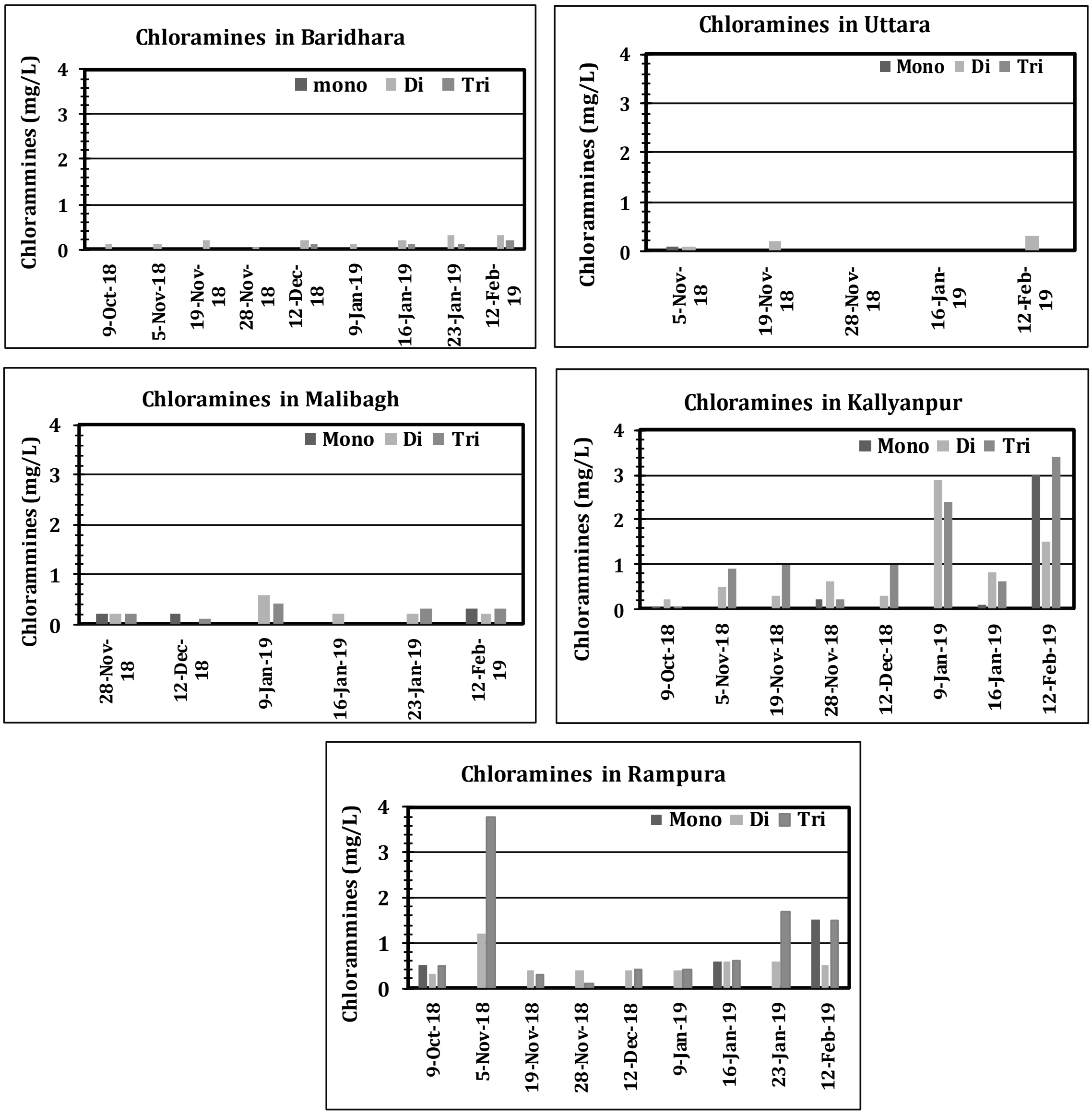


Figure 5: Variation of chloramines concentration in water samples collected from different areas of Dhaka city.

4. CONCLUSIONS

Results from this study suggest that water quality at source of water supply vary significantly. The quality of treated water at the SWTP vary significantly with season, and during the dry season the water is characterized by high concentrations of ammonia, nitrate, phosphate, as well as high concentrations of alkalinity, hardness and EC. On the other hand, the characteristics of groundwater does not usually vary appreciably with season. While chlorination is regularly carried out at the SWTP and chlorine species are present in the treated water at the SWTP, virtually no free chlorine was detected in the water samples collected from three DTW pump stations in Dhaka. This suggests that chlorination is not carried out at theses DTW pump stations.

Results from this study clearly suggest that characteristics of water received at consumer-level in different areas of Dhaka city vary significantly. It appears that the main reason for this variation is the variation in the characteristics of DTW water and water supplied from the SWTP. Water samples collected from households at Rampura and Kallyanpur contained relatively high concentrations of ammonia, free and total chlorine, and chloramines; and concentration of these parameters increased with the progress of dry season (from October to February). This variation of characteristics of water (at consumer level) closely matches the characteristics of treated water as SWTP. This indicates that these two areas receive water predominantly from the SWTP. Very high concentrations of ammonia, exceeding Bangladesh drinking water standard, were detected in the water samples collected from Rampura and Kallyanpur. This possibly suggests inadequate treatment at the SWTP. The water samples collected from Baridhara, Uttara and Malibagh shows similar chemical characteristics as the major source for supplied water in these areas appear to be groundwater.

REFERENCES

Hossain, M. A., Begum, T., Fakhruddin, A. N. M., & Khan, S. I. (2006). Bacteriological and Physicochemical Analyses of the Raw and Treated Water of Saidabad Water Treatment Plant, Dhaka. Bangladesh Journal of Microbiology, 23(2), 133-136.

Mahbub, K. R., Nahar, A., Ahmed, M. M., & Chakraborty, A. (2011). Quality analysis of Dhaka WASA drinking water: Detection and Biochemical Characterization of the Isolates. Journal of Environmental Science and Natural Resources, 4(2), 41-49.

Rajala, P., Carpén, L., Vepsäläinen, M., Raulio, M., Sohlberg, E., & Bomberg, M. (2015). Microbially induced corrosion of carbon steel in deep groundwater environment. Frontiers in microbiology, 6, 647.

Serajuddin, M. (2017). Surface water quality susceptibility in drinking water treatment at Dhaka. Bangladesh. Journal of Biodiversity and Environmental Sciences (JBES), 11(1), 123-133.

Zheng, M., He, C., & He, Q. (2015). Fate of free chlorine in drinking water during distribution in premise plumbing. Ecotoxicology, 24(10), 2151-2155.

ASSESSMENT OF INDOOR AIR QUALITY AT SELECTED SCHOOLS ALONG CUET TO BAHADDARHAT ROAD IN CHATTOGRAM

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ABSTRACT

Indoor air pollution has been a significant an health concern, especially for the children. Breathing clean air at Schools is essential for children's healthy development, but due to use of marker, air freshener, aerosol and vehicular emission from nearby roads, the indoor air quality of schools may be polluted. In this study, the indoor air quality of ten selected Schools along CUET to Bahaddarhat road in Chattogram was assessed from March 2019 to May 2019. A questionnaire survey was also conducted in study area for about 100 number of people mostly 60 students, 20 teachers & 20 guardians. The maximum average concentration of $PM_{2.5}$ and PM_{10} were found 81.1μg/m^3 and 313.1 μg/m^3 respectively at school in S4 locations. The minimum concentration of $PM_{2.5}$ was found in S7 locations (42.3μg/m^3) and that for PM_{10} was also found in S1 location (121.7μg/m^3). As the study is related to very short exposure and there is no standard for indoor air quality of Bangladesh, ambient air quality standards of Bangladesh was used for comparison. The average concentration of PM_{10} for all schools were exceeded threshold value of ambient air quality of Bangladesh. At the schools of S2, S4 & S6 location the mean concentrations of $PM_{2.5}$ were exceeded. This study also shows that the indoor $PM_{2.5}$ and PM_{10} concentration were higher at the schhols adjacent to roadside.

Keywords: *Indoor air quality, Children, PM2.5, PM10, Health.*

1. INTRODUCTION

Indoor Air Quality (IAQ) corresponds to the air quality, all across buildings and structures, particularly as it relates to the occupants ' health and convenience. Due to its adverse effects on human health, indoor air quality (IAQ) has been increasingly worried in latest years (Nagendra & Harika, 2010). Since most of the individuals spend 80 - 90% of their time indoors, excellent indoor air quality is very crucial to everyone (Arif, Katafygiotou, Mazroei, Kaushik, & Elsarrag, 2016). Outdoor air pollutants not only influence the environment, but also our health. Air quality in schools is of particular concern as kids are prone to poor air quality and issues with indoor air can be subtle and do not always have readily recognizable health and well-being effects (USEPA, 1996). Children seem to be more susceptible to the consequences of air pollution than older people because they breathe faster, their lungs are larger in direct proportion to their body size and are not fully formed so that pollutants can become more localized in their systems (Bennett, Zeman & Jarabek, 2008). In Bangladesh, the main education system is divided into three levels: Primary Level (Class 1–5); Secondary Level (6-10) or (9-12 at some schools). There is no middle school system in Bangladesh. Generally, both type of blackboard and whiteboard are used for demonstrating the lecture.

There is sustained proof that indoor air pollution expands the danger in developing nations of chronic obstructive pulmonary disease and acute respiratory diseases, particularly in kids under the age of five (Bruce, Perez-Padilla & Albalak, 2000). Indoor air pollution is liable for 2.7 percent of the global disease burden, according to the World Health Report 2002 (WHO, 2002). Failure to retard indoor air pollution may improve students and staff's chances of long-term and short-term health issues ; decrease teacher productivity; and degrade the teaching climate and convenience of the student (Ismail, Sofian, & Abdullah, 2010). The cause of indoor air pollution is a combinatory effect of physical, chemical and biological factors, and the adequacy of ventilation in the environment. Several researches on this subject over the years have demonstrated both qualitative and quantitative differences in IAQ, highlighting an rise in pollutants and their concentrations.

Research suggests that the Indoor Environmental Quality (IEQ)-wellbeing relationship is complex. A variety of indoor variables such as thermal, visual, acoustic and chemical can affect occupants ' well-being (Apte, Fisk & Daisey, 2000; Jantunen, Hanninen, Katsouyanni, Knoppel, Kuenzli, Lebret, Maroni, Saarela, Sram & Zmirou, 1998; WHO, 2002). These relationships can sometimes be very complicated and can affect individuals both in the short and long term (Babisch, 2008; Fisk, Lei-Gomez & Mendell, 2007; Lewtas, 2007). Concerns like sick building syndrome (SBS), building related disease, and pollutants have an effect on occupants ' general productivity. Studies have connected mental health and diseases which are not readily recognizable in the brief term but which could be significant long-term problems (e.g. cardiovascular diseases, asthma-related problems and obesity) to IEQ (Houtman, Douwes, de Jong, Meeuwsen, Jongen, Brekelmans, Nieboer-Op de Weegh, 2008; Jaakkola, Quansah, Hugg, Heikkinen & Jaakkola, 2013).

Children in Bangladesh, like other countries devote the second largest percentage of their day indoors at school, making classrooms a significant contributor to the exposure of children to air pollution. The objectives of this paper are to measure the concentrations of different indoor air pollutants at schools along CUET to Bahaddarhat road in Chattogram, to compare the measured concentrations with relevant standards, and to suggest ways to reduce the exposure of school children to undesirable pollutants.

2. METHODOLOGY

Indoor air quality was measured in ten classrooms at different schools along CUET to Bahaddarhat road by using Handheld Air Quality Analyzer from March 2019 to May 2019. Before using, the Air Quality Analyzing device is calibrated. The locations of selected schools were introduced in the Table 1. In all locations air quality were measured for three times- morning, noon and afternoon and averaged that data. The data was collected for five times during the study periods.

Table 1: Description of Study Area

No.	Name of Schools	Locations	
		Latidude	Longitude
S1	CUET Primary School	22.464914	91.969029
S2	Pahartali ideal kildergarden school	22.459104	91.964427
S3	Uttar dewanpur government primary school	22.456229	91.954146
S4	Goschi high school	22.447621	91.939965
S5	Noapara high school	22.440104	91.908952
S6	Uttar burischar Government primary school	22.433103	91.870164
S7	Kuyaish burischar sammilani high school	22.407418	91.860325
S8	Poschim Mohora Government primary school	22.402251	91.867835
S9	Hajera Taju school & college &	22.378317	91.854012
S10	Ekhlasur Rahman Government primary school	22.368277	91.845637

A simple questionnaire survey has also been conducted among 100 people (60 students, 20 guardians & 20 staffs) who stay there daily. The questions mainly covered the health problems associated with indoor air pollution. Though, it was important to ask about the classroom comfort levels: ventilation, lighting facilities, cleanliness, temperature, and humidity among the students, teachers and gurdians.

3. RESULTS & DISCUSSION

The survey has been conducted among 100 students, guardians & staffs. The students belonged to the age group of 10–16. From the data of the survey, a pie chart was figured out. The information of Figure 1 shows that, the largest area resembles about 63% of people got sick, 26% didn't get sick and 11% people were not sick due to air pollution but family members of them were sick. It is very difficult to relate the sickness with PM pollution at school as the children are more exposed by fuel combustion emission at home. For justifying this more details study is needed.

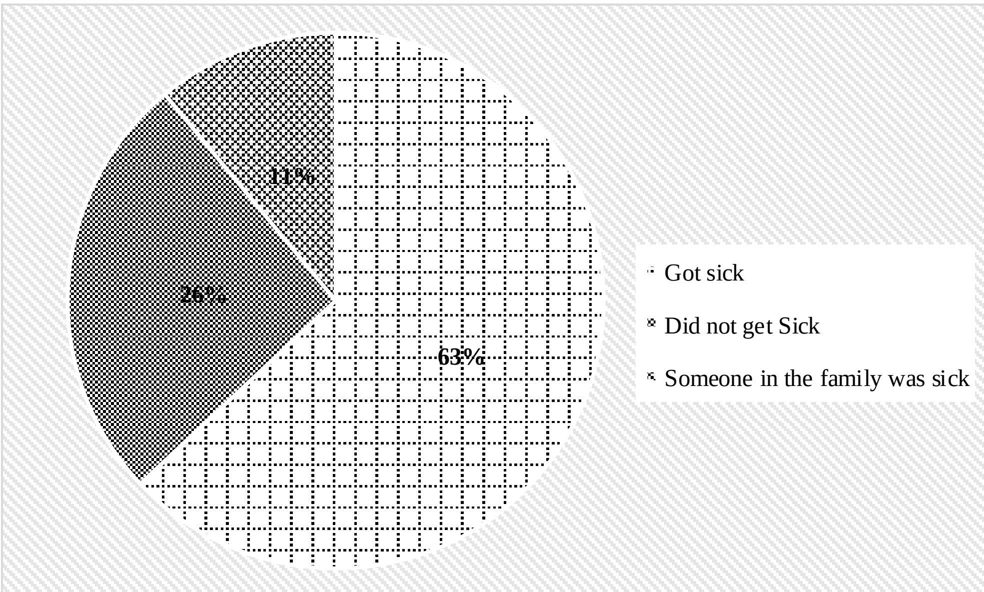

Figure 1: Information of questionnaire survey

The average concentration of $PM_{2.5}$ and PM_{10} were figured out in Figure 2 and Figure 3 respectively. The average maximum $PM_{2.5}$ and PM_{10} concentrations inside the school building were found to be 81.1 $\mu g/m^3$ and 313.1 $\mu g/m^3$, respectively. These values exceed the threshold value recommended by National Ambient Air Quality Standard (NAAQS). The maximum average concentration of $PM_{2.5}$ was found at the school in S4 locations and minimum concentration was recorded at the school in S7 locations which was 42.3μg/m^3. If the National Ambient Air Quality Standard (NAAQS) is considered, in 6 out of 10 schools' indoor air quality in terms of $PM_{2.5}$ were found poor.

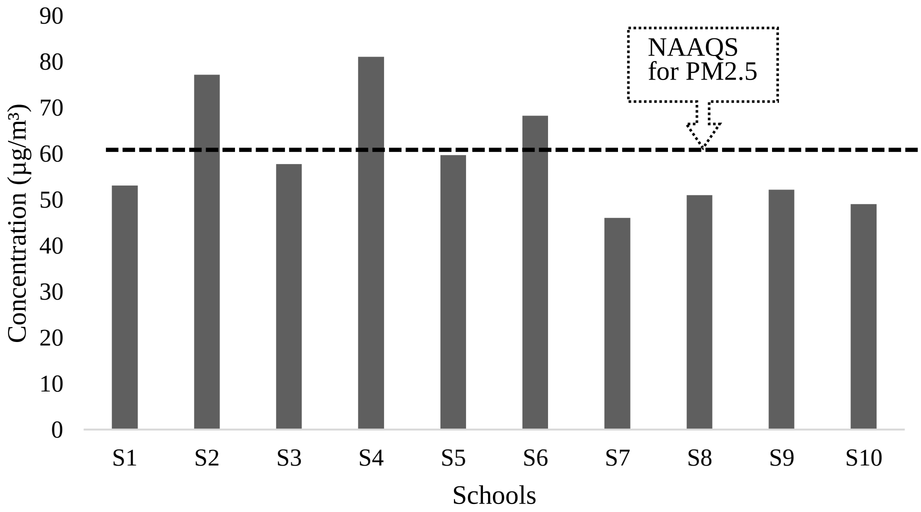

Figure 2: Average concentration of $PM_{2.5}$ at several selected schools.

The maximum and minimum concentration of PM_{10} were found at classroom of schools in S4 and S1 locations respectively (Figure 3). The average concentration of PM_{10} for all schools was exceeded threshold value of National Ambient Air Quality Standard (NAAQS).

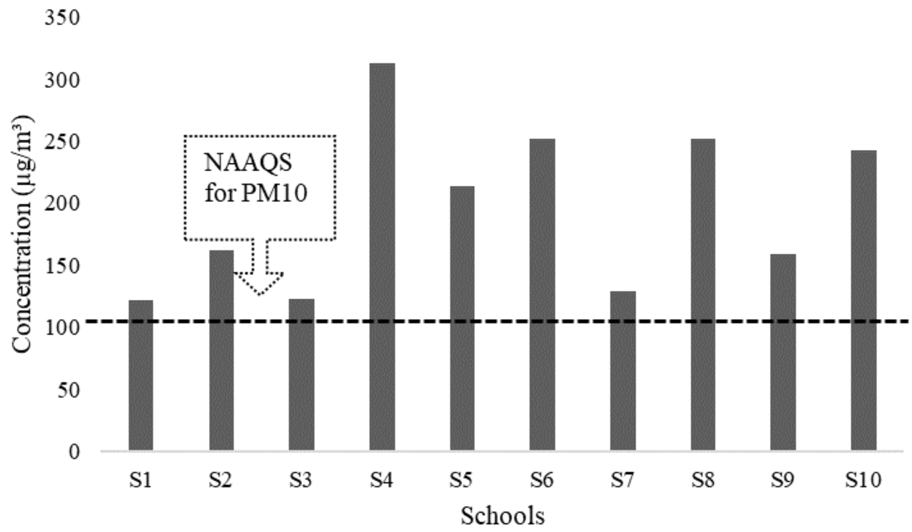

Figure 3: Average concentration of PM_{10} at several selected schools.

4. CONCLUSIONS

In this study, the IAQ in ten classrooms at different schools along CUET to Bahaddarhat road have studied. The IAQ parameters, namely $PM_{2.5}$ and PM_{10} have been measured by using Handheld Air Quality Analyzer from March 2019 to May 2019 in the study region. The results show that The average maximum $PM_{2.5}$ and PM_{10} concentrations inside the school building were found to be 81.1 μg/m^3 and 313.1 μg/m^3, respectively. The average concentration of PM_{10} for all schools were exceeded threshold value of ambient air quality of Bangladesh. At the schools of S2, S4 & S6 location the mean concentrations of $PM_{2.5}$ were exceeded. This study also shows that the indoor $PM_{2.5}$ and PM_{10} concentration were higher at the schhols adjacent to roadside.

REFERENCES

Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. International Journal of Sustainable Built Environment, 5(1), 1-11.

Apte, M.G., Fisk, W.J., Daisey, J.M. (2000). Associations between indoor CO2 concentrations and sick building syndrome symptoms in U. S. office buildings: an analysis of the 1994–1996 BASE study data. Indoor Air 10 (4), 246–257.

Babisch, W. (2008). Road traffic noise and cardiovascular risk. Noise Health 10 (38), 27–33.

Bennett, W.D., Zeman, K.L. and Jarabek, A.M. (2008). Nasal contribution to breathing and fine 421 particle deposition in children versus adults. J Toxicol Environ Health A. 71, (3), 227–237.

Bruce, N., Perez-Padilla, R., & Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. Bulletin of the World Health organization, 78, 1078-1092.

Fisk, W.J., Lei-Gomez, Q., Mendell, M.J. (2007). Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. Indoor Air 17 (4), 284–296.

Houtman, I., Douwes, M., de Jong, T., Meeuwsen, J.M., Jongen, M., Brekelmans, F., Nieboer-Op de Weegh, M., et al., 2008. New Forms of Physical and Psychosocial Health Risks at Work.

Ismail, M., Sofian, N. Z. M., & Abdullah, A. M. (2010). Indoor air quality in selected samples of primary schools in Kuala Terengganu, Malaysia. Environment Asia, 3(103), e108.

Jaakkola, M.S., Quansah, R., Hugg, T.T., Heikkinen, S.A., Jaakkola, J.J. (2013). Association of indoor dampness and molds with rhinitis risk: a systematic review and meta-analysis. J. Allergy Clin. Immunol. 132 (5), 1099–1110, e18.

Jantunen, M.J., Hanninen, O., Katsouyanni, K., Knoppel, H., Kuenzli, N., Lebret, E., Maroni, M., Saarela, K., Sram, R., Zmirou, D., 1998. Air pollution exposure in european cities: the ‘‘EXPOLIS” study. J. Expo. Anal. Environ. Epidemiol. 8 (4), 495–518.

Lewtas, J. (2007). Air pollution combustion emissions: characterization of causative agents and mechanisms associated with cancer, reproductive, and cardiovascular effects. Mutat. Res. 636 (1), 95–133.

Nagendra, S. S., & Harika, P. S. (2010). Indoor air quality assessment in a school building in Chennai City, India. WIT Trans Ecol Environ, 136, 275-286.

USEPA, 1996. Indoor Air Quality Basics for Schools. United States Environmental Protection Agency.

World Health Organization (WHO), The Health Effects of Indoor Air Pollution Exposure in Developing Countries, Geneva, 2002.

WATER SUPPLY, SANITATION SYSTEM AND WATER-BORNE DISEASES OF SLUM DWELLERS OF BASTUHARA COLONY, KHULNA

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ABSTRACT

Slum population has been increasing in Bangladesh day by day. But slum facilities are very much unsatisfactory for them due to lack of proper water supply and sanitation system. Therefore, the major portion of excreta is deposited into water bodies and open places, as such polluting water sources, groundwater, and the environment. As a result, the majority of the population in Bangladesh suffers from different kinds of water and excreta-borne diseases. This study was conducted to investigate the water supply and sanitation facilities at Bastuhara Colony, Khalishpur, Khulna. During the study period, data and information were collected by questionnaire survey with focus group discussion, some photographs were taken to relate this study and tube-well water of this slum was conducted to laboratory analysis. It is found that out of 500 families 70.67% families use to supply water, 24.67% families use tube-well water and 4.67% families use surface water for daily use. It is seen that 58% families use the sanitary latrine, 17.33% use open pit latrine and 24.67% have no latrine. Yet, 59.33% solid waste is disposed of in open place, 25.33% is disposed in open ditch and only 15.33% waste is collected. Contrary, total 58% families use a septic tank, 11.33% families use an open place and 30.67% families use the open canal for disposal human waste. Majority slum people use tube well water for drinking while a significant amount of open defecation is also found. Normally Bastuhara Colony has sanitary latrines, which are partially hygienic as they don’t have a proper septic tank. The drainage system is the most neglected sector in the slums. Besides, in the slum area, solid waste management and drainage system are not satisfying. So, some effective ideas about water supply and sanitation system according to health education program has been suggested for slum dwellers.

Keywords: *Slum, Sanitation system, Water supply system, Hygiene condition.*

1. INTRODUCTION

In Bangladesh, most of the people die every year due to various types of water borne diseases like Diarrhea, Cholera, etc. The World Health Organization estimates that each year 500 million people suffer from various types of water borne diseases due to unsafe water supply (WHO, 1991). For inadequacy in pure water supply, 500,000 infants die each year in the world (Unicef, 2005). Whereas the health situation in Bangladesh however, is gradually improving with the infant mortality declining to 77 per 1000 live births in 1996, with the gradual improvement of the sanitation coverage (33% of rural population and 42% of urban population in 1993) and more importantly, with the introduction of an integrated approach water, sanitation and hygiene education (Halder & Islam, 2015). Invariable the progress of sanitation, throughout the world has been closely associated with the availability of water, and the larger the quantity and the better the quality of the water, it has been advanced among public health more rapidly and extensively. The WHO's figures for 1980 show that, among the urban population of the developing countries, only about 55% had house connections and an additional 20% had access to taps (WHO, 1991). In 1983, over 62% of people in developing countries, some 1100 million people lacked an adequate water supply (Hoque, Juncker, Sack, Ali, & Aziz, 1996). The situation is not the same in all developing countries. 97% of the population had access to water form improved sources in 1996; those served to be 97% in rural and 99% in urban as compared to 1% in 1980, the situation less positive; although important progress has been made (Hoque et al., 1996). It is important to understand that the improvement of health is not possible without sanitary disposal of human excreta. However, neither sanitation nor water supply alone is good enough for health improvement. It is now well established that health education or hygiene promotion must accompany sufficient quantities of safe water and sanitary disposal of excreta to ensure the control of sanitation related disease (Cairncross et al., 2010). Proper sanitation can control many excreta related diseases. However, to improve health conditions through improved sanitation, it is necessary to have a clear understanding of the diseases that are prevalent in the absence of proper sanitation, and their transmission routes. These diseases are excreta-related and are caused by microorganisms such as viruses, bacteria, protozoa and helminths or worms. There are some preventive measures particularly helpful in interrupting disease transmissions such as Safe human excreta disposal, Personal hygiene, Domestic hygiene (and animal management), Food hygiene, Water hygiene/consumption of safe water, and Safe wastewater disposal and drainage (Gross, Schell, Molina, Leão, & Strack, 1989).

There are two sources of water available, one is surface water and another one is ground water. Surface water is the source of an abundant amount of water. Before and during the early stages of tube-wells installation, the rural water supply was largely based on protected ponds (Winter, Harvey, Franke, & Alley, 1998). The biological quantity of water in this pond is extremely poor due to unhygienic sanitary practices and the absence of any sanitary protection. On the other hand, Groundwater is water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is free from disease-producing micro-organisms which are normally present in large numbers in surface waters (Winter et al., 1998). In Bangladesh, it is available in adequate quantity, but the availability of groundwater for drinking purposes has become a problem because of arsenic, dissolved iron, salinity in the shallow aquifers in the coastal areas, lowering of groundwater level, and rocky/stony layers in hilly areas. Sanitation system has arrangements of excretion and storage, collection and transportation, treatment, and disposal of human excreta and other forms of wastes back to nature in a safe manner (Koola & Zwane, 2014). Combination of these functions depends on the local conditions. When the wastes are collected, treated and disposed of at the point of generation it is called an on-site system e.g. pit latrines and septic tank systems. However the wastes are collected and transported to somewhere else for treatment and disposal, the system is called off-site, e.g. bucket latrines systems and conventional sewerage systems (UNICEF/WHO, 2005). In dry systems, no water is used for the dilution of the waste and usually applied in answered areas with no piped water supply. But in the wet system the waste is diluted with flushes of water and suitable where piped water supply systems are available. With respect to sanitation, people's needs are primarily health, privacy, and convenience, and resources include the availability of money, space, and skills. The local factors that influence greatly the nature of sanitation development include the existing environmental setting, e.g. the soil, climate, surface and groundwater, tradition, religion, culture and local leadership patterns, hygiene awareness and the institutions serving the people (WHO/UNICEF JMP for Water Supply and Sanitation, 2014). A sanitation development program should carefully consider these key factors particularly for low and middle communities of developing countries as well as for planning a sanitation development program should consider the collection of background information, cultural aspects, motivational factors, contribution in cash, and social organization for improvements.

Bangladesh experienced extremely rapid growth in the urban population, 4.9% as compared to 2% national coverage in the recent decade, resulting in the present size of the urban population of about 23 million by the year 2000 (Rana, 2011). The available data for the district towns indicate that approximately 33% of the urban population has reasonable public water supply, 10% by house connection calculated @ 13 persons per connection, 6% by public hand posts @ 100 per stand post and 17% by public hand pumps @ 75 persons per hand pump (Rana, 2011). The urban drinking water coverage is 75%, while the coverage under the facility in the suburban areas is 58% only. About 16% of the 90 million rural population use sanitary latrines. In addition, another 22% use the so-called home-made pit latrines. People are now conscious of using latrines and about 62% of the total populations have access to some form of latrine (Hoque et al., 1996). Of about 30 million urban dwellers, sanitation coverage is only about 42%. In urban areas, a range of on-site options such as septic tanks, single and double pit pour-flush latrines are used. Conventional sewerage systems are used only in parts of Dhaka and cover only 18% of the city's 8.5 million people (The World Bank Group, 2007). In this study, a slum area called Bastuhara Colony of Khulna City Corporation has been taken up to consideration as the study area's ongoing development work with water supply and sanitation system particularly related to environmental improvement. Khulna is situated on the southwest side of Bangladesh. It is surrounded by the river Bhairob and Rupsha. At the end of 1984 Khulna City Corporation (KCC) was developed whose land area 45.6 square km and the number of wards are 31. It is to be noticed greatly that the suburban areas of Khulna city are developed in a scattered way. The water supply and sanitation of these areas are far lagging behind the residential area (Sohel Rana, 2009). Main sources of water in these areas are shallow tube-well. In residential area municipality, water supply and sanitary system is also better. The aim of this study was to investigate the current situation of water supply and sanitation system, assess the environmental and social conditions, and improvement of water supply and sanitation system of the Bastuhara colony, Khalishpur, Khulna.

2. METHODOLOGY

2.1 Study Area

Bastuhara Colony of Khalishpur, Khulna was selected as the survey site. This study is undertaken to investigate the existing water supply and sanitation system in the study area. The map of the study area is shown in Figure 1.

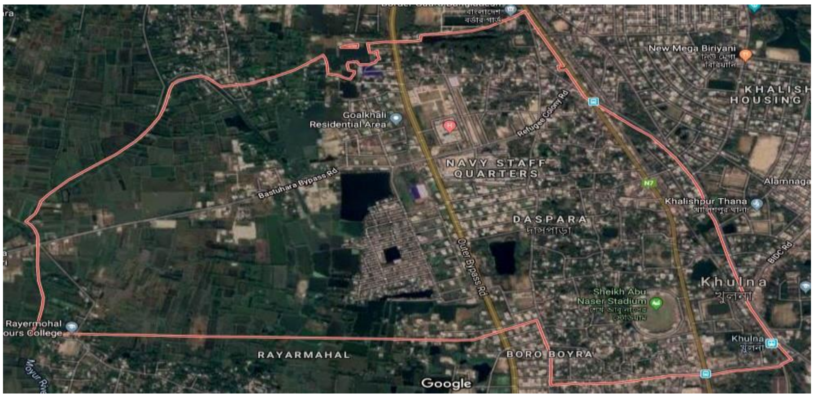

Figure 1: Satellite view of the study area (Source: Google Map)

Bastuhara colony is in Ward no. 09 of Khulna City Corporation which has 62.72 acres area with 19,500 population. It has two water points (both by KWASA) with communal sanitation systems and discontinuous semi-pucca drainage facilities. Most of the solid wastes are disposed in open places.

2.2 Field Data Collection and Laboratory Analysis

For A details questionnaire survey has been done among dwellers of the Bastuhara Colony. It was mainly done to know about water supply sources, water uses, sanitation practices, solid waste management and so on. A total of 500 families were taken into consideration. Some photographs were taken to understand the real situation of the study area. Laboratory analysis of the tube-well water and supply water was conducted. The laboratory tests are consisting of pH, Electrical Conductivity, Turbidity, Hardness, Colour, Iron, Arsenic, Manganese, Chlorine, Total Coliform, Faecal Coliform, and Total Dissolve Solid. Besides, different pieces of information were collected from different government organizations like KWASA, KCC and some non-governmental organizations like Nabolok, BRAC, etc. The types of data that are collected from the slum are tabulated in Table 1.

Table 1: Types of data collected from Bastuhara Colony

Sl. No.	Types of data
1	Educational status of household head
2	Occupation of the slum people
3	Condition of existing House
4	Water use pattern
5	Tube-well ownership ratio
6	Salinity of Tube-well water
7	Types of latrine used
8	Disposal of human excreta
9	Distance between tube-well and latrines
10	Interval of cleaning existing drains
11	Solid waste disposal pattern
12	Diseases caused by contaminated water

2.3 Pictorial View of the Study Area

2.3.1 Communal Sanitation System

In figure 2, Bastuhara Community's Toilet is shown which has some problems. The human excreta is disposed into the soakage pit but the size is very small, the low land area is overflowed at the rainy season. Fouling of latrines and urinals is common and once a latrine is fouled. Subsequent users find no other alternative but to foul it more. Thus operation and maintenance is a major problem in this system. In this slum, there is no full-time attendant for operation and maintenance.

Figure 2: Bastuhara Community Toilet

2.3.2 Over Hanging Latrine

The view of overhanging latrines is shown in Figure 3. These latrines stand by the side of the canal or river which is very unhygienic. Besides, canal water is used by many of the slum dwellers which is a cause for different water-borne diseases.

Figure 3: Over-hanging Latrines

Among community toilets and over-ganging latrines, the disposal of human excreta and urinals in open environment is much higher for over-hanging latrines because in this case direct disposal is happening in canal or river whereas community toilets have small soakage pit by which direct disposal can be avoided.

2.3.3 Tube-well

In the slum area, all the tube-wells are No. 6 tube-well. For drinking, all the slum dwellers use tube-well water. But for daily activities, they mainly use supply water though some people use tube-well water too. The main concern here is most of the tube-well is within 10 meters distance of the latrines which is the cause of groundwater contamination. A No. 6 tube-well is shown in figure 4.

Figure 4: Tube-well (No. 6) used at Bastuhara Colony

2.3.4 Drainage Condition

Figure 5 shown that the drainage condition in this slum is very poor. People of the slum area are not sufficiently aware of waste disposal. Besides, there are no places where solid waste can be disposed of. So, people throw the waste into the existing drains. Solid waste disposed over the drain thoroughly causes a waterlogging problem. Thus, it creates serious environmental pollution.

Figure 5: Existing Drainage Condition at Bastuhara Colony

3. RESULTS AND DISCUSSIONS

The necessary data were collected to analyse the project in two ways. Firstly, for the total analysis, the previous study data were collected from various governmental and non-governmental organizations. Secondly, field data were collected by the questionnaire survey. In this research, the water supply and sanitation situation in this slum area has been investigated. During the investigation, various sources of water and different types of sanitation are observed. The total numbers of families were counted and from here the percent users of different types of water supply and sanitation systems are analysed.

3.1 Educational Status of Household Head

Most of the slum dwellers are not well educated. They are either only capable of signature or having an educational status of below SSC. Only 12% of people are SSC or above SSC level, 39% are below SSC level, 45% are only signature level, and 4% are illiterate.

3.2 Occupation and Personal Income of Existing Household

The survey has been done among 500 families consists of about 2500 people. In about 2500 people, 616 numbers are businessmen, 711 are housewives, 664 are students, and 509 are service holders. Besides, the majority of the population lives under the poverty line as a huge 51.33% household's income lies between 0-5000 taka, 14.67% are lies between 5000-10000 taka, 27.3% are in 15000-20000-taka range, and above 20000-taka income households are 6.67%. It is an alarming issue for this slum.

3.3 Existing Housing Condition and Water Use Pattern for Daily Activities

There is a mixed housing pattern was observed in the slum area. Most of the family live in Pucca/Semi Pucca house (65%) but there are still some families who live in a Tin shed (26%) or Hut (8%) or other types of house (1%). The people in the slum area normally use Supply water (70.67%) for daily activities whereas some use Tube-well water (25.67) too. Besides, there are very few who use Surface water (3.66). But for drinking purposes, all of them use Tube-well water. In the slum area, most of the people don't have any private tube-well. They use water from public sources which are installed by KWASA and KCC as 71.33% of the tube-well used are public tube-well. Among the installed tube-wells, 77% provides sweet water whereas 23% of tube-wells water contains salinity.

3.4 Sanitation System and Disposal of Human Excreta

The overall sanitation system in the slum area is very unhygienic. 58% of the people use sanitary latrine, 17.33% use Open pit. But the alarming fact is that 24.67% of people do not have any sanitation coverage. It has also been observed that 58% of human excreta is disposed of in Septic tank. Others are disposed at either open place (11.33%) or open canal (30.67%). Thus, the canal water gets contaminated. It is a major issue needs to be solved. The minimum safe distance between tube-well and latrine is 10 meters. But it is observed that a total of 84% of tube-well are within 10-meter distance with the latrines. It is not safe as latrine's infiltration sewage can be resurfaced by tube-well.

3.5 Solid Waste Disposal Pattern and Drainage Facility

It is seen that a total of 84.67% of solid waste is disposed of either in an open place or an open ditch. Only a mere 15.33% of solid waste is collected. Drains are mostly cleaned at an interval of more than 30 days. 77% of the drains are cleaned at an interval of more than 30 days whereas only 23% are cleaned in 30 days. To solve the waterlogging problem, the drains should be cleaned regularly.

3.6 Water Quality Parameter (Lab Analysis)

Three samples were tested in the lab to find the water quality parameters. One sample was of Supply water and the other two were from two different Tube-wells of the slum area. The laboratory data are tabulated in Table 2.

Table 2: Water Quality Parameter at Bastuhara Colony

Water Quality Parameter	**Unit**	**Bangladesh Standard**	**WHO Standard**	**Supply Water**	**Tube-well Water-1**	**Tube-well Water-2**
pH	-	6.5-8.5	6.5-8.5	7.4	7.6	7.8
Electrical Conductivity	μ-s/cm	-	-	684	899	718
Turbidity	NTU	10	5	2.37	2.04	1.67
Hardness	mg/L	200-500	500	46.25	50.87	41.63
Color	Pt. Co	15	15	45	18	35
Iron	mg/L	0.3-1.0	00	0.13	0.04	0.15
Arsenic	mg/L	0.05	0.01	0	0	0
Manganese	mg/L	0.1	0.5	0.4	1.2	0.9
Chlorine	mg/L	150-600	-	290	690	140
TC	No./100 ml	0	0	4	0	2
FC	No./100 ml	0	0	0	0	0
TDS	mg/L	1000	1000	840	960	870

From the laboratory experiment, it was found that the sample waters have a problem in color, especially the supply water was a little bit reddish. One of the tube-well has chlorine in excess quantity. Besides, both the tube-well water has Manganese beyond the tolerable limit. Finally, TC was found in supply water and one of the tube-well water. So, the water of both supply water and tube-well water needs treatment.

3.7 Diseases Caused by Contaminated Water

Figure 6 shows that the slum dwellers suffer from various diseases caused by contaminated water. A statistical survey with a duration of three months has done among about 800 slum people who are generally using water for their domestic purposes from the canal whose are polluted by the direct disposal of human excreta and urinals. For this, different diseases like Diarrhea, Dysentery, Jaundice, and Typhoid can be seen among the slum people. Among 800 people, 200 are suffered from Diarrhea, 216 are suffered from Dysentery, 144 are suffered from Jaundice and 240 are suffered from Typhoid.

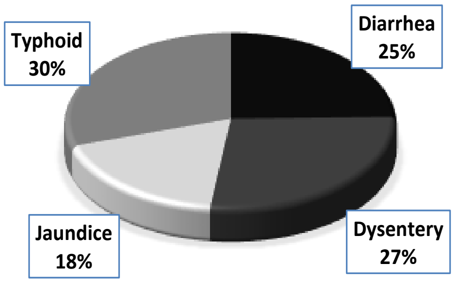

Figure 6: Diseases Caused by Contaminated Water at Bastuhara Colony

4. CONCLUSIONS

The water supply and sanitation problems in the Bastuhara colony are so acute. The problems which are created could be minimized if sufficient care is undertaken during planning and implementation. Most of the people of the colony are illiterate and a total of 88% population are below the SSC level and most of the family live in Pucca/Semi Pucca house. For drinking purposes, dwellers are depended on tube-wells and for daily activities, supply water is used but for drinking it is avoided as it is contaminated. Among the installed tube-wells, 77% provides sweet water whereas 23% of tube-wells water contains salinity. In the case of sanitation, about 58% of people use sanitary latrine whereas 24.67% of people do not have any sanitation coverage. For disposal, about 42% of human excreta are disposed of in open places which are the real cause of canal water contamination. The waste collection and disposal system in the slum area is very poor and about 84.67% of solid wastes are disposed of in an open ditch or open place which causes environmental pollution. Distance between tube-well and latrine is 10 meters or below in 84% cases which increases the chance of groundwater contamination. And the slum people are suffered from various water-borne diseases due to the use of contaminated water.

REFERENCES

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C. H., & Schmidt, W. P. (2010). Water, sanitation and hygiene for the prevention of diarrhoea. International Journal of Epidemiology. https://doi.org/10.1093/ije/dyq035

Gross, R., Schell, B., Molina, M. C., Leão, M. A., & Strack, U. (1989). The impact of improvement of water supply and sanitation facilities on diarrhea and intestinal parasites: a Brazilian experience with children in two low-income urban communities. Revista de Saude Publica. https://doi.org/10.1590/s0034-89101989000300006

Halder, J., & Islam, N. (2015). Water Pollution and its Impact on the Human Health. Journal of Environment and Human. https://doi.org/10.15764/eh.2015.01005

Hoque, B. A., Juncker, T., Sack, R. B., Ali, M., & Aziz, K. M. A. (1996). Sustainability of a water, sanitation and hygiene education project in rural Bangladesh: A 5-year follow-up. Bulletin of the World Health Organization.

Koola, J., & Zwane, A. P. (2014). Water Supply and Sanitation. In Encyclopedia of Health Economics. https://doi.org/10.1016/B978-0-12-375678-7.00111-5

Rana, M. M. P. (2011). Urbanization and sustainability: Challenges and strategies for sustainable urban development in Bangladesh. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-010-9258-4

Sohel Rana, M. D. (2009). Status of water use sanitation and hygienic condition of urban slums: A study on Rupsha Ferighat slum, Khulna. Desalination. https://doi.org/10.1016/j.desal.2008.04.052

The World Bank Group. (2007). Dhaka: improving living conditions for the urban poor. Bangladesh Development Series Paper.

UNICEF/WHO. (2005). WHO 2004 Meeting the MDG Drinking Water and Sanitation Target: A Mid-Term Assessment of Progress. In UNICEF/WHO, Geneva, Switzerland.

Unicef. (2005). WHO 2004 Meeting the MDG Drinking Water and Sanitation Target: A Mid-Term Assessment of Progress. UNICEF/WHO, Geneva, Switzerland.

WHO/UNICEF JMP for Water Supply and Sanitation. (2014). Progress on drinking-water and sanitation - 2014 update. In … Monitoring Programme for water supply and sanitation …. https://doi.org/978 92 4 150724 0

WHO. (1991). International Drinking Water Supply and Sanitation Decade Mid-decade Progress Review. WHO Library (39th World Health Assembly), 53(9), 1689–1699. https://doi.org/10.1017/CBO9781107415324.004

Winter, T. C., Harvey, J. W., Franke, O. L., & Alley, W. M. (1998). Ground Water Surface Water and A Single Resource. In USGS Publications.

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PARTICULATE MATTER CONCENTRATION EMITTED FROM HETEROGENOUS TRAFFIC NEAR URBAN ROADWAYS IN KHULNA CITY

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ABSTRACT

Particulate matter is the major contaminants of air pollution especially in the urban roadway and industrial air which can cause adverse effects both to human health and environment. A significant seasonal variation was noticed in the study areas and it was found that at Fulbarigate $PM_{2.5}$ concentration was 136±14 μg/m^3 in winter and 60±7 μg/m^3 in summer. The concentration of $PM_{10.0}$ was 199±19 μg/m^3 during winter and 113±21 μg/m^3 in summer. PM concentration concentrations was highest at Fulbarigate than other sites as the maximum Heavy Commercial Vehicle (HCV) 7% was found at Fulbarigate. The Air Quality Index (AQI) was 340 for $PM_{2.5}$ and 249 for $PM_{10.0}$ indicating a poor air quality. The particulate matter concentration at every location exceeds 40 μg/m^3 for $PM_{2.5}$ and 80 μg/m^3 for $PM_{10.0}$ based on Environmental Protection Agency (EPA) at 1-hour average PM standard level. Moreover, at Fulbarigate $PM_{2.5}$ exceeds 125 μg/m^3 and $PM_{10.0}$ exceeds 141 μg/m^3 which implies the polluted air. As air related study is rare in Khulna city, this study would be very effective to maintain the air quality especially the urban roadways and industries.

Keywords: *Particulate Matter (PM), Urban roadway, Seasonal variation, Air Quality Index (AQI).*

1. INTRODUCTION

Air quality degradation is occurring around the world and it becomes a global problem recently due to rapid urbanization, industrialization, high growth rate of population and increasing amount of traffic movement. Around 4.2 million deaths occur every year throughout the world as a result of exposure to ambient (outdoor) air pollution (WHO,2016). According to WHO (2016), around the world 20 cities, 14 cities in India are more polluted due to $PM_{2.5}$. Srimuruganandam, *et al*. (2010) conducted a study at Chennai City in India states that about 50% of particulate matter emits due to vehicular emissions in this city keeping more than 600 million people in a dangerous situation and 30% of respiratory diseases are directly related to particulate matter. A study by Adeniran, *et al.* (2017) states that particulate matter attracts the human respiratory track, respiratory and cardiovascular diseases such as asthma. Bangladesh is a densely populated country, is known to all and air pollution is one of the major problems declared very recent World Air Quality Report (2018). Except Dhaka City, Khulna is the third largest city in Bangladesh and is facing the air pollution problems greatly in the urban roadways due to the increase of particulate matter concentration. According to the Department of Environment the Air Quality Index (AQI) in Khulna City is 402, which indicates extremely unhealthy condition. Vehicular emissions are one of the main sources of particulate matter (PM) and various gases are also emitted from the emissions. A study in Europe City by Visin, *et al.* (2016) states that air quality is the main burden of human health and long-term concern in this city. Fine particles are more harmful than coarse particles and the long-term PM exposure cause the premature death evident by the same study by Srimuruganandam, *et al*. (2011). Particulate matter is also generated by friction between, brakes, tires, road surface. Road dust flying due the movement of vehicles is one of the sources of PM due to meteorological condition. Jain, (2017) reported that PM concentration depends on several factors such as wind speed, relative humidity, temperature, driving lane, roadway type, congestion level, seasonal changes, vehicles type, vehicles emissions rate etc. Singh, *et al.* (2017) reported that airborne particulates are the mixture of various component and suspension of liquid and solid particles which impose a negative impact on human health, climate change, food security and reduction of visibility. A research by Mahapatra, et al. (2018) conducted in Eastern India, Bhubaneswar found the seasonal and meteorological variation of PM concentration and it was higher in winter than summer. Pant, *et al.* (2013) states that exhaust emissions and non-exhaust emissions are the two main sources of emissions. Qiu, *et al*. (2018) conducted a case study in China states that the coarse particles ($PM_{10.0\text{-}2.5}$) and fine particles ($PM_{2.5\text{-}1.0}$) are emitted respectively from non-exhaust and full engine combustion. The concentration of particulate matter (PM) is a key air quality indicator since it is the most common air pollutant that affects short term and long-term to health. Particulate matter (PM) is the major risk to public health in urban areas as well as environment. Around 91% of the world′s population lives in places where air quality levels exceed WHO limits. Sreekanth, *et al.* (2018) reported that ambient air pollution is the main contributor of the Global Burden Diseases (GBD) and their harmfulness is increasing more than the previous 25 years.

Another study conducted by Pant, *et al.* (2017) in Birmingham (UK) states that road traffic emissions are considered to be the major source of particulate matter emission. Pant, *et al.* (2015) conducted his research in Birmingham (UK) and New Delhi (India) found that PM concentration was higher in New Delhi than Birmingham. Desai, (2018) reported that vehicular emissions are becoming major source of air pollution during recent years. During 2011, India reported 141.8 million registered vehicles. Motorization rate in India is 26 vehicles per 1000 people. Particulate matter concentration is increasing due to the increases of motorized vehicles and high combustion of low-quality fuel. According to Khulna Districts Statistics 2011, the total number of registered Easy bike and Auto-rickshaw is 683, Tempo is 568 and non-registered Easy bike and Auto-rickshaw is 159, Tempo is 38 in Khulna City Corporation areas. The large number of buses and trucks is also moving through this city as Mongla Port, Jute Mills, and Cement Factories and other different factories are situated here. This indicates Khulna is one of the congested cities in Bangladesh and vehicular emission is the major pollutants in the roadway air pollution. Among the three roadways study areas, Fulbarigate is the major traffic congested points as most of the heavy buses and trucks are passing through it and a railway crossing also situated here. Various short- and long-term diseases are caused due to large exposure of fine particles ($PM_{2.5}$) and coarse particles ($PM_{10.0}$). Children and adults are mostly affected by these particulate matters final result of PM exposure is premature death. Guttikunda, *et al.* (2013) reported that limited studies have been conducted about air pollution in Dhaka and among them most of the studies were focused on the air pollution from brick kiln and motor vehicles in Dhaka city. Recently, a few studies are conducting in Khulna City about air pollution due to traffic emitted particulate matter and this study would be very effective to realize this type of pollution and introduce the harmful effects.

2. METHODS AND DATA ARCHIVING

There are several methods for sampling the airborne particulate matter. Most of them are needed the continuous data collection. The method used this study is very simple and collecting data continuously in a short duration. The digital PM counter Handheld 3016 model is used for PM data collection.

2.1 Selection of Study area

Monitoring sites are established for different reasons based on the monitoring objectives. Improperly located sites will provide unsuitable results for the intended purpose of monitoring and will in turn lead to incorrect decisions. The study location also has CC camera, suitable power supply, setting equipment facilities and other facilities. The equipment is set up at the place which don′t interference the vehicles and pedestrian movement. The heavy dusty areas, construction sites, external fuel combustion areas etc. are avoided for selecting the study location.

2.2 Location and site description

The selected location for this study are Fulbarigate (Lattitude-22º53′47.8″N and 89º30′36.0″E), Sonadanga Bus Terminal (Lattitude-22º49′01.8″N and Longitude-89º32′32.7″E), New Market (Lattitude-22º49′29.7″N and 89º33′04.9″E) and a Cement Factory at Labanchara (Lattitude-22º47′05.7″N and Longitude-89º34′42.8″E) in Khulna City as shown in Figure 1. The air quality in KUET campus is considered as controlled ambient air having the bearable PM concentration. Fulbarigate is one of the busiest places and traffic congested as the Khulna-Jashore -Dhaka highway (N7) passing through it and one of the renowned public university KUET situated adjacent to it. It also has a school, mosque, a railway crossing, two banks and bazar place. Sonadanga Bus Terminal is main bus terminal in Khulna City. One can travel any places from here within Bangladesh such as Khulna to Dhaka, Bagerhat, Satkhera, Chittagong, Jashore, etc. There are several waiting rooms for passengers and rest rooms. New Market is one of the old and prestigious shopping destinations at Khulna City for middle- and upper-class people. People enjoy shopping in a big wide and open area. Sharee, Gold & silver jewelry, cosmetics, carpets, mobile handsets readymade garments, gift shops and fast food shops are available there. That′s why it is all time in dense population and traffic. A big factory of Seven Rings Cement was established in 2014 in Labanchara, KDA Industrial Area, Khulna under the name Shun Shing Cement Mills Ltd (SSCML) on the bank of Rupsha River which is only 7 KM away from Khulna City Center with production capacity of 1.6 Million M/tons per annum to cover the demand of southwest zone and northern districts of the country. A considerable amount of road dusts and the bag filters dusts are generated from CMF at Labanchara during the manufacturing and marketing process.

Figure 1: Study Location Map (Source: Google Map)

2.3 Particulate Matter (PM) Monitoring

The equipment, laser particle counter named as Handheld 3016 set up on each monitoring location with the help of tripod stand or small table as shown in Figure 2. The equipment was calibrated and then start by pressing ON button. The data was taken at different dates for 1-hour continuously from April to December, 2018 on the four selected locations in Khulna City. It takes the particulate matter concentration data per min with various particle sizes such as 0.3µm, 0.5µm, 1.0µm, 2.5µm, 5.0µm and 10µm.

2.4 Traffic Monitoring

Traffic concentration was collected simultaneously within the period of PM monitoring at all considered locations. Traffic data was collected by recording the video of moving vehicles while the PM concentration was taken with the selected location. At Fulbarigate CC camera was used for recording the movement of vehicles and where CC camera was not available mobile camera was used. The videos were transferred to computer and vehicles were counted manually. For counting the traffic, digital counter was used and vehicles were counted at a constant 5 minutes interval. The types of vehicles moving in Khulna city are heterogenous in character. Motorized and non-motorized both types vehicle moving the same road and caused a heavy congestion. For simplicity, only motorized vehicles were considered. Buses, trucks, motorcycles and private cars are found this study areas. Taxi and Tuk-tuk are considered as 3-Wheeler (3W), Small buses and private car, large buses and trucks, motorcycle are considered as 4-Wheeler (4W), Heavy Commercial Vehicle (HCV) and 2-Wheeler (2W) respectively.

Figure 2: Particulate Matter and traffic monitoring

3. RESULTS AND DISCUSSIONS

3.1 PM mass concentration

According to National Ambient Air Quality Standard in Bangladesh (BAAQS, 2005) the PM standard for $PM_{2.5}$ for 24-hour average is 65 (µg/m^3) and annual average is 15 (µg/m^3). The PM standard for $PM_{10.0}$ for 24-hour average is 150 (µg/m^3) and annual average is 50 (µg/m^3). National Ambient Air Quality Standard in Bangladesh does not recognize yet for 1-hour average PM standard level for PM monitoring. Environmental Protection Agency (EPA) follows some PM ranges for evaluating air quality for 1-hour and 24-hour average PM data.

1-hour average $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ concentration at KUET campus as 62±1.0 µg/m^3, 125±1.50 µg/m^3 and 141±3.0 µg/m^3 respectively. These concentrations are little higher than other monitoring locations. This scenario may be evident due the effect of monitoring period. Monitoring campaign at KUET campus was conducted in the month November of 2018 presenting post-monsoon season. As presented in Table 1, Fulbarigate location depicts highest concentration of $PM_{2.5}$ and $PM_{10.0}$ as 135.97 µg/m^3 and 198.91 µg/m^3 respectively. Due to the higher vehicular movement at Fulbarigate could be responsible for these higher concentrations. Highest concentration of $PM_{1.0}$ found at Sonadanga location as 72.62 µg/m^3 among all the observed locations, which indicates the presence of higher amount fine particle at this location during the mentoring period.

Table 1: PM monitoring data for 1-hour average during study period

Description Months	Item	Fulbarigate (December)	Sonadanga (October)	New Market (December)	Labanchara (September)
PM Mass in (concentration ±SD)	$PM_{1.0}$	31.71±2.92	72.62±6.33	45.05±18.36	62.25±4.55
	$PM_{2.5}$	135.97±13.84	119.11±9.01	93.17±51.97	93.17±7.42
	$PM_{10.0}$	198.91±19.06	187.87±11.89	139.61±55.70	133.23±8.02
PM Mass ratio	$PM_{1.0}/PM_{10.0}$	0.16±0.001	0.39±0.01	0.32±0.01	0.47±0.003
	$PM_{2.5}/PM_{10.0}$	0.68±0.01	0.64±0.001	0.67±0.10	0.70±0.01
	$PM_{1.0}/PM_{2.5}$	0.23±0.002	0.61±0.01	0.48±0.05	0.67±0.004
Pearson Corre.	$PM_{1.0}$ vs $PM_{10.0}$	0.91	0.27	0.98	0.69
Coefficient (R^2)	$PM_{2.5}$ vs $PM_{10.0}$	1.00	0.45	0.98	0.73
	$PM_{1.0}$ vs $PM_{2.5}$	0.92	0.97	0.90	1.0

Environmental protection agency (EPA) follows the following PM ranges for evaluating air quality based on 24 hour and 1-hour average PM data with dividing air various air quality category as shown in Table 2.

Every sampling location, $PM_{2.5}$ exceeds the 60 (μg/m^3) and $PM_{10.0}$ exceeds 120 (μg/m^3) for 1-hour average data and indicates that air quality category is very poor at the sampling sites as shown in Table 2. The highest 1-hour average PM mass concentration for $PM_{2.5}$ is 135.97±13.84 (μg/m^3) and $PM_{10.0}$ is 198.91±19.06 (μg/m^3) are obtained at Fulbarigate due to larger quantity of HCV and 4W vehicles moving here as shown in Table 3.

Table 2: Air Quality Category based on $PM_{2.5}$ and $PM_{10.0}$

Air Quality Category	**24-hour average (μg/m^3)**		**1-hour average (μg/m^3)**	
	$PM_{2.5}$	**$PM_{10.0}$**	**$PM_{2.5}$**	**$PM_{10.0}$**
Very Good	0-8.2	0-16.4	0-13.1	0-26.3
Good	8.3-16.4	16.5-32.9	13.2-26.3	26.4-52.7
Fair	16.5-25.0	33.0-49.9	26.4-39.9	52.8-79.9
Poor	25.1-37.4	50.0-74.9	40.0-59.9	80.0-119.9
Very Poor	37.5 or greater	75.0 or greater	60.0or greater	120 or greater

The good relationship is obtained for $PM_{2.5}$ vs $PM_{10.0}$ and $PM_{1.0}$ vs $PM_{2.5}$ where R^2 is 1.0 for both as shown in Table 1.

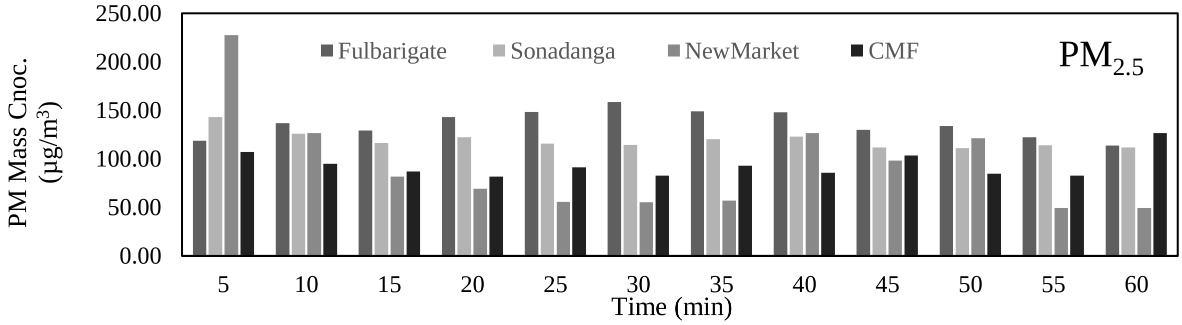

Figure 3: $PM_{2.5}$ mass concentration with 5 minutes time interval at the sampling locations.

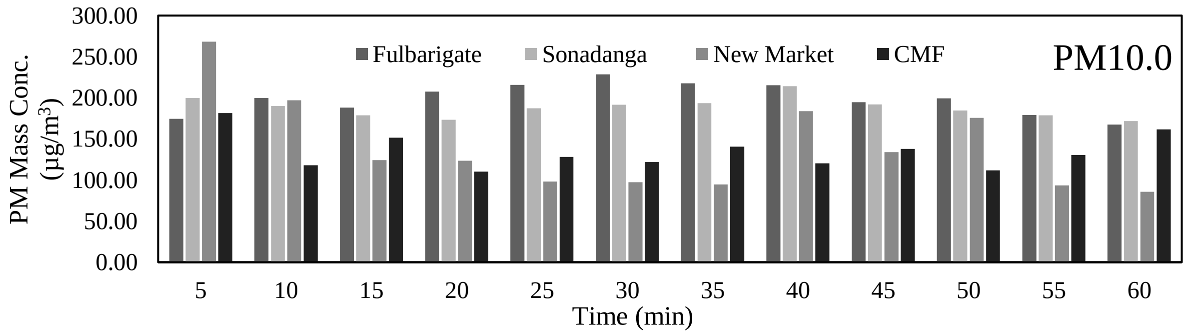

Figure 4: $PM_{10.0}$ mass concentration with 5 minutes time interval at the sampling locations.

Bar diagrams represent that $PM_{1.0}$ is all time higher in Fulbarigate than the other three locations. $PM_{2.5}$ and $PM_{10.0}$ at first 5 minutes is high at New Market but other three locations these values are low as shown in Figure 3 and Figure 4 as at New Market the vehicles volume is high and movement is so speedy due to less congestion. After that, PM mass concentration is high at Fulbarigate. At Labanchara CMF has the lowest PM concentration because of less vehicular emissions here. Raw materials, chimney′s emission and whole manufacturing process of cement are mainly contributing these particles at CMF.

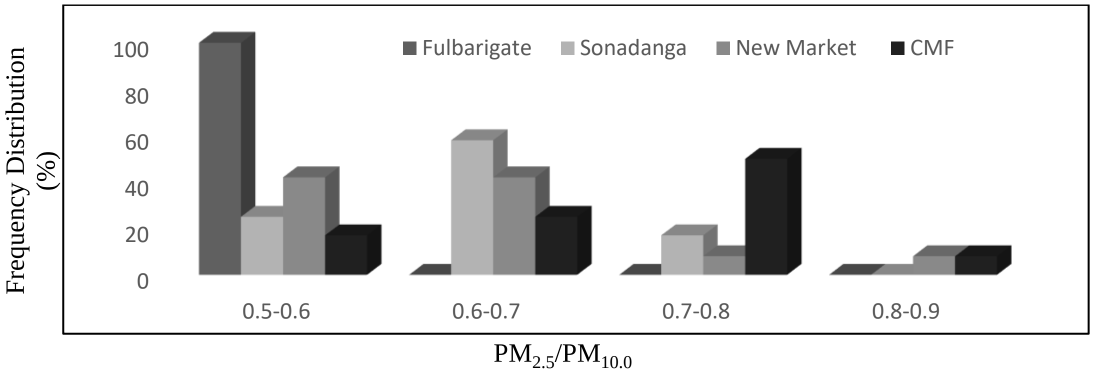

Figure 5: Frequency Distribution of $PM_{2.5}/PM_{10.0}$ ratio

The peak is found for $PM_{2.5}/PM_{10}$ ratio at 0.5-0.6 at Fulbarigate which shows a symmetric pattern as shown in Figure 5. High ratio indicates that significant portion of particulate matter responsible fall under the size distribution of PM for air pollution.

3.2 Traffic concentration

The average traffic moving per five minutes at Fulbarigate, Sonadanga and New Market are 101, 116 and 156 respectively. Average traffic was obtained by counting the vehicles manually at 1-hour duration and five minutes interval in the study locations. Among these three locations, at Fulbarigate has the maximum amount of HCV (7%) which is the major contributors for PM highway emissions. The 4Wheeler (4W) vehicles volume also high at Fulbarigate. The national Khulna -Jashore-Dhaka road goes through the Fulbarigate and a large number of buses and trucks moving here. The highest concentration of PM at Fulbarigate can be supported by the rising concentration of vehicle. Although average moving vehicles at New Market is maximum, the PM concentration is low. The reasons behind this condition are huge number of auto rickshaw moving here but large buses and trucks are rarely found. The meteorological conditions also a major factor for this condition. At Sonadanga the HCV is less than the Fulbarigate because the sampling site is few distance far from the main Sonadanga Bus Terminal. The following Table 3 and Figure 6 represent the 1-hour average traffic concentration precisely.

Table 3: Categories of vehicles in the sampling locations

	Fulbarigate	**Sonadanga**	**New Market**
2W	28%	22%	28%
3W	55%	65%	59%
4W	10%	9%	11%
HCV	7%	4%	2%

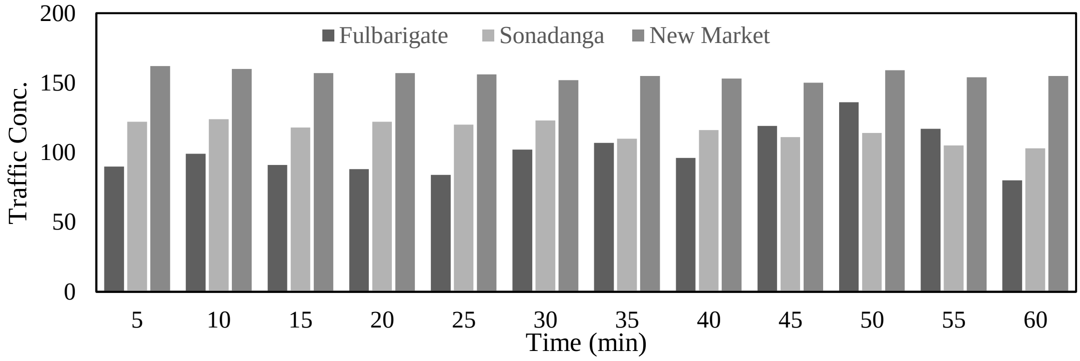

Figure 6: Traffic Conc. Vs Time at sampling location

3.3 Variation of PM Mass Concentration and traffic concentration

Particulate matter concentration is increasing with the increases of traffic concentration. The following figures represent that at first PM concentration in these three locations are increasing gradually with traffic volume. Sometimes, it was seen that PM concentration increases although the traffic decreases specially in Fulbarigate as shown in Figure 7. As at Fulbarigate heavy congestion is noticed when train is crossing the Khulna -Jashore-Dhaka Highway. When the congestion occurs the vehicles still standing at the same place no movement is possible. The vehicular emissions increase due to their fuel combustion although vehicles number is not increased. The shops near the sampling locations sweeps their yard and it affects the exact PM concentration. For these reasons, some unexpected points are obtained in graphical representation.

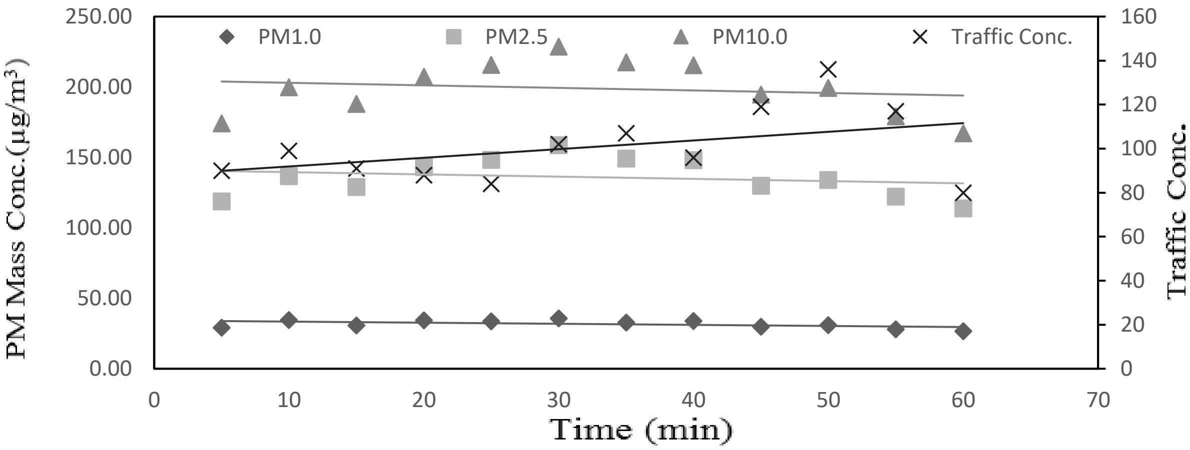

Figure 7: PM Mass Conc. vs Traffic Conc. at Fulbarigate

At Sonadanga the variations are comparatively less than New Market as shown in Figure 8 and Figure 9. There were no congestions noticed at New Market because the road was wider than other locations and vehicles moving so fast.

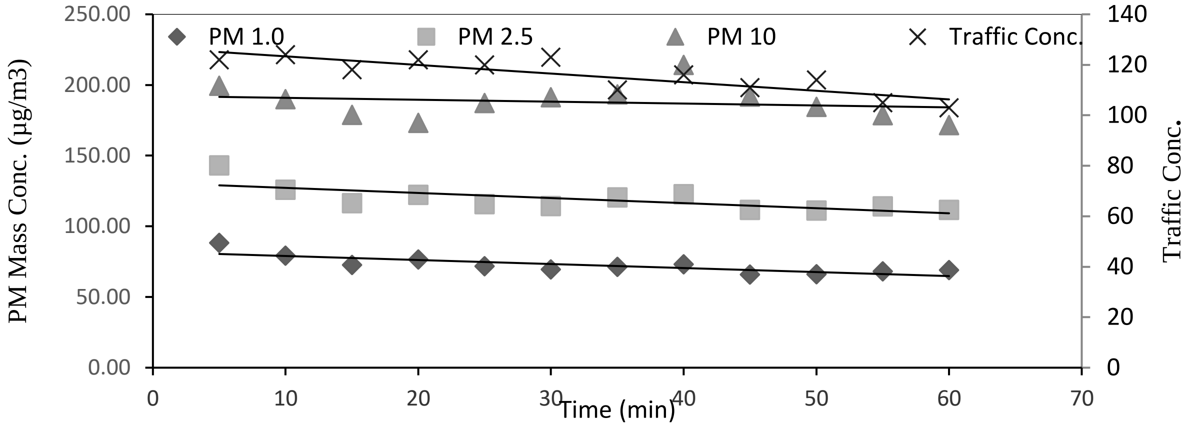

Figure 8: PM Mass Conc. vs Traffic Conc. at Sonadanga

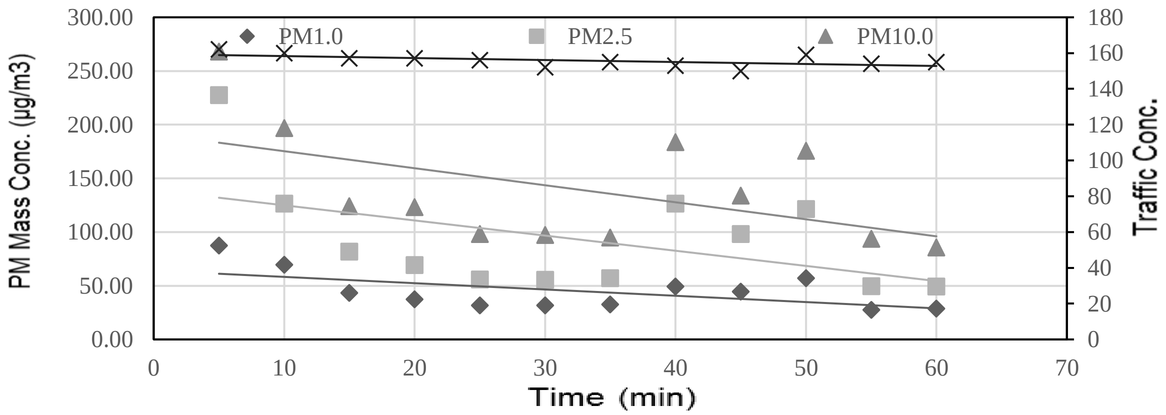

Figure 9: PM Mass Conc. vs Traffic Conc. at New Market

3.4 Determination of Air Quality Index (AQI)

Air Quality Index is tools for reporting the daily air quality and tells how clean or polluted the ambient air and whether it is suitable to breathe in. It focuses on the human health effects that one might experience within a few hours or days after breathing polluted air. According to the National Air Quality Standard for the pollutants the AQI value generally corresponds to 100 which is the level that set by the mandated Environment Protection Agency (e.g., for the Bangladesh Department of Environment) to protect public health. The acceptable value of AQI is 100 which represents the healthy air but exceeding this value the air becomes unhealthy.

To determine the Air Quality Index (AQI) the following formula is usually used

$$\text{Air Quality Index (AQI)} = \frac{\text{Pollutant concentration}}{\text{Pollutant standard level}} \times 100 \tag{1}$$

Table 4: Air Quality Index at sampling locations based on EPA standard

Location		1-hr average $PM_{2.5}$(µg/m3)	AQI for $PM_{2.5}$	1-hr average $PM_{10.0}$(µg/m3)	AQI for $PM_{10.0}$
Fulbarigate	Dec.	136	340	199	249
	April	60	150	113	142
Sonadanga BS		119	298	188	235
New Market		93	233	140	175
CMF(Labanchara)		93	233	135	169
KUET campus		125	192	141	94

There is currently no national standard for the 1-hr $PM_{2.5}$ and $PM_{10.0}$ average but EPA uses the value 40

(µg/m3) and 80 (µg/m3) as the level that triggers a poor or unhealthy for all air quality category.
Example: AQI = 136* 100/40 =340

Every location the AQI exceed 100 which indicates that recently, the air quality in the sampling sites is in worse conditions. The DoE of Bangladesh has set national ambient air quality standards for air pollutants as follows in Table 5.

At Fulbarigate the air quality lies in extremely unhealthy and very unhealthy category due to the AQI of $PM_{2.5}$ and $PM_{10.0}$ are 340 and 249 respectively in the month of winter season as December as shown in Table 4. In summer season the air quality at Fulbarigate is comparatively better than other locations. Only this location was monitored twice during the study period. At Sonadanga, New Market and CMF (Labanchara) the ambient air quality also lies in unhealthy and very unhealthy category.

Table 5: Approved Air Quality Index for Bangladesh

AQI Range	Category	Color
0-50	Good	Green
51-100	Moderate	Yellow Green
101-150	Caution	Yellow
151-200	Unhealthy	Orange
201-300	Very Unhealthy	Red
301-500	Extremely Unhealthy	Purple

This study implies that the air quality in the sampling goes to deteriorate conditions due to vehicular emissions. Immediate steps must be taken to proper monitoring the ambient air quality otherwise the roadway atmospheric air becomes unsuitable to breathe in.

4. CONCLUSIONS

The maximum $PM_{1.0}$ was 73±6.5 (µg/m3) found at Sonadanga, and $PM_{2.5}$ as 136±14 (µg/m3) and $PM_{10.0}$ as 199±19 (µg/m3) were found at Fulbarigate for 1-hour average PM monitoring. The PM concentration at Labanchara Cement Factory for $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ were found 62±5 (µg/m3), 93±7 (µg/m3) and 133±8 (µg/m3) respectively. Significant correlation coefficient found for $PM_{2.5}$ and $PM_{10.0}$ at Fulbarigate, for $PM_{1.0}$ and $PM_{2.5}$ at CMF where Pearson Correlation Coefficient (R^2) was 1. 0. The AQI value at Fulbarigate indicates extremely unhealthy air quality among all the observed locations.

REFERENCES

Adeniran, J. A., Yusuf, R. O., and Olajire, A. A. (2017) Exposure to coarse and fine particulate matter at and around major intra-urban traffic intersections of Ilorin metropolis, Nigeria. Atmospheric Environment, **166**,383–392.https://www.sciencedirect.com/science/article/pii/S1352231017304909 (Accessed February 26, 2019).

Desai, A. A. (2018) A review on Assessment of Air Pollution due to Vehicular Emission in Traffic Area. , **8**(2), 356–360

Jain, S. (2017) Exposure to in-vehicle respirable particulate matter in passenger vehicles under different ventilation conditions and seasons. Sustainable Environment Research, **27**(2), 87–94. [online] http://dx.doi.org/10.1016/j.serj.2016.08.006.

Mahapatra, P. S., Sinha, P. R., Boopathy, R., Das, T., Mohanty, S., Sahu, S. C., and Gurjar, B. R. (2018)

Seasonal progression of atmospheric particulate matter over an urban coastal region in peninsular India: Role of local meteorology and long-range transport. Atmospheric Research, **199**, 145–158. [online] http://dx.doi.org/10.1016/j.atmosres.2017.09.001.

Pant, P., Baker, S. J., Shukla, A., Maikawa, C., Godri Pollitt, K. J., and Harrison, R. M. (2015) The PM10 fraction of road dust in the UK and India: Characterization, source profiles and oxidative potential.Science of The Total Environment, **530–531**, 445–452. [online] https://www.sciencedirect.com/science/article/pii/S0048969715301315 (Accessed February 26, 2019).

Pant, P. and Harrison, R. M. (2013) Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements: A review. Atmospheric Environment, **77**, 78–97. [online] http://dx.doi.org/10.1016/j.atmosenv.2013.04.028.

Pant, P., Shi, Z., Pope, F. D., and Harrison, R. M. (2017) Characterization of traffic-related particulate matter emissions in a road tunnel in Birmingham, UK: Trace metals and organic molecular markers. Aerosol and Air Quality Research, **17**(1), 117–130.

Qiu, Z., Song, J., Hao, C., Li, X., and Gao, H. O. (2018) Investigating traffic-related PM exposure on and under pedestrian bridges: A case study in Xi'an, China. Atmospheric Pollution Research, **9**(5), 877–886.

Singh, N., Murari, V., Kumar, M., Barman, S. C., and Banerjee, T. (2017) Fine particulates over South Asia: Review and meta-analysis of PM2.5 source apportionment through receptor model. Environmental Pollution, **223**, 121–136. [online] https://www.sciencedirect.com/science/article/pii/S0269749116328378 (Accessed February 26, 2019).

Sreekanth, V., Mahesh, B., and Niranjan, K. (2018) Gradients in PM2.5 over India: Five city study. Urban Climate, **25**(January), 99–108. [online] https://doi.org/10.1016/j.uclim.2018.06.001.

Srimuruganandam, B. and Shiva Nagendra, S. M. (2010) Analysis and interpretation of particulate matter – PM10, PM2.5 and PM1 emissions from the heterogeneous traffic near an urban roadway. Atmospheric Pollution Research, **1**(3), 184–194. [online] http://linkinghub.elsevier.com/retrieve/pii/S1309104215305456.

Srimuruganandam, B. and Shiva Nagendra, S. M. (2011a) Characteristics of particulate matter and heterogeneous traffic in the urban area of India. Atmospheric Environment, **45**(18), 3091–3102.

Visin, F., Rampazzo, G., Squizzato, S., Hopke, P. K., Cazzaro, M., and Innocente, E. (2016) Urban air quality in a mid-size city — PM2.5 composition, sources and identification of impact areas: From local to long range contributions. Atmospheric Research, **186**, 51–62. [online] http://dx.doi.org/10.1016/j.atmosres.2016.11.011.

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AN ASSESSMENT ON WATER QUALITY OF THE ICHAMATI RIVER AND ITS IMPACTS ON LIVELIHOOD OF PABNA CITY

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ABSTRACT

Ichamati is a unique river bounded by two major rivers Brahmaputra and Ganges. Though the river is interlinked with two major rivers, it is losing its environmental flow day by day. Change of Ganges river flow, Farakka Barrage, Pabna Irrigation Project and river land grabbing are responsible for present state of Ichamati river. The water quality of the river has also deteriorated due to the continuous disposal of waste water from industrial effluents, domestic wastes, agricultural wastes. For the study, some water samples of Ichamati river are collected from five major points of Pabna city : Ramchandrapur Regulator, Shadupara-SP Bungalow, Bridge-Kheyaghat, Meril-u/s and Meril-d/s. Different water quality parameters such as p^H, TDS, alkalinity, temperature, conductivity, DO of the sample water are determined and it is observed that some water quality parameters are not satisfactory. There have been huge influences on the ecology and environment, livelihood of people living surrounding the Ichamati river at Pabna city because of this waste water. This paper aims to present the recent scenario of Ichamati river water quality due to the disposal of waste water and the adaptation practises of local people through Driving Forces–Pressure–State–Impact–Response (DPSIR) framework analyses. The Driving-Forces–Pressure–State–Impact–Response (DPSIR) indicator framework is useful for identifying and developing indicators of sustainable development for water management of Ichamati river. From the field survey, driving forces have been identified as the population growth, their habitat pattern as well as the industrial development and economic activity of Pabna city. Pressures include the natural and anthropogenic demand and supply of water in agriculture, fisheries etc and water pollution of the river. State indicators can be split into those of the Ichamati water quantity and those of quality in different areas. Impacts include those that affect the ecosystems directly and livelihood pattern of the surrounding area. Response includes the regulation, law and activities taken by government, NGO and local stakeholders. In this study, the objective is extended to observe the complete assessment of present water quality scenario and a detailed perceptional study on its impact on ecosystem, socio-economic activities, livelihood on the Ichamati river.

Keywords: *Wastewater, Water quality parameter, DPSIR framework, Livelihood, Ecosystem.*

1. INTRODUCTION

Bangladesh is a riverine country. There are many rivers flowing through the North-West part of the country. Ichamati is one of them. Major part of the river flows over the district of Pabna and it is a unique river bounded by two major Rivers of Bangladesh: the Brahmaputra and the Ganges. The Ichamati river is passing through the middle of the Pabna Pourashava along the north-south direction. But presently this river is in dead condition. The Ichamati river is filled with water weeds and siltation. The river is lost her navigation during the long years. The downstream part of the river silted up by encroachment during the long ago. The Ichamati river has already been lost her natural levy in many years ago (Hasan et al. 2018). The reason behind it is some significant interventions constructed over it. Change of Ganges river flow, Farakka Barrage, Pabna Irrigation Project and river land grabbing were responsible for present condition of Ichamati river. A significant portion of Ichamati river has already dried up also the degrading water quality of the river water is also a huge matter of concern. Pabna has fledgeling knitted fabric and handloom related textile industries. There are also several consumer and pharmaceutical producing factories. Square (Bangladesh) is the largest pharmaceutical company in Bangladesh. Majority of its factories are situated near Jubilee Tank area of the town. One of the country's oldest pharmaceuticals Edruc has a plant at Ononto neighbourhood. Consumer food producer Universal Food Limited and POROB Foods are also situated there. Gas-based Al Amin Biscuit and Food Limited is the largest of its kind in Rajshahi Division. Waste material that includes these industrial liquid waste and sewage waste that is dumped in different points of the upstream urban area of the Ichamati river is the main cause behind the deterioation of water quality of Ichamati river. This pollution is propagated towards the rural downstream area and effects the fisheries and agriculture in a significant way.

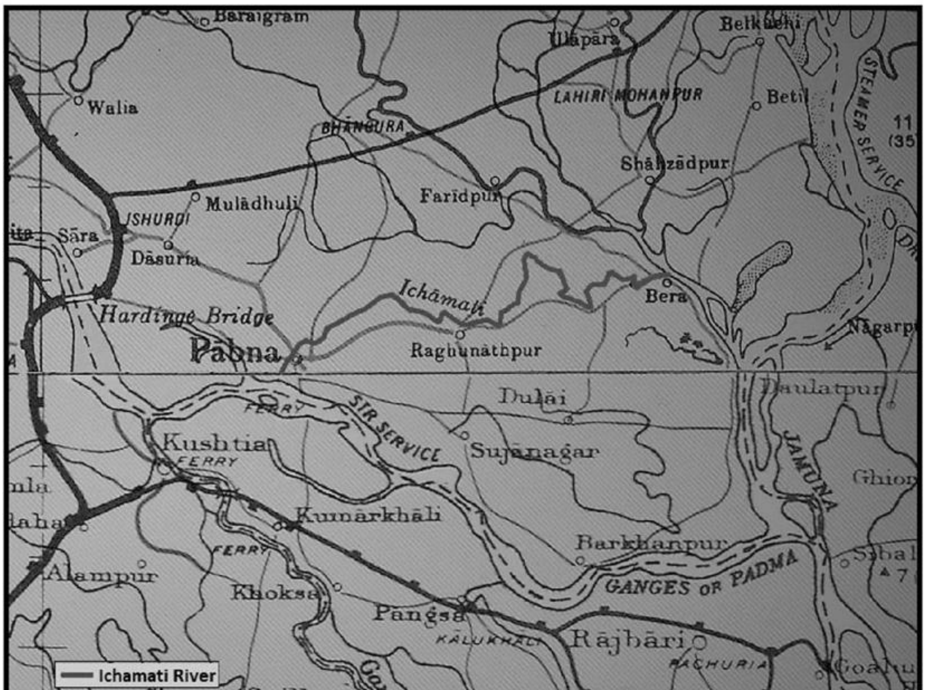

Figure 1 : Ichamati river

In Bangladesh, total environment, as well as economic growth and developments, are all highly influenced by water. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal waste water, runoff pollution from chemical fertilizers, vehicle emission pollutants, pesticides, etc. (Bhuiyan et al. 2011). Pabna is a town in Rajshahi Division of Bangladesh and the administrative capital of eponymous Pabna District. It is located on the north bank of Padma river and has a population of about 138,000 (Shaha, 2013). Major portion of the Ichamati river passes through it. So, the increasing pollution of the Ichamati river can affect the ecology, environment, social pattern, economy, agriculture and overall livelihood pattern of Pabna district in a significant way. Thus, this study's objective is to assess the present water quality scenario and its impact on ecosystem, socio-economic activities, livelihood on the Ichamati river by DPSIR framework.

2. METHODOLOGY

The data collected for the study is both primary and secondary. A field survey was conducted for the study and five water samples were collected from five points of the Ichamati river for the assessment of water quality. Primary data are collected through the water quality testing report, field survey, direct observation, focus group discussion, stakeholder and community consultations and interviews of the field survey. Total 7 FGD are conducted and 89 people are interviwed at the field survey. They were asked questions about their impacts on livelihood, socio economic condition, environment pollution etc. Secondary data is collected from different sources including published and unpublished literature, different databases, newspapers and the World Wide Web. Secondary information, preliminary stakeholder discussions and field visits led to selection of preliminary study sites for detailed baseline study.

2.1 Water Quality Analysis

For checking the water quality, water samples of Ichamati river are collected from five major points of Pabna city: Ramchandrapur Regulator, Shadupara-SP Bungalow, Bridge-Kheyaghat, Meril-u/s and Meril-d/s. The five collection points are shown in Figure 2 and collection location of Shadupara-SP Bunglow is shown in Figure 3. Different water quality parameters such as pH, TDS, alkalinity, temperature, conductivity, DO of the sample water are estimated.

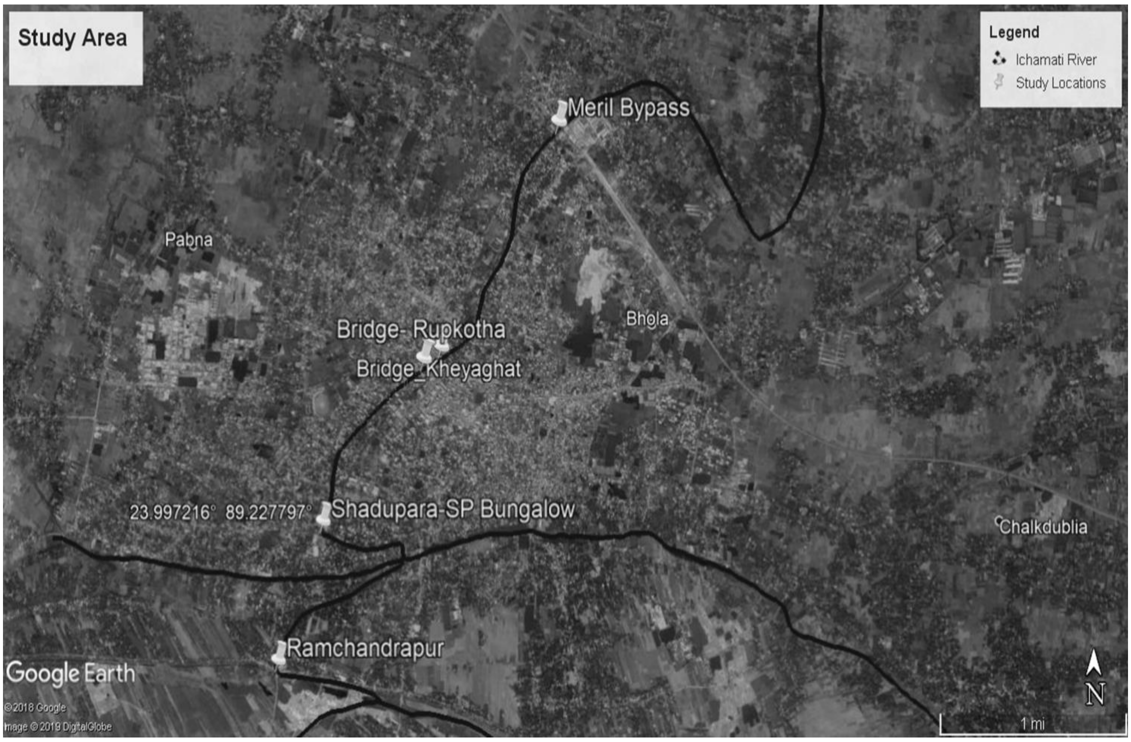

Figure 2: Five collection points of water of the Ichamati river

Figure 3: Water collection location Shadupara-SP Bunglow

2.2 Field survey and Focus Group Discussions

For this study, field surveys were conducted in Pabna at different points of the Ichamati river. Focus Group discussions were conducted and resources mapping were created at different locations. A sample resource mapping of Kheyaghat location is shown in Figure 4.

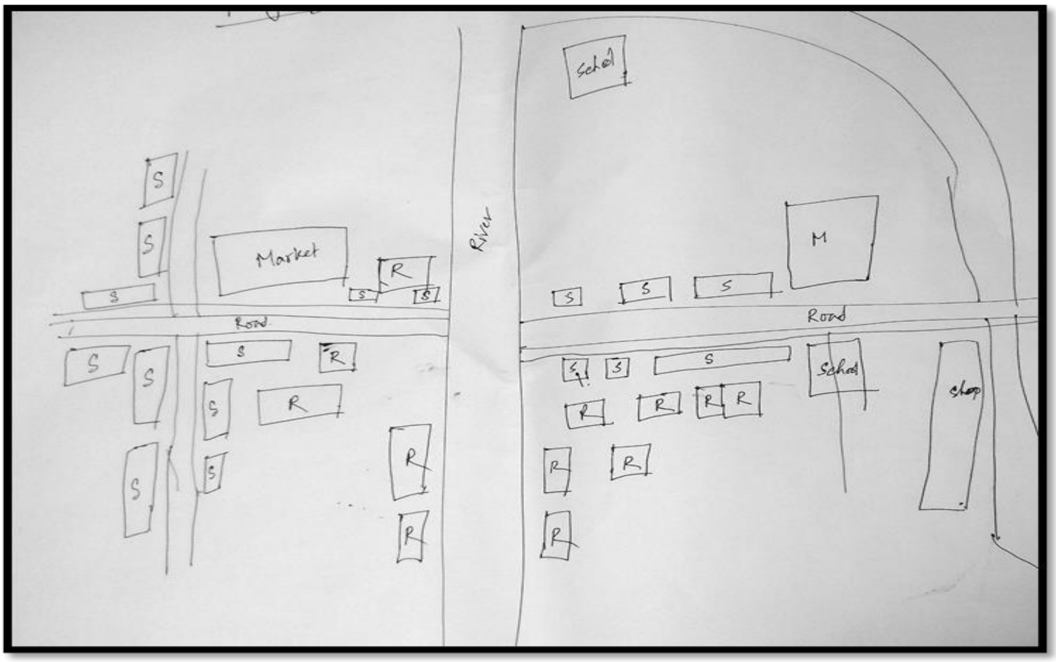

Figure 4: Resource Mapping of Kheyaghat location

Several interviews and Focus Group Discussions (FGD) were conducted in many places with different stakeholders like fishermen, farmers, local associations, marginalized group like women. The information collected from the different stakeholders were collected and various water conflicts were identified. A Focus Group discussion with farmers is shown in Figure 5.

Figure 5: FGD with farmers in study area

2.3 DPSIR framework analysis

The DPSIR framework was devised in the late 1990s as a tool for the reporting and analysis of environmental problems, ranging in scale from global systems to localized watersheds. Since then, international organizations have begun to apply this framework to the evaluation of sustainable development initiatives, to better understand and overcome barriers to sustainability (Carr et al., 2007). DPSIR framework means Driving-Forces–Pressure–State–Impact–Response (DPSIR) indicator framework where

- Driving forces are the human influences and activities that combine with environmental conditions and underpin environmental change;
- Pressure indicators measure the pressures that are exerted on resources and ecosystems from human activities (e.g., emissions, consumption, and utilization);
- State indicators assess the condition of the resource or ecosystem as a result of the pressures;
- Impacts, which are the results of pressures on the current state;
- Response indicators relate to the societal responses via policies, laws, programmes, research etc.

The Driving-Forces–Pressure–State–Impact–Response (DPSIR) indicator framework is useful for identifying and developing indicators of sustainable development for water management of Ichamati river. From the field survey, driving forces have been identified as the natural conditions occurring in the river and the level of industrial development and economic activity of Pabna city. Pressures include the natural and anthropogenic demand and supply of water in agriculture, fisheries etc and water pollution of the river. State indicators can be split into those of the Ichamati water quantity and those of quality in different areas. Impacts include those that affect the ecosystems directly and livelihood pattern of the surrounding area. Response includes the regulation, law and activities taken by government, NGO and local stakeholders.

3. RESULTS AND DISCUSSION

3.1 Water Quality parameters

The sample water of the Ichamati river which was collected from five different locations of Pabna city was tested and different water quality parameter is determined and compared with standard values. The values are shown in the table 1.

Table 1: Water Quality parameter of different points of the Ichamati river

Parameter	**Unit**	**Location of water sample collection point**					**ECR’97 (Inland Surface Water)**
		Ramchandrapur Regulator	**Shadupara-SP Bungalow**	**Bridge-Kheyaghat**	**Meril-u/s**	**Meril-d/s**	
Temp.	°C	28.6	28.2	29.4	28.8	30.8	≤40
pH		6.14	6.33	6.36	6.58	6.45	6.0-9.0
EC	μS/cm	710	1188	774	858	840	≤1200
TDS	mg/L	317	540	339	380	367	≤2100
DO	mg/L	0.36	3.52	0.98	1.25	0.83	4.5-8.0
Turbidity	NTU	17.2	49.4	59.7	13.36	19.4	---
Color	Pt-Co	71	65	153	45	62	---
Suspended Solids	mg/L	47	42	51	38	39	≤150
Alkalinity (Total)	mg/L	255	315	270	325	290	---
Iron	mg/L	1.03	0.22	0.31	0.09	0.13	2
Ammonia-Nitrogen (NH3-N)	mg/L	4.7	10.4	10.15	5.15	8.65	5
Nitrate-N	mg/L	0.2	2.8	0.2	0.7	1.2	10
Phosphate	mg/L	6.6	5.5	8.1	4.7	4.6	
Sulfide	mg/L	4	10	7	2	9	1
Chloride	mg/L	70	70	70	10	50	≤600

It is clearly observed that dissolved oxygen of all the points of Ichamati river is very low which indicates the increasing pollution of the Ichamati river. Now-a-days, the DO is too low to survive for aquatic lives as all the samples are below the standard DO limit 4.5-8.0mg/L. From the interviews of nearby resident and specially FGD with fishermen at Shreepur, it was mentioned that now-a-days, they are having loss in fishery business because in the degrading water quality the fishes and aquatic lives can’t survive properly. But before some years, they used to have really good profit from the fishery business. But now people living downstream of the Ichamati river are suffering this socio-economic problem. They mentioned the prime reason is the wastes released from Square industries from upstream. However, from Table 1, it is also seen that there is high iron in “Ramchandrapur Regulator” compared to other points. The probable cause that was understood from the field survey was the released industrial wastes from the nearby industries where metal wastes are also released without proper monitoring and there is significant amount of iron and other metals. Thus, the presence of metal wastes may increase the iron content. Apart from that, the value of Ammonia-Nitrogen (NH3-N) was quite high in “Shadupara-SP Bungalow” and “Bridge-Kheyaghat” point. The reason was in that location, there is an outlet of several domestic sewer lines or drains where human wastes and other household wastes are dumped. During the field survey our team collected the water sample from that outlet point. From the information of the local residents, the practise is quite old, the human wastes from surrounding locality are passed by the several drains and the connecting outlet is at the point beside SP Bunglow. So, as expected we found high amount of Ammonia-Nitrogen (NH3-N) due to the organic waste.

The comparison of dissolved oxygen in various locations of the Ichamati river is shown in Figure 6. It is clearly evident that due to the extreme disposal of industrial wastes the dissolved oxygen in Meril bypass area is very low. From the site visit, it was observed that due to the untreated wastes released from the Meril soap industry located at that point, the colour of the river water becomes darker and there was odour problems due to the wastes. From the visual condition, it was assumed that the water may have low amount of DO which was confirmed after tests.

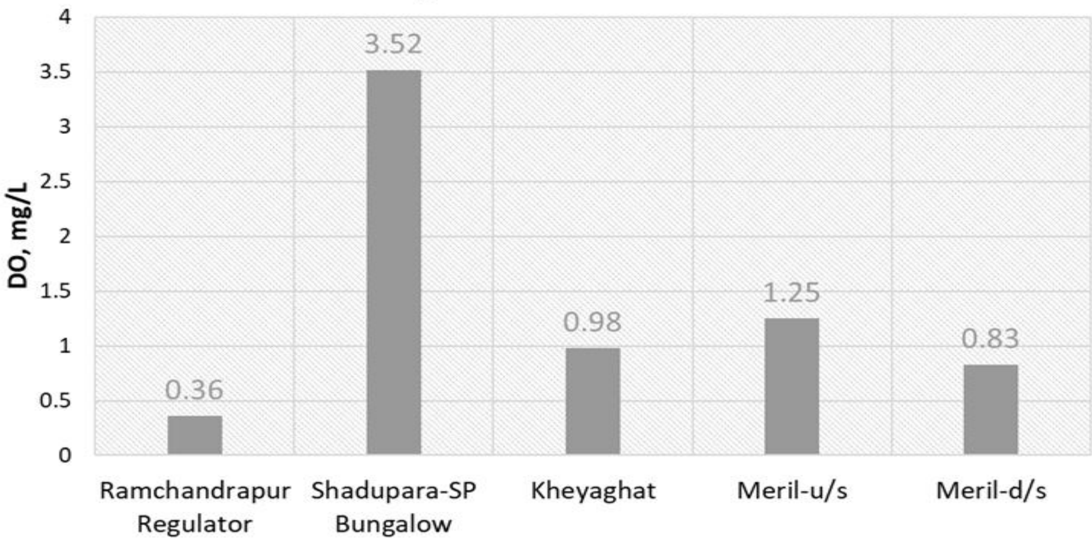

Figure 6: Variation of DO in different locations of the Ichamati river.

The comparison of EC in various locations of the Ichamati river is shown in Figure 7. EC mainly indicates the amount of ionic content in a solution. From Figure 7, it is seen that all the sample water has shown EC<1200 μS/cm. It indicates the ionic content or salt content is in the permissible state.

The comparison of p^H, alkalinity, sulfide in various locations of the Ichamati river is shown in Figure 8. The p^H of all the samples are within 6.1-6.6 which indicates slightly acidic nature of the water. The alkalinity content is overall is in the normal limit. But the sulphide level is a bit higher at the Shadupara-SP Bungalow due to the direct release of wastewater from households and Meril d/s due to the direct release of industrial wastewater from Meril industry.

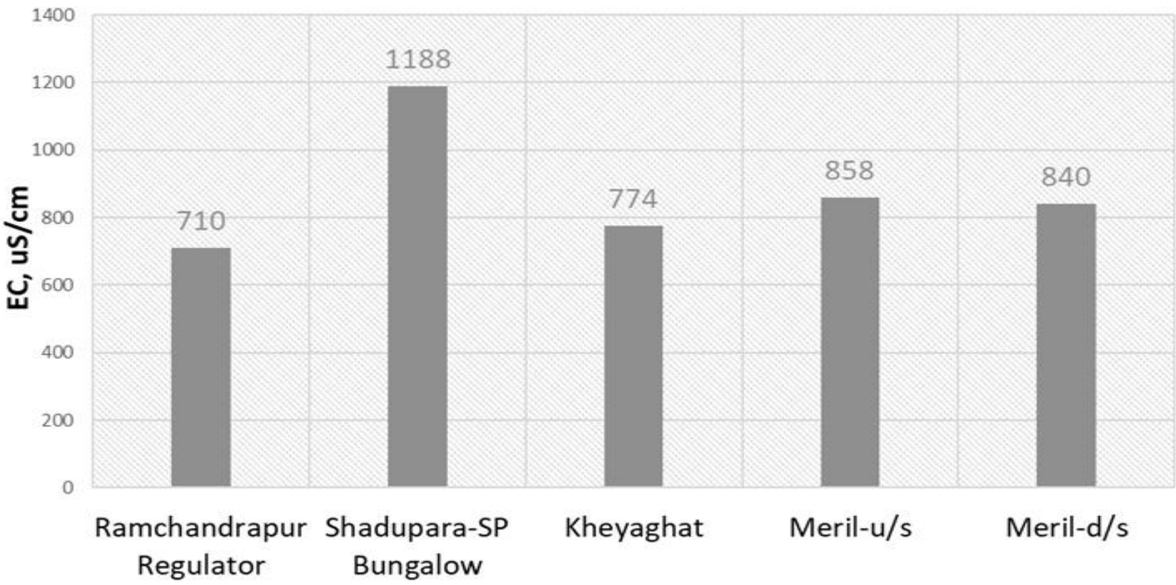

Figure 7: Variation of EC in different locations of the Ichamati river.

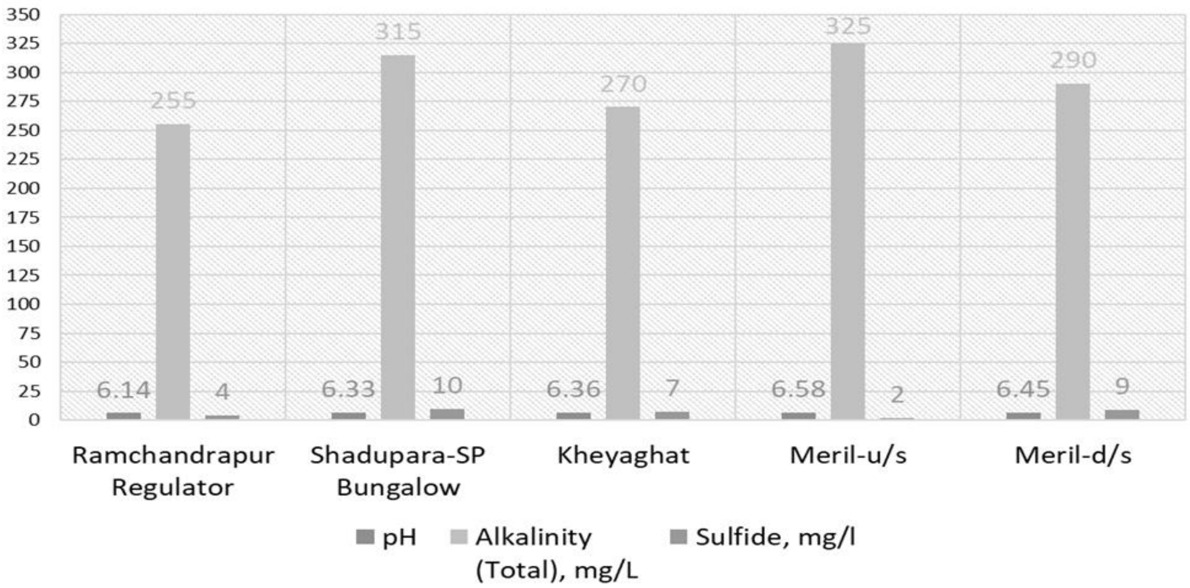

Figure 8: Variation of p^H, alkalinity, sulfide in different locations of the Ichamati river.

3.2 DPSIR framework analysis

From the collected data, driving forces have been identified as the level of industrial development and economic activity of Pabna city with the increasing population growth. The Meril industrial area is one of the main industrial zones of it from where the industrial wastes release. Due to the population growth, there is unplanned habitat patern in the city. Some poor people has started living in the parts of river that has dried up and silted. Some of the household wastes are released on an outlet connected to the river. The population growth, their habitat pattern as well as economic and industrial development is identified as the driving forces here towards the whole scenario.

Pressures include the natural and anthropogenic demand and supply of water in agriculture, fisheries etc and water pollution of the river. At the downstream peri urban area, the fisheries and agricultural sector needs vast amount of water. But due to the low flow of water and degrading water quality in the river there is a huge impact on the agricultural and fisheries sector. The fishermen group near the Shreepur area has mentioned huge loss in fisheries for consecutive 3 years due to the pollution coming from the industries. Though the farmers are using the groundwater instead of surface water for irrigation purpose, but it is lowering the groundwater table each year. As the Ichamati river is dried up, the groundwater recharge is also not too high.

State indicators can be split into those of the Ichamati water quantity and those of quality in different areas. The Ichamati river is almost a dead river now. The natural flow of the river is too low to meet the environmental flow. The water quality parameters are listed before which shows that the dissolved oxygen is very low due to the excessive disposal of wastes which indicates an unfavourable condition for aquatic life. Thus, the biodiversity and habitat diversity is decreasing.

Impacts include those that affect the ecosystems directly and livelihood pattern of the surrounding area. The excessive dumping of industrial waste has already polluted the river to a great extent. The main adverse ecological impact was on aquatic flora and fauna of the Ichamati river. From the FGD of several farmer groups and experts, it is found that several fish types that used to be found naturally at the rainy season when there is water isn't found for last two years. The pollution also propagated to the downstream rural area of the Ichamati river which affected the fishery sector a lot. Many fishermen have shifted their profession and become day labourers or farmers. The groundwater is being used extensively as surface water of the river is not available in many points due to lack of flow of the Ichamati. Thus, the groundwater table is also degrading. The ecosystem is also hampered significantly. As the dissolved oxygen is very low, its hard for the aquatic lives to survive in the river water. Thus, the biodiversity is degrading due to the pollution.

Response includes the regulations, law taken by government, NGO and local stakeholders. Bangladesh Water Development Board (BWDB) has undertaken a project of “Re-excavation of the Ichamati river” under the “Bangladesh Delta Plan 2100” to revive the river.

The DPSIR framework is shown in Figure 9.

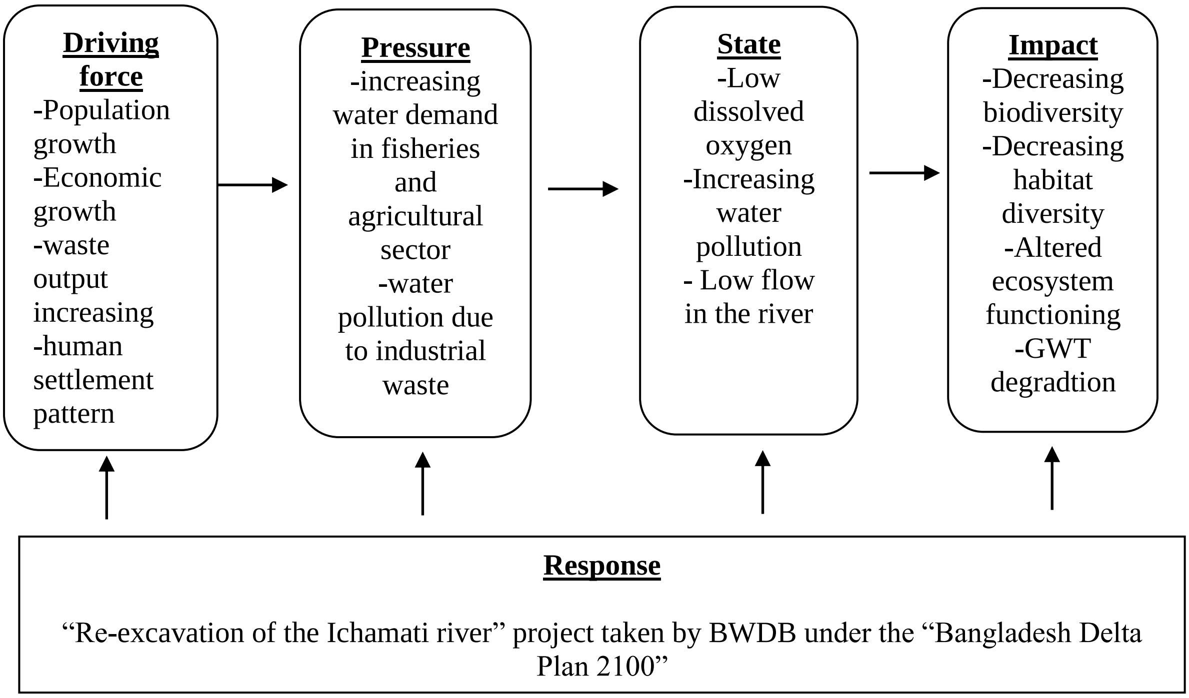

Figure 9: DPSIR framework on the Ichamati River

4. CONCLUSIONS

The Ichamati river is almost a dead river now. Apart from losing its environmental flow, the water quality of the river has also deteriorated due to the continuous disposal of waste water from industrial effluents, domestic wastes, agricultural wastes. To assess the water quality of the Ichamati river, five samples were collected from five different points of the river and different water quality parameters of the Ichamati river such as pH, TDS, alkalinity, temperature, conductivity, DO of the sample water are determined and it is observed that the amount of dissolved oxygen is not enough to maintain the aquatic life. The impact of the wastewater is significant on the surrounding ecosystem and livelihood of Pabna city which is shown through the DPSIR framework. From this study, it can be concluded that the degrading water quality of the Ichamati river is a great concern for the ecosystem, socio economic aspect and overall livelihood of Pabna city. Its recommended to take necessary steps to reduce pollution and restore the flow of the Ichamati with the integrated participation of concerned stakeholders.

REFERENCES

Bhuiyan, M.A.H., Rakib, M.A., Dampare, S.B., Ganyaglo, S., & Suzuki, S. (2011). Surface water quality assessment in the central part of Bangladesh using multivariate analysis. KSCE Journal of Civil Engineering 15(6), 995–1003.

Carr, E.R., Wingard, P.M., Yorty, S.C., Thompson, M.C., Jensen, N.K., & Roberson, J. (2007). Applying DPSIR to sustainable development. International Journal of Sustainable Development & World Ecology 14 (2007), 543–555.

Hasan, S. R., Hossain, M.T., Khan, L.A., & Afrin, S. (2018). Seasonal water logging problem in an urban area of Bangladesh: a study on Pabna Pourashava. Paper Presented in 1st National Conference on Water Resources Engineering (NCWRE 2018), 21-22 March 2018, CUET, Chittagong, Bangladesh.

Saha, A.K. (2013). Environmental aspects of solid waste management: a case study of Pabna city in Bangladesh. IJASET 2(2), Vol. 02. Issue 02. Article No. 01, 1-8.

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APPLICATION OF A POLYMER IN DRINKING WATER TREATMENT: A CASE STUDY

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ABSTRACT

Due to the severe pollution in the ShitalakshyaRiver, the raw water source of the largest drinking water treatment plant at Dhaka, some experts had suggested using polymer as a purification aid in the water treatment chain at Dhaka in order to keep it as sustainable source. But it was declined due to almost unknown characteristics of polymer in drinking water treatment in this country and knowing that the use of polymer in urban large scale drinking water treatment is banned in many countries.

The present study was taken to examine the effect of the use of a polymer in the removal efficiency of pollutants especially the turbidity and total organic carbonmeasured in the form UV_{254} as surrogate. Samples were taken from the intake point of the largest treatment plant in Dhaka for several months. Jar tests were conducted with the raw water with alum and commercially available anionic polymer FLOERGER AN 934 SH, as was proposed by some constructor.

It is observed that When the said anionic polymer coupled with Alum was used, keeping Alum dose fixed at 85mg/L adding 0.05 mg/L of polymer the increase in the % removal of turbidity is only 1.23% which is insignificant. By doubling the polymer dose (0.1 ppm from 0.05 ppm) keeping the alum dose same (85 ppm) the removal efficiency increases only 0.47 percent. Adding only 0.05 mg/L of polymer alone into the raw water (Turbidity 106 NTU) gives a resulting turbidity of 65 NTU indicating 38.68% turbidity removals. Doubling the polymer dose that is by adding 0.10 mg/L of polymer alone the resulting turbidity is 64.5 NTU indicating a turbidity reduction of 39.15 %. It is worth noting that by doubling the dose of polymer from 0.05 to 0.10 mg/L the change in turbidity removal is hardly increases lest expecting double reduction in turbidity removal.

It is evident that addition of Alum alone to the raw water is far more effective than adding only polymer in this particular sample of raw water for the removal of turbidity. Furthermore, similar result is seen in case of removal of UV_{254}. With 85 mg/L of Alum alone the removal of UV_{254} is 47.14%. When 0.05 mg/L polymer is added along with 85 mg/L of Alum the removal is decreased by 3.06% rather than increase. Even adding 0.10 mg/L polymer along with 85 mg/L of Alum removal of UV_{254} stands to 46.90% yet below what is achieved by adding Alum alone.

Thus the addition of polymer does not have any major effect on the removal of total organic carbon. Therefore extensive study is needed to decide on Polymer as a workable, and dependable, potable water treatment process aid at Dhaka when the this river is used as the raw water source.

Keywords: *Coagulant, Drinking water treatment, Polymer, Turbidity.*

1. BACKGROUND

Dhaka now, with a population of over 15 million is one of the most populous and congested cities in the world. This mushrooming city is located on the northern bank of the River Buriganga and surrounded by other Rivers, namely, the Turag to the west, the Tongi Khal to the north and the Balu & the Shitalakshya to the east. Yet, the city carried a legacy of water shortage since the independence of Bangladesh in 1971 up to very recently (DWASA, 2007; Serajuddin, 2009).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 surfacewater. In this context, Saidabad Water Treatment Plant (SWTP) in two phases was constructed with atotal capacity of 450MLD . The Shitalakshya river at theeastern periphery of Dhaka city is the source of raw water for the plant.

The river Shitalakhya was recommended since early eighties as the source of raw water for the aforesaid plants after several studies by the local and international experts (BCEOM, 1992; DWASA, 1994). Unfortunately, the Shitalakshya river now facing serious problems of pollution, principally contributed by industries (Begum & Ahmmed, 2010; GOB & UNDP, 2010; Rahman & Hadiuzzaman, 2005; Sania et al., 2012). This severity of river water pollution started to be visible from around two decades back when the construction of the first plant started. The international constructor, who observing the severe pollution especially during dry season, proposed to use polymer as a purification aid in the treatment chain. The bidder advocated that due to various reasons there are situations where inorganic flocculants cannot solve the problem caused by the poor quality of inflow water alone. They urged that the different behavior of polymer flocculants, as compared with the inorganic flocculants used in conventional water treatment plants, might have a positive effect on future water treatment process design as the destabilization of fine particles by organic polymer flocculants has been increasingly important, because of their demonstrated effectiveness on poor raw water quality (Lee, 1998; SNF, 2002). But the authority at Dhaka decline to allow using polymer in this plant due to the almost unknown characteristics of polymer in drinking water in this country, furtherer more, it was known that the uses of polymer in drinking water treatment are banned in a country like Japan (Gregor et al., 1993; Letterman & Pero, 1990). They sought to know the detail on it from the bidders.

This background incited the present study to see the effect of the use of polymer in the removal of pollutants especially the turbidity & organic material from the raw water of the Shitalakshya river, the source of the drinking water at Dhaka.

2. INTRODUCTION

The impurities in water occur in three progressively finer states - suspended, colloidal and dissolved matter. The particulate impurities (commonly called suspended solids) cover a broad size range. Smaller sized particles, such as spores, cysts, plankton, fine clays and silts with their associated bacteria, do not readily settle and treatment is required to produce larger particles that are more amenable to removal. These smaller particles are often called nonsettleable solids or colloidal matter (Mahvi & Razavi, 2005).

The purpose of coagulation and flocculation in water treatment is to condition impurities, especially non-settleable solids and colour, for removal from the water being treated. (Carty et al., 2002).Chemicals used in coagulation / flocculation are referred to either as primary coagulants or as coagulant aids. The purpose of coagulant aids may be to condition the water for the primary coagulant being used, to add density to slow-settling flocs or toughness so the floc will not break up in the following processes (Carty et al., 2002).

Salts of aluminium or iron are the most commonly used coagulant chemicals in water treatment because they are effective, relatively low cost, available, and easy to handle, store, and apply. Aluminium sulphate - commonly called alum or sulphate of alumina - is still very widely used although concern about the possible adverse effects of dissolved aluminium has recently been expressed in some quarters (Bratby, 1980). It has been reported that a high intake of aluminium ions in the water may cause neurological diseases such as Alzheimer's disease and pre-senile dementia. WHO has recommended regulating the residual aluminum ion concentration. In Bangladesh, from 1997 the acceptable residual aluminum ion level in drinking water has been regulated to be below 0.2 mg/L (DoE, 1997; EPA 2012).

2.1 Organic polymers

Polymer flocculants are water soluble organic polymers carrying functional groups such as amino or carboxyl functionalities in their polymer backbone. Their molecular weight ranges from a few thousands to millions. According to the electric charge carried by the polymer flocculants in aqueous medium, they can be classified as cationic, anionic, and non-ionic (Lee et al., 1998).

Organic polymers have said to gain widespread use as water treatment coagulants and flocculants in a quite large number of developed countries since their introduction in the early 1950's. and in enhancing the removal of turbidity and colour (Bolto &Gregory, 2007).

Organic polymers are long-chain molecules consisting of repeating chemical units (monomers) with a structure designed to provide distinctive physicochemical properties to the polymer. The polymers usually have an ionic nature, and are also referred to as polyelectrolyte. The total number and types of monomer units in a polymer can be varied in manufacture.Consequently, a large variety of polymers can be produced. Cationic polymers are used in the water treatment industry as primary coagulants, whereas nonionic and anionic polymers are used as flocculants or filter aids, and are usually used in conjunction with inorganic coagulants.

Polyelectrolytes as demanded by manufacturers offer an alternative means of improving the quality of the water by (sometimes) effectively removing particles and natural organic matter.As flocculants aids, polyelectrolytes reduce the dose of aluminium required to achieve acceptable quality water. Polyelectrolytes have two main objectives in water treatment; destabilization of colloids and particulates, and formation of larger and more shear-resistant flocs. Anonic, nonionic, and cationic polymers may function as bridging polymers increasing floc once destabilization has been achieved.
In general, anionic polymers have been shown to be effective flocculation aids, while nonionic polymers have been effective as filter aids (Bae et al., 2007). Over the past 25 years, an increasing number of polyelectrolytes have become available to the water treatment industry. Many of these products are merely different mixtures of, or polyrners of slight modification to a much smaller group of mainstream polymers. Since manufacturers supply very little technical information on the polymers, and since the modes of action are less well understood than those of inorganic coagulants, selecting a polymer from these products to provide optimal treatment is generally done by product representatives and often by trial-and-error (NZWWA, 1999).

2.2 Concerns in use of Polymers

For many years and still in some countries yet, there was much reservation in the use of polymer in drinking water treatment due to negative health effect of the polymer residual in the treated water. Switzerland and Japan do not permit the use of synthetic polyelectrolyte in drinking water treatment, and West Germany and France have stringent limits on application rates (Letterman & Pero, 1990). It was concluded that acrylamide is a genotoxic carcinogen.

The most important source of drinking water contamination by acrylamide is the use of polyacrylamide flocculants that contain residual levels of acrylamide monomer. WHO guidelines value associated with cancer risk has been estimated at 0.5 microgram per liter. USEPA has set an MCLG (Maximum contaminant level goal) of zero mg/L (EPA,2012).

2.3 Objective of the study

The prime objective of the study is to investigate the effect of a particular polymer in the flocculation efficacy with the raw water from the Shitalakshya river, the raw water used in the largest treatment plant in Bangladesh.

Polymer doses have been applied to Shitalakshya river water treatment plant in Bangladesh to check its efficiency in reducing turbidity and organic material. The effects of polymer, polymer quantity, initial turbidity, and pH of raw water on turbidity and organic material removal were also investigated. The motivation for this research on the use of polymer was inquisitiveness. Laboratory tests were carried out before taking a decision on the introduction of the synthetic polymer in drinking water treatment at Dhaka, though in a very limited quantity and duration, to be used as flocculants aids. The claim demanded by the constructor was that the technical efficacy of polymer as fluctuant aid in clarification as well as in cost savings is evident when polymer is used along with a coagulant than the coagulant itself when used alone.

3. MATERIALS AND METHODS

3.1 Study Area, sample collection & analysis

The study area is Dhaka the capital city of Bangladesh with a population of more than fifteen million located in the central part of Bangladesh. Dhaka has a distinct monsoonal season, with an annual average temperature of 26°C (79°F) and monthly means varying between 19°C (66°F) in January and 29°C (84°F) in May, sometimes reaching to 40 degrees Celsius. Approximately 87% of the annual average rainfall of 2,123 millimeters (83.6 inches) occurs between May and October. Dhaka is located at 23°42′N 90°22′E, on the banks of the Buriganga River and surrounded by other peripheral Rivers.

The largest surface water treatment plant of the country is situated beside the river Shitalakshya in the eastern periphery of Dhaka city at Latitude 23°43'11.25"N & Longitude 90°26'14.25" E (Serajuddin et al., 2018) (Figure 1).

The raw water from the intake of this plant was collected and taken to the laboratory by following the precautions laid by standard methods (APHA, 2005). Each of the water samples was analyzed for pH, turbidity, temperature, UV_{254}.Alum as an inorganic coagulant ($Al_2(SO_4)_3,18H_2O$), were used in the experiments. This Coagulant was collected from drinking water treatment plants which are produced by BSK chemical Industries, in Bangladesh. This Alum contain 17.10% water soluble aluminium compound as Al_2O_3, water soluble iron compound as Fe, 0.5%, Fe_2O_3,0.5%, insoluble matters 0.5%,pH of 1% solution 3.5 – 4.5, colour milky white.Commercially available anionic polymer FLOERGER AN 934 SH produced by SNF FLOERGER, as was proposed by the constructor to be used in the plant was used in the study. In appearance it is white granular powder whose generic name is copolymer of acrylamide and sodium acrylate, anionic, with molecular weight 5 - 22 million, pH 4.08. All the chemical tests and analysis were done according to the Standard Method for examination of water & wastewater (APHA, 2005).

3.2 Experimental setup

A six-cube jar test apparatus was used with each 1 litre jar containing 1 litre of water. The rapid mixing time for coagulant was 5 min at a paddle speed of 200 rpm (Figure 2). The slow mixing for flocculation was 5 min at 50 rpm, and the sedimentation time was 30 min. After settling, 50 ml of supernatant was taken out and turbidity (HACH 2100Qis) and pH (HACH SensIon+MM150) were measured immediately. UV_{254} were determined (DR 6000) as surrogate parameter to observe the removal of dissolved organic matter in the water by Alum and/or polymer.

One of the methods nowadays utilized to monitor organic load is the ultraviolet absorption of water at 254 nm wavelength UV_{254}. Because the UV_{254} absorbance parameter is proportional to the concentration of organics in the water most natural water sources such as raw water for drinking water and municipal wastewater have a good correlation between, for example, TOC and UV_{254} absorption, and COD and UV_{254} absorption (Edzwald et al., 1985; Kim et al.,2016, Quayle et al.,2009; Serajuddin et al.,2018). Many organic compounds occurring naturally in the environment, such as humic substances, are aromatic and exist in high concentrations in surface water. These compounds are known to be a major precursor of DBP formation. Therefore, UV_{254} provides one of the best indications of water's potential to form DBPs upon chlorine addition and should be monitored throughout the treatment process to ensure organics are removed. The effective turbidity was measured at the end of each test. The concentration of total organic carbon in surrogate of UV_{254} was measured by a DR 6000 spectrophotometer.

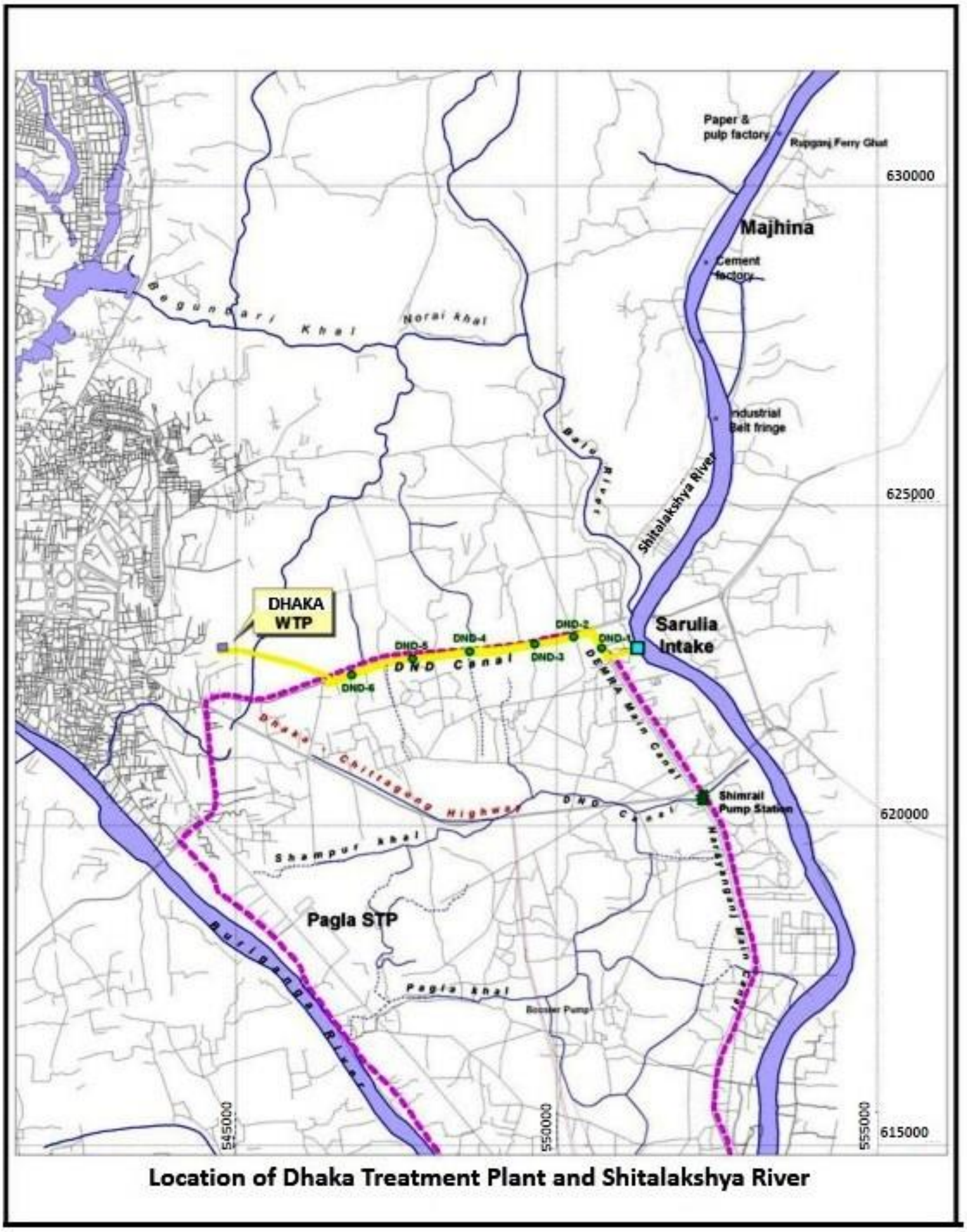

Figure 1: Raw water source from Sitalakhya River to Water treatment plant

3.1 First test

On 14 March 2019 six jar tests were conducted with six different doses of alum alone then with six different doses of polymer alone & then three samples with combination of alum & polymer were conducted. The entire tests were done with the same sample of raw water

3.2 Second test

On 25 March 2018, six jar test with this raw water sample were conducted simultaneously with six different doses and combination of Alum & Polymer doses being selected on the basis of plant operation experiences, namely: (1) with no chemical addition, (2) adding Alum alone with a concentration of 85 mg/L, (3) adding 0.05 mg/L of polymer alone, (4) adding 0.10 mg/L of polymer alone, (5)Adding 0.05 mg/L of polymer along with 85 mg/L of alum and (6)Adding 0.10 mg/L of polymer along with 85 mg/L of alum.

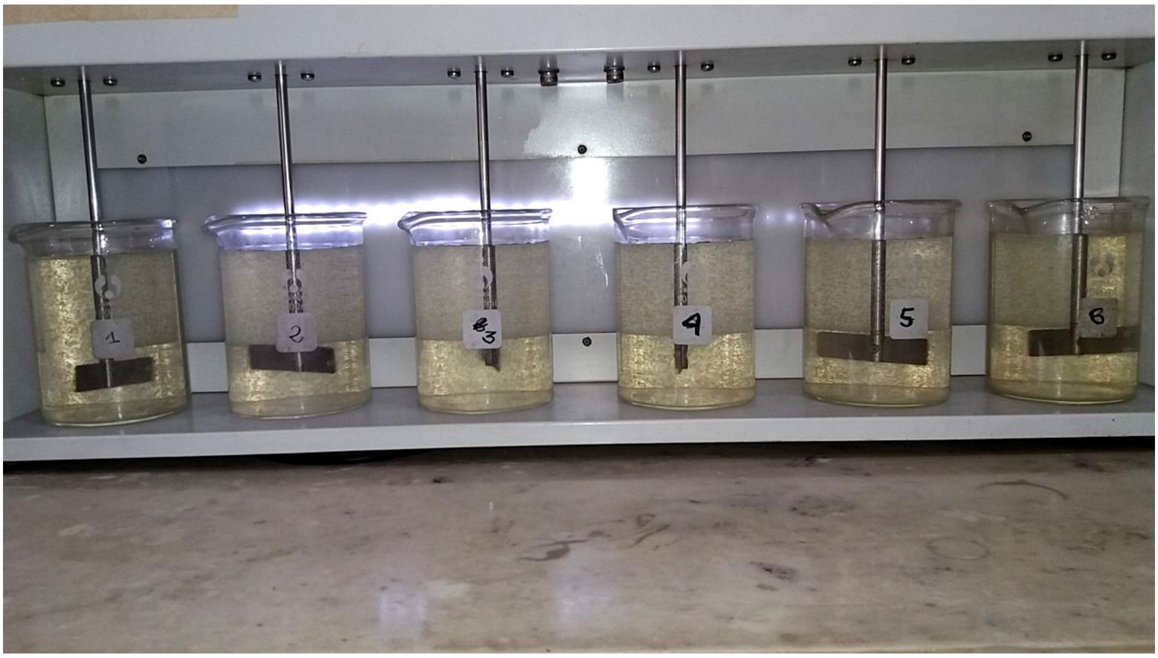

Figure 2: Experimental setup

4. RESULTS AND DISCUSSIONS

A number of jar test were conducted taking sample of raw water from the intake of the largest treatment plant of Dhaka. Generally the months of February to April are the critical months of the year in terms of raw water quality and quantity in the ShitalakshyaRiver near the intake. As such jar test were carried with this raw water mostly from January to April 2019, 2018 and 2017 to observe the effect of addition of alum and polymer alone with their variation in concentration and in combination of both and at different concentration of polymer with fixed concentration of alum on the removal of turbidity and organic compound from the raw water.

4.1 Results from first test

4.1.1 Effect of addition of Alum alone & its variation in concentration

The rapid mixing was done for 2 minutes with a speed of 200 RPM and slow mixing was done for 20 minutes with a speed of 50 RPM. Chemical analysis was done after 30 minute. Alum dosing started with 90 mg/L of alum & progressively up to 140 mg/L with an incremental increase of 10 mg/L in each jar. At 90 mg/L of alum addition to the raw water the % removal of turbidity is 64.44% & at 140 mg/L the % removal is 73.88 % (Table 1).

Table 1: Effect of adding Alum alone on turbidity removal

Date		**14/03/2019**					
Stock solutions		**Full strength coagulant**					
	Jar no.	**1**	**2**	**3**	**4**	**5**	**6**
	Sample	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**
Raw water characteristics	Raw water turbidity(NTU)	90	90	90	90	90	90
	Raw water pH	7.63	7.63	7.63	7.63	7.63	7.63
Adding Alum alone	Alum Dosage (PPM)	90	100	110	120	130	140
	Polymer Dosage (PPM)	0	0	0	0	0	0
	Time of flocculation / Settling time	20	20	14	14	13	13
	Flocculation rating / floc size	+	+	++	++	++	+
Chemical analysis of flocculated water after 30minutes	Turbidity	32.0	31.3	29.9	24.1	23.9	23.5
	pH	7.19	7.14	7.10	7.06	7.03	6.99
	% removal of Turbidity	64.44	65.22	66.78	73.22	73.44	73.88

It is seen that increasing the alum dose from 90 to 140 mg/L i.e. increasing the alum dose by 55.55% the percent increase in turbidity removal is only 9.44%. With progressive increase of 10 ppm of alum from 90 to 140 ppm i.e. with increase of alum dose by 11.11%, 22.22 %, 33.33%, 44.44%, & 55.55% the percent increase in turbidity removal are respectively 0.78%, 2.34%, 8.78%, 9.00% & 9.44%.

4.1.2 Effect of addition of Polymer alone & its variation in concentration

Similar six jar test were conducted with only polymer with doses of 1, 2, 3, 4, 5, & 10 ppm of polymer. 0.1% solution of polymer was used as stock solution. At 1 ppm addition of polymer the % removal of turbidity is 22% & at 10 ppm % removal of turbidity is 29.44% (Table 2).

It is seen that progressive increase in polymer dose does not increase turbidity removal rate proportionately yet sometimes decreases than the earlier lesser dose. By increasing polymer dose from 1 ppm to 10 ppm i.e. 10 times increase in polymer dose increase the % removal of turbidity only by 1.33 times.

With progressive increase in polymer dose namely 1, 2, 3, 4,5, & 10 ppm i.e. with increase of polymer dose by 100, 200,300,400, 500 & 1000 percent the percent increase in turbidity removal are respectively (-2.89)%, 5%, 2.11%, (-2.78)%, 2.34% & 5.77%.

It is not unlikely. When anionic organic polymers are used as coagulant aids with inorganic coagulants, dosages in the range of 0.1 to 0.5 ppm are most frequently employed. Dosages from 0.1 to 0.2 are usually sufficient for most waters. On the other hand drastic overdoses have little or no effect on the result. It is reported that good flocculation does not occur if more than 50% of the particle surface is covered by polymer (Cohen et al. 1958).
On the same date another three jar test were conducted with the same raw water with combined doses of alum + polymer respectively as (100+20), (100+0) & (0+ 100) ppm.Addition of 20 ppm of polymer with 100 ppm of alum increases the % removal of turbidity only by 8.22%.

Table 2: Effect of adding Polymer alone on turbidity removal

Date		**14/03/2019**					
Stock solutions		**0.1 % solution of polymers**					
	Jar no.	**1**	**2**	**3**	**4**	**5**	**6**
	Sample	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**	**Raw Water**
Raw water characteristics	Raw water turbidity(NTU)	90	90	90	90	90	90
	Raw water pH	7.63	7.63	7.63	7.63	7.63	7.63
Adding Only polymer	Alum Dosage (PPM)	0	0	0	0	0	0
	Polymer Dosage (PPM)	1	2	3	4	5	10
	Time of flocculation / Settling time	(-)	(-)	(-)	(-)	(-)	(-)
	Flocculation rating / floc size	(-)	(-)	(-)	(-)	(-)	(-)
Chemical analysis of flocculated water after 30minutes	Turbidity	70.2	72.8	68.3	70.8	68.7	63.5
	pH	7.81	7.74	7.75	7.74	7.77	7.74
	% removal of Turbidity	22	19.11	24.11	21.33	23.67	29.44

4.1.3 Effect of pH on raw water turbidity removal with the addition of alum and polymer

Figure 3 shows the effect of alum dose on pH of the raw water & turbidity on pH. It is seen that with the increase in alum dose the pH of the water is gradually decreasing in a linear manner. Similarly with decrease in the turbidity of the water the pH of the water is decreasing. Thus there is more or less a definite straight line decrease pattern observed. But it is obvious that there is no direct influence of water pH on turbidity significantly but there might exist site specific certain insignificant positive correlation with other factors in specific water under testing (Mandal, 2014).

On the other hand with the increase of polymer dose (Figure 4) the pH of the raw water does not decrease or increase with a definite pattern. With the addition of incremental polymer doses the pH first increases then decreases then increases and so on. Similarly decrease in turbidity does not decrease or increase pH in definite pattern.

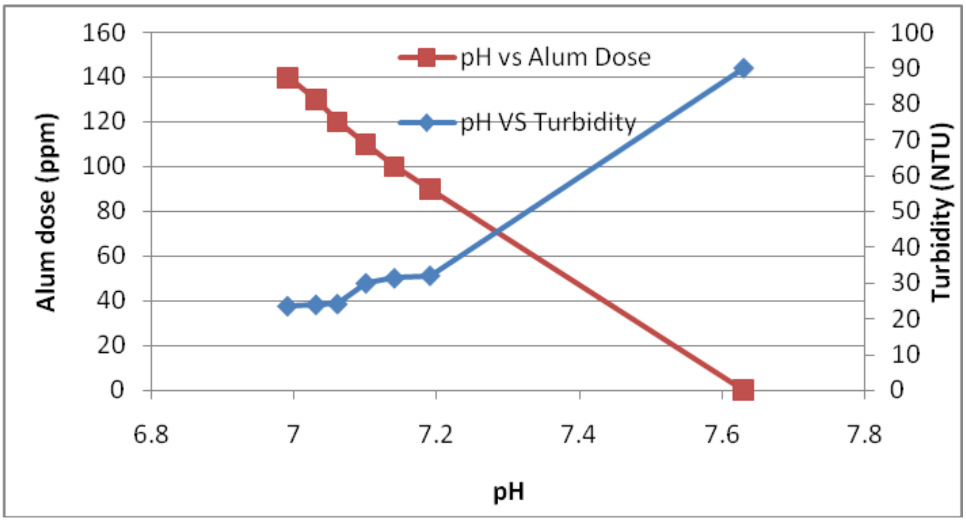

Figure 3: Effect of pH on raw water turbidity removal with the addition of alum

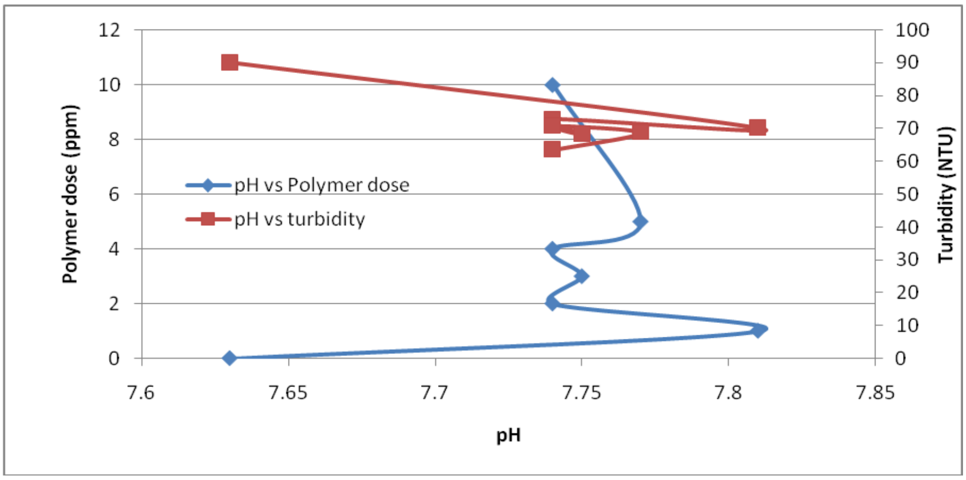

Figure 4: Effect of pH on raw water turbidity removal with the addition of polymer

4.2 Results from second test

The measured turbidity of the raw water sample was 106 NTU. The rapid mixing was done for 2 minutes with a speed of 200 RPM and slow mixing was done for 20 minutes with a speed of 50 RPM. Chemical analysis was done after 30 minutes. The primary findings from the chemical analysis are briefly discussed in the following.

4.2.1 Effect of no chemical addition

It is observed that even with adding nothing to the raw water sample, simple stirring and subsequent natural settlement resulted a turbidity of 75 NTU of the settled raw water from raw water turbidity of 106 NTU that is 29.4% of turbidity removal after 30 minutes (Figure 5).

4.2.2 Effect of addition of Polymer alone & doubling its concentration

Adding only 0.05 mg/L of polymer alone into the raw water gives a resulting turbidity of 65 NTU indicating 38.68% turbidity removals. Doubling the polymer dose that is by adding 0.10 mg/L of polymer alone the resulting turbidity is 64.5 NTU indicating a turbidity reduction of 39.15 %. It is worth noting that by doubling the dose of polymer from 0.05 to 0.10 mg/L the change in turbidity removal is hardly increases lest expecting double reduction in turbidity removal.

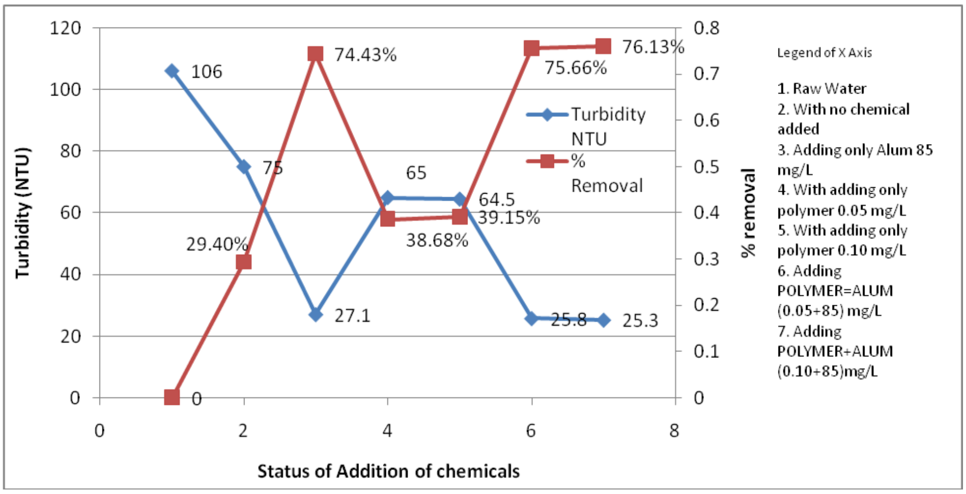

Figure 5: Effect of adding alum & polymer alone and in conjunction in turbidity removal

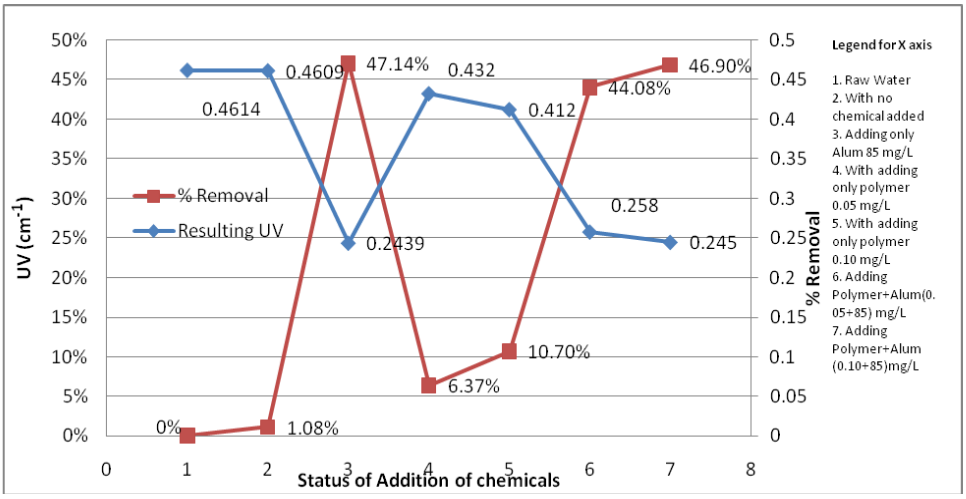

Figure 6: Effect of adding alum & polymer alone and in conjunction in organic carbon removal

It is also apparent from level 4 & 5 (Figures 5 & 6) that adding only alum is more effective than adding only polymer in removing turbidity and organic material for this particular water. It coincides with earlier findings that with an anionic polyelectrolyte (hydrolysed polyacrylamide), although it functioned well as a flocculant aid, no significant turbidity removal was evident without prior aluminium sulphate addition. Dosage of the polyelectrolyte was very critical: excessdosages gave rise to restabilization.

4.2.3 Effect of addition of Alum alone

Adding 85 mg/L of Alum alone into the raw water the resulting turbidity gives a value of 27.1 NTU that is resulting 74.43% of turbidity removal.

It is evident that addition of Alum alone to the raw water is far more effective than adding only polymer in this particular sample of raw water for the removal of turbidity (Figure 5).

4.2.4 Effect of addition of Alum combined with Polymer

The next jar test with 85 mg/L of Alum along with 0.05 mg/L of polymer gives a resulting turbidity of 25.8 NTU that is 75.66% removal of turbidity. Thus keeping Alum dose fixed at 85 mg/L adding 0.05 mg/L of polymer the increase in the % removal of turbidity is only 1.23% which is insignificant (Figure 5).

By doubling the polymer dose that is instead of 0.05 mg/L adding 0.1 mg/L of polymer along with 85 mg/L of Alum as before the resulting turbidity stands to 25.3 NTU indicating 76.13% of turbidity removal. Thus keeping alum dose same at 85 mg/l, doubling the polymer dose from 0.05 to 0.10 mg/ turbidity removal increases only by 0.47% (Figure 5).

It is evident from the jar test result that adding this particular polymer alone or in combination with Alum coagulant, even doubling the dose of polymer did not bring any remarkable changes in the turbidity removal percentage than the result obtained by adding Alum alone to this particular raw water.

4.2.5 Effect in the removal of UV_{254}

Similar result is seen in case of removal of UV_{254}. With 85 mg/L of Alum alone the removal of $UV_{254}$is 47.14% (Figure 6). When 0.05 mg/L polymer is added along with 85 mg/L of Alum the removal is decreased by 3.06% rather than increase. Even adding 0.10 mg/L polymer along with 85 mg/L of Alum removal of UV_{254} stands to 46.90% yet below what is achieved by adding Alum alone (Figure 6).

It is worthy to note that applying 0.1 ppm of polymer alone (When turbidity 106 NTU) we get 39.15% removal of turbidity (Figure 5) whereas applying 10 ppm (100 times higher) of polymer gives 29.44% removal of turbidity (When turbidity is 90 NTU) (Table 2).

Again adding 20 ppm of polymer with 100 ppm of alum gives 73.44% of removal of turbidity where as 0.1 ppm polymer + 85ppm Alum gives 76.13% removal (Turbidity 106NTU).

5. CONCLUSIONS

The organic polymers and inorganic salts alone and in combination were applied to Shitalakshya river raw water in Bangladesh to check their efficiency in reducing in turbidity and TOC, measured in the form UV_{254} as surrogate. It is observed overall that synthesized polymer flocculants can not improve removal efficiency of turbidity and TOC when applied alone or in combination. Progressive increase of polymer dose does not increase the turbidity removal proportionately, yet, sometimes the percentage removal decreases with the increase of polymer doses when applied alone.When polymer is added in addition to alum the increase in turbidity removal efficiency is not remarkable, even by doubling the polymer dose with the fixed alum dose it hardly gives any positive effect.It is evident that addition of Alum alone to the raw water is far more effective than adding only polymer in this particular sample of raw water for the removal of turbidity.

It is worth noting that by doubling the dose of polymer from 0.05 to 0.10 mg/L keeping the alum dose fixed the change in turbidity removal is hardly increases lest expecting double reduction in turbidity removal.In case of organic carbon removal as tested by UV_{254} as surrogate the addition of polymer do not bring any positive result rather it decreases the removal efficiency of UV_{254} than what is achieved by alum alone.The jar test result shows that adding this particular polymer alone or in combination with Alum coagulant, even doubling the dose of polymer did not bring any remarkable changes in the turbidity removal percentage than the result obtained by adding Alum alone to this particular raw water.

6. ACKNOWLEDGEMENTS

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REFERENCES

APHA. (2005). *Standard methods for the examination of water and waste water: 21st edn*. Washington, DC, USA: American Public Health Association.

Bae, Y. H., Kim, H. J., Lee, E. J., Sung, N. C., Lee, S. S., & Kim, Y. H. (2007). Potable water treatment by polyacrylamide base flocculants, coupled with an inorganic coagulant. *Environmental Engineering Research*, 12(1), 21-29.

BCEOM. (1992). *Dhaka emergency water supply project: Feasibility study*. Dhaka: BCEOM.

Begum, D.A. & Ahmmed, K.M.T. (2010, September). Water quality aspects in and around Dhaka city. *Proc. of International Conference on Environmental aspects of Bangladesh*. University of Kitakyushu, Kitakyushu, Japan.

Bolto, B., & Gregory, J. (2007). Organic polyelectrolytes in water treatment. *Water research*, *41*(11), 2301-2324.

Bratby, J. (1980). *Coagulation and flocculation: With an emphasis on water and wastewater treatment*. Uplands: Croydon, England.

Carty, G., O'Leary, G., & Crowe, M. (2002). Water Treatment Manuals: Coagulation, Flocculation and Clarification. *Environmental Protection Agency*, Ireland: Environmental Protection Agency.

Cohen, J. M., Rourke, G. A., & Woodward, R. L. (1958). Natural and synthetic polyelectrolytes as coagulant aids. *Journal (American Water Works Association)*, *50*(4), 463-478.

Department of Environment (DoE). (1997). *Environmental Conservation Rules (ECR)*. Dhaka: Ministry of Environment and Forest. Government of Bangladesh.

DWASA. (1994). *Dhaka WASA IV project: EIA study*. Dhaka: BCEOM.

DWASA.(2007).*Joint feasibility study of pre-treatment for water supply for the Saidabad water treatment plant II, Dhaka, Bangladesh.*Final report. Conducted by Grontmij &Carl Bro.

Edzwald, J. K., Becker, W. C., & Wattier, K. L. (1985). Surrogate parameters for monitoring organic matter and THM precursors. *Journal‐American Water Works Association*, *77*(4), 122-132.

EPA. (2012, June). *Optimisation of Chemical Coagulant Dose in at Water Treatment Works* (*Drinking water advice note no. 15).* Ireland: Environmental Protection Agency.

GoB,& UNDP. (2010). *Pollution abatement strategies for Rivers and wetlands in and around Dhaka City, Bangladesh*. Dhaka: Parliamentary Standing committee on Ministry of Environment & Forests. Government of Bangladesh.

Gregor, J. E., Simpson, S. L., & Andrew, C. (1993). *Health risks of synthetic polymers and monomers, and methods of monitoring and control*. Institute of Environmental Health and Forensic Sciences.

Kim, C., Eom, J., Jung, S., & Ji, T. (2016). Detection of organic compounds in water by an optical absorbance method. *Sensors*, 16(1), 61.

Lee, J. F., Liao, P. M., & Wen, P. T. (1998). Behavior of organic polymers in drinking water purification. *Chemosphere*, 37(6), 1045-1061.

Lee, S. H.,Shin,M. C.,Choi,S. J., Shin, J. H.,& Park, L. S. (1998). Improvement of flocculation efficiency of water treatment by using polymer flocculants.*Environmental Technology*, 19(4), 431-436.

Letterman, R. D., & Pero, R. W. (1990). Contaminants in polyelectrolytes used in water treatment. *Journal‐American Water Works Association*, *82*(11), 87-97.

Mahvi, A. H., & Razavi, M. (2005). Application of polyelectrolyte in turbidity removal from surface water.*American Journal of Applied Sciences*. 2(1), 397-399.

Mandal, H. K. (2014). Influence of wastewater pH on turbidity. *Int. J. Environ. Res. Dev*, *4*(2), 105-114.

New Zealand Water & Wastes Association (NZWWA). (1999). *Standard for the supply of polyacrylamides for use in drinking water treatment: First Edition*, Retrieved from https://www.waternz.org.nz/

Quayle, W. C., Fattore, A., Zandona, R., Christen, E. W., & Arienzo, M. (2009). Evaluation of organic matter concentration in winery wastewater: a case study from Australia. *Water Science and Technology*, *60*(10), 2521-2528.

Rahman, D., & Hadiuzzaman, M. (2005). *Pollution status and trends in water quality of the Shitalakhya and Balu Rivers*. Master’s thesis. Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

Sania, M., Nawshad, H., & Lutfur, R.(2012). A study on the industrial River pollution in DEMDP area and planning approaches.*The Jahangir nagar review, Part II: Social Science*. XXXIII. 259 – 270.

Serajuddin, M. (2009, March). Issues and challenges of water supply for a safer megacity - Perspective Dhaka.*Proceedings of the national seminar on engineers role in developing a safer megacity*, Dhaka, 2009. The Institution of Engineers, Bangladesh (IEB), 37 – 48.

Serajuddin, M., Chowdhury, M. A. I., & Ferdous, T. (2018). Correlation among some global parameters describing organic pollutants in River water: A case study.*International Journal of Research- Granthaalayah*. 6(7), 278-289.

SNF. (2002). *Handbook: For drinking water*.

STATISTICAL AND GIS BASED ANALYSIS OF PHYSICOCHEMICAL PARAMETERS OF GROUND WATER SAMPLES AROUND RAJBANDH DUMPING SITE

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ABSTRACT

Khulna is the 3rd largest metropolitan industrial and port city in Bangladesh. The enhancement of business and financial activities resulted in a sharp increase in city population. Therefore, the amount of municipal solid waste (MSW) generation has increased with population. A pilot scale sanitary landfill and an open dumped site are situated at Rajbandh, Khulna. Groundwater samples were collected from tube-wells from Rajbandh, Khulna dumping site as well as its adjoining area to find out the concentration of different water quality parameters. In the laboratory, nine different water quality parameters such as pH, E.C, TDS, Cl^-, NO_3^-, turbidity, alkalinity, Mn and Fe were measured through standard test methods. In order to establish the relationship between physicochemical parameters to predict the intensity of one parameter with respect to another for a particular location, statistical analysis has been done by Microsoft Excel. It includes correlation coefficient, t-test, and regression analysis. Methodical calculation of correlation co-efficient between water quality parameters has been done. Regression equations also established. This is because of to find out the strength and the linear relationship between different pairs of parameters as well as to predict the level of pollution of groundwater. The significance level further verified by t-test. The water samples were collected and analyzed from four distinct locations. In this study an appreciable strong positive correlation was found for E.C with turbidity, alkalinity; turbidity with alkalinity also for chloride with TDS. A strong negative correlation was found for pH with turbidity, alkalinity, E.C. All the physicochemical parameters of respective groundwater were within limit set by ECR (1997). The water quality index (WQI) was used to analyze the groundwater quality of study site. The water quality parameters such as pH, E.C, TDS, C^{l-}, NO_3^-, turbidity, alkalinity, Mn, and Fe were used which were collected from four different locations since a period of 2018. The test result reveals that 50% water samples were found poor quality and 50% samples were found unsuitable for drinking purposes. The WQI ranges from 72.998 to 164.332. Further, the WQI at different locations were analyzed with respect to variation in space using spline curve technique using ArcGIS 10.5 software. Therefore, there is a need of some treatment before usage of water and also require to protect the area from landfill contamination.

Keywords: *Statistical analysis, Groundwater, ArcGIS, Physicochemical parameters, WQI.*

1. INTRODUCTION

Municipal solid waste (MSW) disposal in the surrounding environment has increased a large amount due to rapid urbanization and industrialization. Disposal of solid waste and sewage, urban runoff, agricultural activities and polluted surface water are major contributors to deteriorate urban groundwater resources (Jain et al., 1995). Groundwater are used for domestic and agricultural purposes. According to WHO organization, about 80% of all the diseases in human beings are caused by water. The water quality may be described by its physicochemical and micro-biological parameters. The quality is a function of the physical, chemical and biological parameters, and could be subjective, since it depends on a particular intended use (Tatawat et.al, 2008). Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from (Ramakrishnaiah et.al, 2009) the source. So, continuously water quality monitoring is very much necessary. The modeling, arrangement and explanation of checking data are the most important steps in the appreciation of water quality. Generally, water quality parameters are interacting with each other. Although laboratory facilities and sufficient manpower, regularly checking all the parameters is very much challenging tasks. Generally, the laboratory methods are time consuming and very much costly so, some methods can develop which will provide easy, reliable and cost effective methods to collect data and provide information of the level of pollution by different parameters(Agarwal et.al, 2011). For this reason, in recent years a very simple method track based on statistical correlation has been developed using mathematical relationship for comparison of physicochemical parameters (Kaur et.al, 2011). Uncertainty range reduces by the study of correlation. Further, correlation coefficients have been tested by using t-test to determine the significance.

Khulna, Rajbandh zone was selected because city corporation solid waste is dumped in that area. So, it can be said that groundwater can normally be polluted in that area and people get affected by ingestion though people drink water from deep tube-well. For this study, four locations namely Hogladanga landfill (location 1), Joykhali landfill (location 2), Progoti Secondary School, Hogladanga (location 3), R.S.O Hasari and Culture station (location 4) were selected.

Statistical studies have been done on different pairs of parameters to find out the correlation coefficient and then regression equations were established to understand the limit of pollution level by parameters. Further t-test was applied for checking significance. Now a day's software- based analysis for the assessment of groundwater quality is increasing. Different types of software are used for groundwater modelling as well as groundwater quality assessment for examples Modflow, Phreeqe, MT3D, GIS etc. To determine the water quality, these software -based study is followed to compare the numerical or analytical based study. So, there are several techniques used to determine groundwater contamination or water quality assessment which is caused by landfill.

2. MATERIALS AND METHODS

2.1 Study area

Khulna Rajbandh location was selected for this study. It is 8 km far from the city center. Groundwaters were collected from tube-wells from 4 locations around landfill site.

Location:
Latitude: 22º47'43.17''
Longitude: 89º29'58.35"

Figure 1: Selected study area at Rajbandh from google earth

2.2 Analytical method

The groundwater samples were immediately transferred to the laboratory and stored in Refrigerator. The analysis was started without any delay in the lab based on APHA (1999) methods. In case of physicochemical parameters includes pH was measured by pH meter, Electrical Conductivity (EC) was measured by EC meter, turbidity was measured by Turbidimeter. On the other hand, Chloride, alkalinity was tested by titration. TDS was tested by gravimetric method.NO_3^-, Fe, Mn were tested by Spectrophotometer.

2.3 Statistical analysis

The correlation between various physicochemical parameters of water samples were analyzed statically conducting Pearson correlation through Microsoft Excel by equation (1).

Coefficient of correlation (r):

$$r = \frac{n\left(\sum xy\right) - \sum x * \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right] * \left[n\sum y^2 - \left(\sum y\right)^2\right]}} \quad (1)$$

where,

x = Individual reading of 1st parameter
y = Individual reading of 2nd parameter
n = number of values of single parameter

The correlation among the different parameters will be true when the value of correlation coefficient (r) is high and approaching to one (Joshi et.al, 2009). Correlation, the relationship between two variables, is closely related to prediction. The greater the association between variables, more accurately can predict the outcome of events (Kaur et.al, 2011).

2.4 t-test

For checking the significance t-test was conducted and the formula is given below by equation (2):

$$t = \frac{\left|\overline{x1} - \overline{x2}\right|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (2)$$

where,

$\bar{x}1$ = average value of 1st parameter
$\bar{x}_2$ = average value of 2nd parameter
n_1 = number of reading of 1st parameter
n_2 = number of reading of 2nd parameter
s_1 = standard deviation of 1st parameter

s_2 = standard deviation of 2nd parameter

In case of standard deviation, the formula is given below by equation (3):

$$S = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} \quad (3)$$

After finding the t value it was checked by the critical value from t-table provided by (Pearson et.al, 1966). The table 1 is shown below.

Table 1: Critical values of the t distribution

df	One-Tail = .4 Two-Tail = .8	0.25 0.5	0.1 0.2	0.05 0.1	0.025 0.05	0.01 0.02	0.005 0.01	0.0025 0.005	0.001 0.002
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	22.327
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.214
4	0.271	0.741	1.5333	2.132	2.776	3.747	4.604	5.598	7.173
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707	4.317	5.208
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.029	4.785
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501
9	0.261	0.703	1.383	1.833	22.262	2.821	3.250	3.690	4.297

I Considered p level at p = 0.05 (5%), which means 95% confident. Also considered two tailed tests.

> If calculated t value < critical t value, then accept null hypothesis (H_0)
> If calculated t value > critical t value, then reject null hypothesis (H_0)

Where null hypothesis means there is no significant difference and $t > t_c$ this would mean there is a significant difference.

2.5 Regression analysis

Regression analysis is a set of statistical methods for estimating the relationships among variables. It measures the nature and extent of correlation and predicts the unknown values of one variable from known values of another variable (Agarwal et.al, 2011). The regression equation (4) is shown below

$$y = a + bx \quad (4)$$

where a is called y axis intercept and b is the slope of regression line. Now a and b can be expressed by the following equations (5) & (6).

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} \quad (5)$$

and $a = \bar{y} - b\bar{x}$ (6)

2.6 Drinking water quality index (DWQI)

Water quality assessment was carried out using WQI, which is widely used for evaluating drinking water quality. The WQI was initially invented by Brown et.al (1970) and then modified by Backman et.al (1998). According to the reports by the "World Health Organization (WHO)" in 2004, using

WQI would help to clarify combinatorial effect of each parameters as well as all qualitative parameters on drinking water quality (Abbasnia et.al, 2018). Each of the parameters has been assigned according to its relative importance in the overall quality of water for drinking purposes. The relative weight was computed using the following equation (7):

$$Wi = \sum \frac{wi}{\sum_{i=1}^{n} wi} \tag{7}$$

Where,
Wi = relative weight of each parameter
wi = weight of each parameter
n = number of parameters

For each parameter, the quality rating scale was calculated by dividing its concentration in each water sample to its respective standards (released by World Health Organization 2011) (Edition 2011) and finally multiplied the results by 100 through equation (8).

$$qi = \left(\frac{Ci}{Si}\right) x\ 100 \tag{8}$$

Where,
qi = the quality rating
Ci = concentration of each parameter (mg/L)
Si = standard limit (mg/L) according to WHO released in 2011

The quality of water is calagorized into five types which is shown in table 2

For computing of sub index of each parameter, weight (Wi) of each parameter is needed which is shown in table 3.

Table 2: Rating of water quality index (Tyagis et.al, 2013)

WQI value	Rating of water quality	Grating
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purposes	E

Table 3: The weight (wi) and WHO standard values for drinking water

Parameters	Concentration (mg/L) (Ci)	WHO (mg/L) (Si)	weight (wi)
pH	7.64	6.5-8.5	4
E.C	1102	750	4
TDS	1280	500	4
Cl-	600	250	3
NO3-	0.15	10	5
turbidity	3.01	4	3
alkalinity	260	300	3
Mn	0.1	0.1	4
Fe	0.32	0.3	4
		Sum =	34

In the final stage of WQI computing the SIi was first determined for each parameter and then the sum of SIi values gave the WQI for each sample shown in equations (9) &(10)

$$SIi = Wi \times qi \tag{9}$$

Where, SIi is the sub-index of each parameter

$$WQI = \sum_{i=1}^{n} SIi \tag{10}$$

Where, WQI is the water quality index

3. RESULTS AND DISCUSSION

At first the concentration of water quality parameters was determined in the laboratory and compared with allowable limit referred by ECR (1997) for groundwater sample. The data are shown in Table 4.

Table 4: Values of physicochemical parameters with Bangladesh standard

Items	pH	Chloride (mg/L)	E.C (μs/cm)	Turbidity (NTU)	TDS (mg/L)	alkalinity (mg/L)
Location 1	7.2	420	1400	4.44	860	295
Location 2	7.6	230	538	2.11	486	255
Location 3	7.64	600	1102	3.01	1280	260
Location 4	7.82	500	800	1.95	980	225
Sum	30.26	1750	3840	11.51	3606	1035
average (X)	7.565	437.5	960	2.8775	901.5	258.75
Standard deviation (S)	0.261	156.710	373.0273	1.1413	328.5254	28.686
Variance	0.068	24558.333	139149.3	1.3027	107929	822.916
n	4	4	4	4	4	4
BD standard	6.5-8.5	150-600(mg/L)	-μs/cm	10 NTU	1000 (mg/L)	200 (mg/L)

The above value shows pH are within allowable limit, chlorides are also within allowable limit, but in case of Bangladesh some region above 250mg/L amount of chloride creates salty tastes in drinking water. Due to moderate amount of chloride present in water EC shows high values and there is no Bangladesh standard limit in this case. Turbidity values are within limit. Drinking natural alkaline water is generally considered safe, since it contains natural minerals. Alkalinity acts as a buffer.

For the calculation of correlation coefficient and t-test, some calculation has already shown above table. Different pairs of water quality parameters with significant correlation coefficients are given in Table 5.

Table 5: correlation between different pairs of parameters and t-test results

SL No	Pairs of Parameters	correlation	t test	Significant or not significant ($p<0.05$)
1	pH & Cl-	0.2216	5.4869	Significant
2	pH & E.C-	-0.7024	5.1065	Significant
3	pH & Turbidity	-0.9201	8.0063	Significant
4	pH & Alkalinity	-0.9721	17.5117	Significant
5	pH & TDS	0.1901	5.4421	Significant
6	Cl- &E.C	0.5299	2.5827	Significant
7	Cl- &Turbidity	0.1779	5.5467	Significant
8	Cl- & Alkalinity	-0.1306	2.2439	Not Significant
9	Cl- & TDS	0.9929	2.5495	Significant
10	E.C & Turbidity	0.9227	5.1316	Significant
11	E.C & Alkalinity	0.7198	3.7487	Significant
12	E.C & TDS	0.5392	0.2354	Not significant
13	Turbidity & Alkalinity	0.9263	17.8251	Significant
14	turbidity & TDS	0.2056	5.4706	Significant
15	alkalinity & TDS	-0.0750	3.8981	Significant

In the present study, pH has strong significant negative correlation with E.C (r = -0.7024, t = 5.1065), turbidity (r = -0.9201, t = 8.0063). The chloride has weak negative correlation with alkalinity (r = -0.1306, t = 2.2439); weak correlation for alkalinity with TDS (r = -0.0750, t = 3.8981) also pH has strong negative correlation with alkalinity (r = -0.9721, t = 17.5117). This shows that with any increase or decrease in the values of pH; electrical conductivity (E.C), turbidity, alkalinity exhibit decreases or increase in their values.

EC shows significant strong positive correlation with turbidity (r = 0.9227, t = 5.1316), alkalinity (r = 0.7198, t = 3.7487) also for chloride with TDS (r = 0.9929, t = 2.5494). Turbidity shows significant strong positive correlation with alkalinity (r = 0.9263, t = 17.8251). Chloride has moderate positive correlation with E.C (r = 0.5299, t = 2.5827) also has weak positive correlation with turbidity (r = 0.1779, t = 5.5467).E.C has moderate positive correlation with TDS (r = 0.5393, t = 0.2354). pH shows weak positive correlation with chloride (r = 0.2216, t = 5.4869) also for pH with TDS (r = 0.1901, t = 5.4421); for turbidity with TDS (r = 0.2056, t = 5.4706). The result of calculated correlation coefficient using equation further checked by MS Excel using CORREL function. Figure 2 represent strong positive correlation between alkalinity and turbidity. Regression equation also shows in the graph. R^2 (coefficient of determination) reveals that 86% in the variation of turbidity is due to variation of alkalinity.

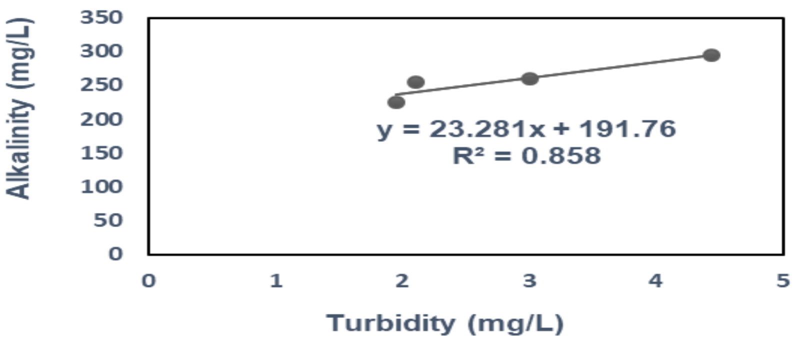

Figure 2: Correlation between alkalinity and turbidity

Figure 3 represents strong negative correlation between alkalinity and pH. Regression equation of pH also shows in this graph. The intercept (expected mean) value is 1065.6 and slope is -106.66. For any value of pH the value of alkalinity can forecast.

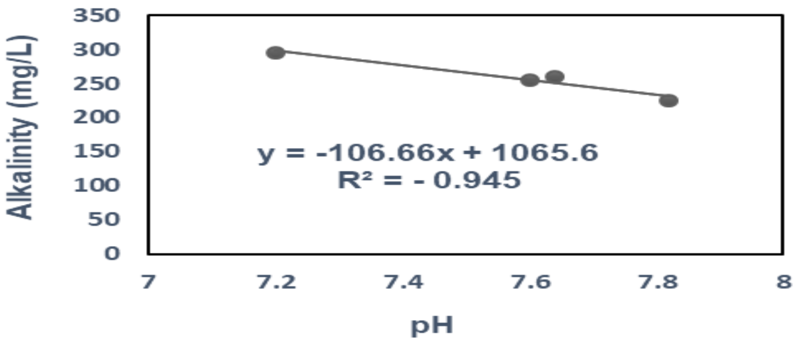

Figure 3: Correlation between alkalinity and pH

Figure 4 represents strong positive correlation between TDS and chloride. Regression equation of chloride also shows in this graph. The intercept value is -9.1591 and slope is 2.081. For any value of chloride, the value of TDS can forecast without laboratory test. If the independent variables can't all equal zero, or one get an impossible negative y-intercept, don't interpret the value of the y-intercept! The developed equations can further apply to predict the approximate value of one variable with respect to another which is a time saving process.

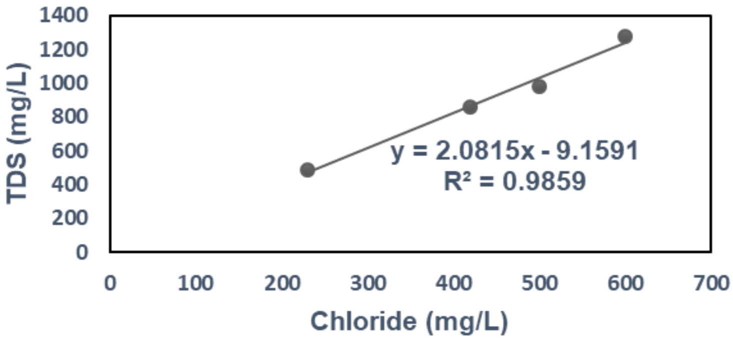

Figure 4: Correlation between TDS and Chloride

Now it is necessary to calculate the degrees of freedom and go to the t-table 1 to determine if the t-test is significant at $p < 0.05$. The degree of freedom in this study was (4+4-2) = 6 and for 5% p value and for two tailed test the critical t value was 2.447.

So, the t-test result indicating a 95% probability of a significant difference between pH with chloride, electrical conductivity (E.C), turbidity, alkalinity. Also, a 95% probability of a significant difference between electrical conductivity with turbidity, alkalinity; turbidity with alkalinity; chloride with E.C, turbidity. But in case of chloride and alkalinity null hypothesis means there is no significant difference shows.

Table 6: Results of WQI for location 1

Parameters	Concentration (mg/L) (Ci)	WHO (mg/L) (Si)	weight (wi)	relative weight(Wi)	qi = (Ci/Si)*100	SIi = Wi*qi
pH	7.2	6.5-8.5	4	0.117647	96	11.29412
E.C	1400	750	4	0.117647	186.66	21.96
TDS	860	500	4	0.117647	172	20.23529
Cl-	420	250	3	0.088235	168	14.82353
NO3-	0.2	10	5	0.147059	2	0.294118
turbidity	4.44	4	3	0.088235	111	9.794118
alkalinity	295	300	3	0.088235	98.33	8.676176
Mn	0.5	0.1	4	0.117647	500	58.82353
Fe	0.47	0.3	4	0.117647	156.66	18.43059
		Sum =	34		WQI =	164.3315

As the required WQI exceeds value of 100, so it is said that the water quality in this location is not suitable for drinking purposes and grating as E (Table 2).

The value of WQI was found 72.99 reveals in the ranges of 76 to 100, so the water quality is very poor for location 2 and grating as D. In addition, the value of WQI exceeding 100 (119.38) for location 3 and the water quality is not suitable for drinking purposes and the grating is as E. And finally, for location IV the value is 80.08 which is between the range of 76 to 100 that means water quality is very poor of this location and grating as D.

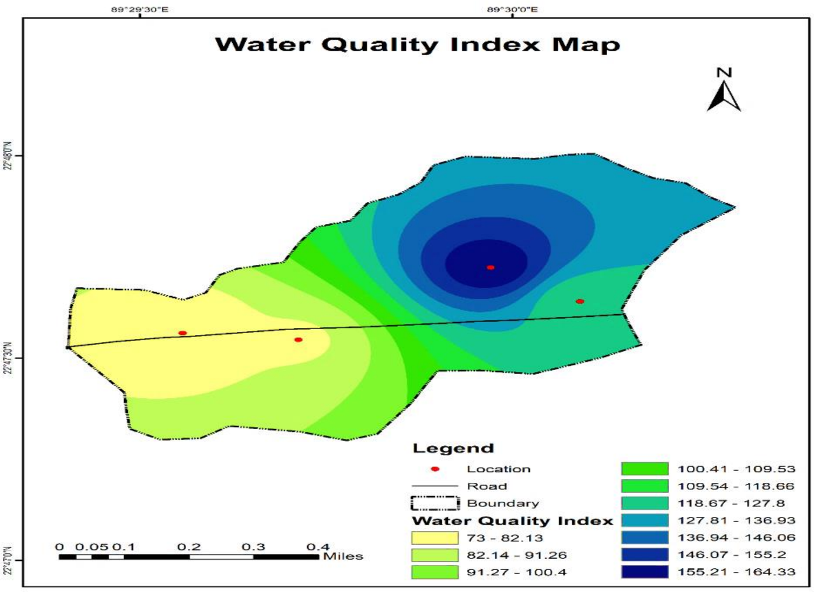

Figure 5: Spatial variation of water quality index by ArcGIS

The graph represents the spatial variation of WQI around Rajbandh dumping site. Low WQI value less than 50, represent good quality water. The yellow to green sign indicates the location of poor to very poor water quality, on the other hand, the blue to deep blue sign indicates lager WQI values unsuitable water quality for drinking purposes because it is location of landfill. So, graph mainly represents WQI reduces from landfill to surrounding locations because at landfill location groundwater quality somehow affect by solid waste.

4. CONCLUSIONS

Generally, groundwater is an important source for drinking purposes. Usually use of correlation coefficient (a value between -1 and 1) to display how strongly two variables are related to each other. A comprehensible negative correlation was found for pH with electrical conductivity (E.C), turbidity, alkalinity. A significant positive correlation was found for E.C with turbidity, alkalinity and for turbidity with alkalinity. The obtained values of correlation coefficients and their significance levels which was tested by t-test will help in selecting the precise treatments to reduce the contamination of groundwater around Rajbandh dumping site. Regression analysis also determined. The developed equations further can be used to findout the value of one parameter with respect to another if time is limited or budget is shorted. The above analysis is also cost effective and time saving because statistical equations used for calculating the value of physicochemical parameters and to measure the limit of pollution in groundwater around Rajbandh so that some preventive measure can take before the detailed observation. The average data of at least two years as well as by considering seasonal variation could bring more accurate analysis.WQI was used to analyze the underground water quality of study site.The test result reveals that 50% water samples were found poor quality and 50% water samples were found unsuitable for drinking purposes. Also, GIS based Graph showed WQI reduced from landfill to surrounding locations.So, it can be said that overall the groundwater quality of most of the locations were not suitable for drinking purposes or need to be treated. The results support the need for continuous monitoring of the groundwater.

REFERENCES

Abbasnia, A., Yousefi, N., Mahyi, A. H., Nabizadeh, R., Radfard, m., Yousefi, M & Alimohammadi, M. (2018). Evaluation of groundwater and its suitability for assessing water for drinking and irrigation purposes: Case study of Sistan and Baluchistan province (Iran). An International Journal of Human and Ecological Risk Assessment

Agarwal, A., & Saxena, M. (2011). Assessment of pollution by Physicochemical Water Parameters Using Regression Analysis : A Case Study of Gagan River at Moradabad- India, 2(2), 185–189.

Agrawal, N. (2009). Statistical anlysis of physicochemical parameters of water of river of river Ganga in Haridwar district,Vol. 2, No. 3, 579–587.

APHA (1999). Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Water Environment Federation.

Jain, C., K. Bhatia and T. Vijay, (1995). Ground water quality monitoring and evaluation in and around Kakinada Andhra Pradesh. Technical Report, CS (AR)172, National Institute of Hydrology, Roorkee.

Kaur, R., & Singh, R. V. (2011). Correlation Analysis of Groundwater Quality of Bichhwal Industrial Area, Bikaner, Chemical, Environmental and Pharmaceutical Research, Vol. 2, No.2-3, 146-151.

Pearson, E.S., & Hartley, H.O (1966). Biometrika Tables for Statisticians, Vol 1, third edition, P. 146.

Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk , Karnataka State , India, 6(2), 523–530.

Tatawat, R. K., & Chandel, C. P. S. (2008). A hydrochemical profile for assessing the groundwater quality of Jaipur City, 337–338, DOI 10.1007/s10661-007-9936-3.

MUNICIPAL WASTEWATER TREATMENT USING NATURAL ADSORBENT IN RAJSHAHI CITY CORPORATION

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ABSTRACT

Water is one of the most important components involved in the creation and development of healthy life. As the demand for safe water is increased but the water resources are limited, there is a growing awareness to treat the wastewater and make more efficient use of the wastewater. The conventional methods for treating wastewater are expensive. Consequently, the search for contrarily but effective, efficient and economic methods has been prime concern in recent times. Thus, the use of biomaterials, such as agricultural waste as adsorbents for organic and metal ions is being exploited due to their availability and low cost. Filtration is one of the simplest and low cost treatment technology based on the principle of attached growth process. Multimedia filters represent a significant improvement over single media filters. A multimedia filter model was developed by plastic bottle for treatment of wastewater. Different packing media such as Activated carbon, Rice husk, and Sand are used. The wastewater samples were physically and chemically characterized before and after treatment according to standard procedure using these adsorbents. The obtained results after treatment shows an appreciable improvement on the quality of the water. The pH value changed upto 2.63%, the colour changed from soapy and cloudy to colourless, conductivity, turbidity was reduced upto12.43% and 85.70%, respectively, while the chemical oxygen demand (COD) was reduced upto 80%. The significant removal of suspended solids and dissolve solids was upto 47.06% and 47.88%, respectively. This study intense to provide an overall vision of multimedia filter technology an alternative of conventional method for treating wastewater. Treated wastewater can be reused for various purposes such as irrigation, toilet flushing, car washing, gardening, firefighting, etc.

Keywords: *Wastewater, Adsorbents, Multimedia filter, Activated carbon, Rice husk.*

1. INTRODUCTION

Nowadays, water pollution is one of the major problems in the world. In Bangladesh, major problem leading to water pollution is increasing population, industrialization and urbanization (Hasan et.al., 2019). Collection, treatment and disposal of domestic and industrial wastewater are the significant issues to be handled for preventing damage to the environment. Discharge of untreated sewage is the most important reason for pollution of surface and ground water in Bangladesh. Besides that, the purpose of wastewater treatment is to remove pollutants that can harm the aquatic environment if they are discharged into it. Wastewater generated in urban areas normally treated in the treatment plant includes the processes like primary sedimentation, aeration, secondary treatment and chlorination. The arrangement for this treatment plants requires high cost and large land area. About 50 percent of used water is being lost each year (US EPA, 2018).

Water is a vital part of environment which is polluted by indiscriminate dumping of Municipal wastewater in the natural water bodies. To dispose this huge daily produced wastewater safely into the environment, an affordable technology should be introduced. Again for irrigation, large amount of water is pumped throughout the year which continuously lowering the ground water table. So to satisfy the environmental condition and economic restraints, low cost natural adsorbent filter media is used to treat the wastewater. This treated water is testified to checks weather it can be used for irrigation water resources or not.

Wastewater treatment may include mechanical, biological, and physical-chemical methods (Crini&Lichtfouse,2019). Selection of suitable treatment method depends on the types of pollutant available in raw wastewater. One wastewater treatment using physiochemical methods is adsorption, which has the advantages of being fast, cheap, and universal for removing organic pollutants from water. For removing variety of pollutants from water, different low-cost materials are used as adsorbents, including agricultural products, industrial wastes, and activated carbon.

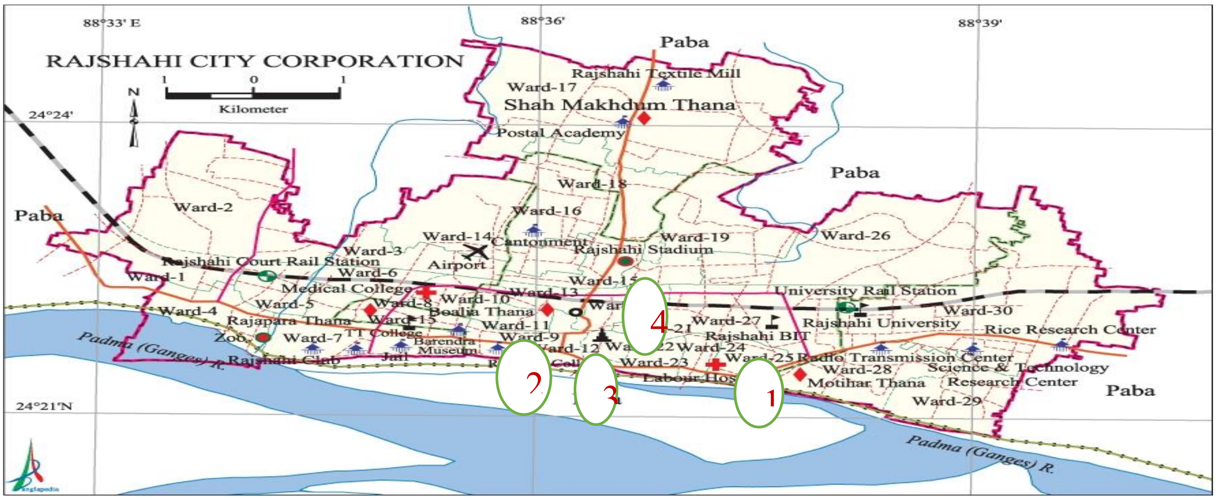
Filtration is one of the oldest and simplest methods of removing contaminants. Generally, filtration methods is known as sand filtration. Sand filtration is suitable for low turbidity and suspended solid of water. But for water contain high turbidity and suspended solid, multimedia filtration is more suitable. For characterization of municipal wastewater, many researchers had done their experiment on wastewater. For example, Sagara (2000) has done a recharge on filtration for point of use drinking water treatment in Nepal. His research was focused on turbidity and microbial removal efficiencies. For this treatment, he has used three filter or purification systems such as Nepalese ceramic candle filter and IPI purifier (Junko Sagara, 2000). His research showed that the turbidity removal efficiency of multifilter media was very high. Priyadarsini (2013) has conducted a study on development of low cost water purification technique. In this study, the turbidity and iron of wastewater were characterized and different materials were used to purify the wastewater to find the low cost water purification technique (Priyadarsini, 2013). The removal of iron content was 5.785 to 0.299 ppm and turbidity was 13.5 to 5.3 when ceramic filter was used. She also used activated carbon, wood charcoal, plain sand and ash of banana leaf as adsorbent for making the filter unit. Ratnoji and Singh (2014) have done a research on coconut shell- activated carbon for filtration and its comparison with sand filtration. They have done this research on the reduction and removal of iron, turbidity, biochemical oxygen demand (BOD) (Ratnoji & Singh, 2014). Shilpa S. Ratnoji and Nimisha singh used coconut shell and activated carbon as adsorbent and removal efficiency of COD was found 53%. Mathias Osterdahl (2015) has done a research on slow sand filters purification rates in rural areas in Colombia. In this study, the characteristics such as alkalinity, color, pH, turbidity, nitrate, nitrite, phosphate, coliforms and Escherichia coli are analyzed (Osterdahl, 2015). Study result shows that, the percentages removal of turbidity, color, alkalinity, nitrite, nitrate, phosphate were 86%, 0%, +2.8%, 0%, 0%, and 72% respectively. Grace et. al. (2016) has done a research on development of filtration technologies for an alternative filtration configuration, harnessing the adsorption potential of industrial waste products and natural media. The study was focused on the variety of contaminants such as aluminium, ammonium, nitrate, turbidity and total organic carbon (TOC), (Graceet. al., 2016). This study developed an effective, cost efficient and robust filtration technologies for water treatment, where the percentage removal of aluminium, TOC and ammonium was about 97%, 71% and 88%. Emara, et. al. (2016) have done a research on phsico-chemical studies for boiler water treatment and its impact on the quality of final industrial product. In this study, wastewater was characterized on turbidity, hardness, total dissolved solid, alkalinity, organic matters, silica and pH (Emara, et al., 2016). The study result shows the removal of turbidity, hardness, total dissolved solid, alkalinity, organic matters and silica was 0.72 to 0, 164 to 0, 396 to 20, 146 to 22.3, 2 to 0, and 7.5 to 1.5 respectively. The removal efficiency for the used multimedia filter is upto 85.70% for turbidity, 80% for COD and 68.75% for organic content which can be considered as advance removal efficiency as used filter media was made of sand, activated carbon and rice husk which layer thickness was too much small.

The above studies showed significant performances of granular media as adsorbent materials in filtration technology. However, the performance of multimedia filter is much better than filter unit containing single filter media. In addition, a few studies was conducted to evaluate the efficiency of multimedia systems which can be improved by optimizing the process parameters such as filter media types, contact time, wastewater loading rate etc. Hence, the main objective of this study is to design the low-cost multimedia filter model using low-cost natural adsorbents so that most of the pollutants can be removed from wastewater. The multimedia filter is also cost effective and environment friendly which can be easily constructed and implemented for wastewater treatment. The multimedia filtration system can be integrated with wastewater treatment plant for removal of objectionable pollutants. Treated wastewater can be reused for various purposes such as irrigation, toilet flushing, car washing, gardening, firefighting, etc.

2. METHODOLOGY

2.1 Study Area Selection

The study area was selected at four different locations in Rajshahi City. These locations are Fultola Drain, Dorgapara Drain, Padma Garden Drain and Shuvo petrol Pump Drain as shown in Figure 1. The source of wastewater in these drains are mainly storm water runoff from road surfaces.



Fultola[1] Dorgapara[2] Padma Garden[3] Shuvo Petrol Pump[4]

Figure 1: Locations of study site.

2.2 Sample Collection and Preservation

Wastewater samples were collected from selected four drains. The sample collection was carried out about eight weeks between the periods of April-May in the year of 2019.At each location, random sample collection frequency was five times. Accordingly, a total of 20 samples were collected from four drains within eight weeks. The wastewater samples were collected according to the EPA (1992) guideline. The collected sample details such as time, date, location were properly leveled for future identification. The samples were kept in a refrigerator at a temperature of 0-4°C to conduct the filtration, physical and chemical parameters test.

2.3 Laboratory Testing

The physical parameters such as pH, Electrical conductivity, turbidity etc. were tested instantly in the Environmental Engineering laboratory, RUET to get the accurate results at room temperature. The chemical parameters such as COD, Acidity, etc. were also measured in the laboratory.

2.4 Design and Construction of the Multimedia Filtration System

2.4.1 Materials

The multimedia filtration system was designed and constructed using following materials.

1. Plastic bottle is used as filter's unit body. The length of the bottle was 25 cm containing top diameter of 7.5 cm, middle diameter of 6 cm and bottom diameter of 7.5 cm.

2. Absorbent media's

- Fine sand for screening purpose
- Rice husk
- Activated carbon

The three types of filter media's are shown in Figure 2.The size of the filter media's varies from 0.1 mm to 1.4 mm.

a b c

Figure 2: Filter media's (a) Rice Husk (b) Activated Carbon (c) Sand

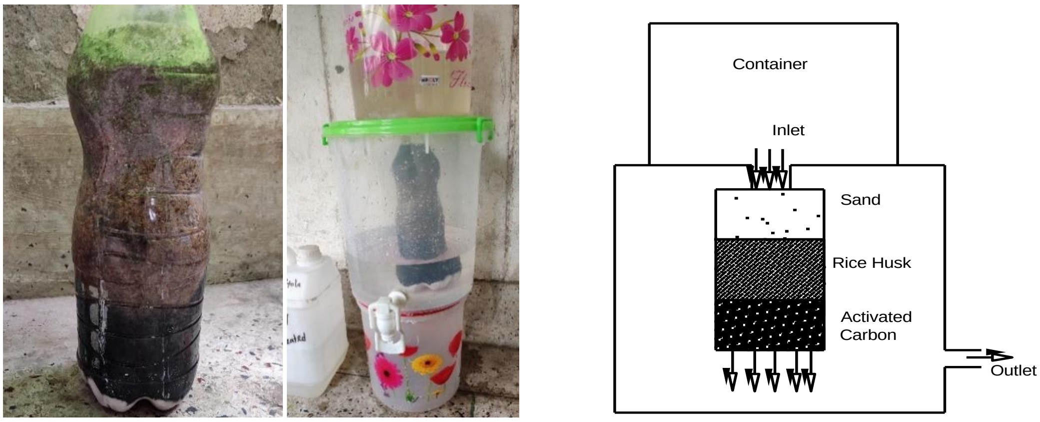
2.4.2 Construction Procedure

The lab scale multimedia filtration system was constructed, using a 1000mL plastic bottle. The cork and bottom of the bottle was drilled to a diameter of 2.2mm. Then filtration materials were placed into three different layers and each layer thickness was 80 mm. These three layers are arranged and placed in order as follows:

1. The first layer was fine sand. The size of the fine sand varies from 0.8 to 1.1 mm and layer thickness was 80 mm.
2. Rice husk is the second layer that is placed below the fine sand. The size of rice husk varies from 0.1 to 1.4 mm and the thickness of the layer is 80 mm.
3. Activated carbon is the last layer and placed at the bottom of the bottle below the rice husk layer. The thickness of rice husk is 80 mm.

For the protection of filtering media from drain out during filtration, a 25mm thickness of cotton was used after the activated carbon layer of the bottle.

The filtration system and arrangement of filter media's are presented in Figure 3.



(a) **(b)** **(c)**

Figure 3: (a) Arrangement of filter media (b) filtration system (c) Line diagram of laboratory arrangement

3. RESULTS AND DISCUSSION

The selected adsorbent media's such as sand, rice husk and activated carbon was found to be more effective in improving the physical and chemical parameters of wastewater (Bryant et. al., 2015). This filter media also assist in removing of COD, TSS, TDS,OC, EC, turbidity and also improve pH quality of the treatment water. Hence, these results prove that adsorbent filter media can be more efficient in removing of impurities and make the water suitable for natural discharge and irrigation purposes. The collected samples were filtered through multimedia filtration system and tested in the Laboratory. The test results for various water quality parameters are presented in Tables 1-7 and Figures 4-10. The details investigation about specific parameters are explained in the following sections. Maximum permissible limit (MPL) for both natural discharge and irrigation was compared according to Indian standard IS: 2490, part-I-1981.

3.1 pH

The term pH refers to the measure of hydrogen ion concentration in a solution and defined as the negative log of H^+ ions concentration in a water and wastewater. The values of p^H ranges from 0 to a little less than 7 are termed as acidic and the values of p^H a little above 7 to 14 are termed as base. When the concentration of H^+ ions and OH^- ions are equal then it is termed as neutral p^H. The tolerable limit is varying from 5.5 to 9.0. The value of pH was measured by the Multi-parameter analyzer (DZB-718). The results are shown in the Table 1 and variations at different study locations are presented in Figure 4. As seen in Figure 4, the multimedia filtration system are capable of removing pH value upto 2.63%. The pH value for all study locations were found within the permissible limit required for irrigation and safe disposal (Table 1).

Table 1: P^H value of municipal wastewater of Rajshahi City

Location	**P^H before treatment**	**P^H after treatment**	**% of removal**	**MPL for irrigation**	**MPL for discharge**
Fultota	7.28	7.10	2.47	5.5-9.0	5.5-9.0
Dorgapara	6.85	6.70	2.18	5.5-9.0	5.5-9.0
Padma garden	6.98	6.80	2.57	5.5-9.0	5.5-9.0
ShuvoPetrol pump	7.20	7.01	2.63	5.5-9.0	5.5-9.0

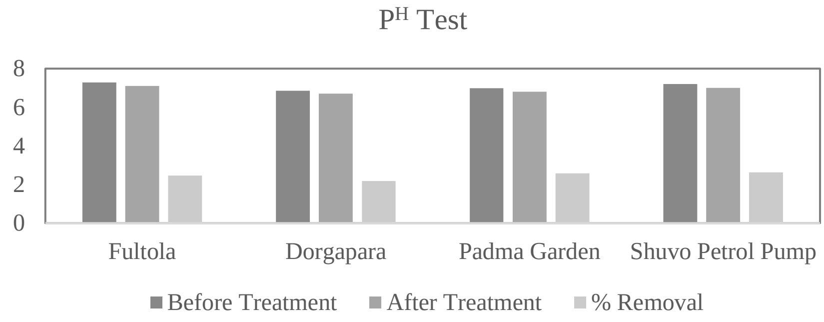


Figure 4: Variation of pH and % removal at study locations

3.2 Conductivity

Conductivity of a substance is defined as 'the ability or power to conduct or transmit heat, electricity or sound'. When an electrical potential difference is placed across a conductor, its movable charges flow, the substances are giving rise to an electric current. The maximum permissible limit of conductivity is 2250 µmhoes/cm. The value of Conductivity was measured by the Multi-parameter analyzer (DZB-718). The results are shown in Table 2 and graphically presented in Figure 5. As seen in Figure 5, the multimedia filtration system are capable of removing conductivity value upto 12.43%. The conductivity value for all study locations were found within the permissible limit required for irrigation and safe disposal (Table 2).

Table 2: Conductivity values of municipal wastewater of Rajshahi City.

Location	Before treatment	After treatment	% of Removal	MLP for irrigation	MPL for discharge
Fultota	2200	1950	11.36	2250	2250
Dorgapara	1900	1750	7.7	2250	2250
Padma garden	1850	1620	12.43	2250	2250
Shuvo Petrol pump	2000	1800	10	2250	2250

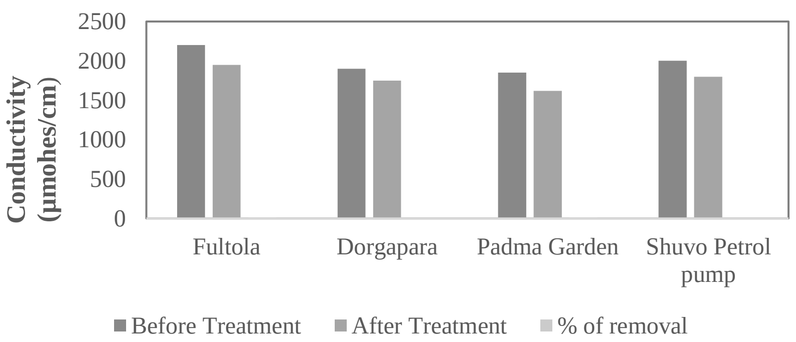


Figure 5: Variation of turbidity and % removal at study locations

3.3 Turbidity

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. The maximum permissible limit for turbidity is 35 NTU. The value of pH was measured by the Turbidimeter (TN-100). Figure 6 shows that the multimedia filtration system is capable of removing turbidity value upto 85.70%. The turbidity value for all study locations were found within the permissible limit required for irrigation and safe disposal (Table 3).

Table 3: Turbidity values of municipal wastewater of Rajshahi City

Location	**Before treatment**	**After treatment**	**% of Removal**	**MPL for irrigation**	**MPL for discharge**
Fultota	27.1	5.17	80.92	35	35
Dorgapara	15.60	2.23	85.70	35	35
Padma garden	17.73	3.01	83.02	35	35
Shuvo Petrol pump	27.02	4.14	84.67	35	35

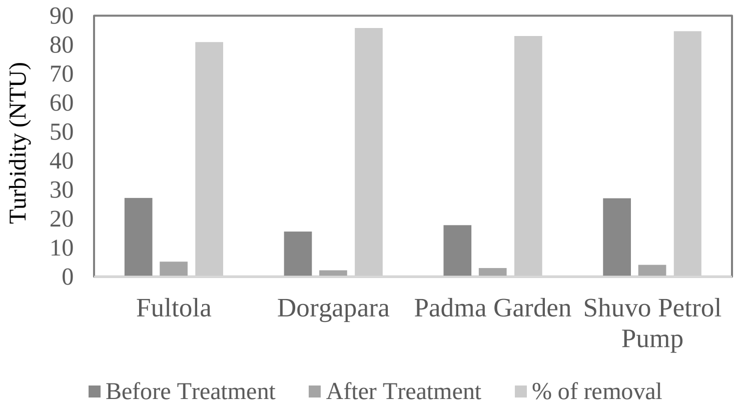


Figure 6: Variation of turbidity and % removal at study locations

3.4 COD

The Chemical Oxygen Demand (COD) method determines the quantity of oxygen required to oxidize the organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. It is measured in mg/L. The results for COD are shown in the Table 4 and graphically presented in Figure 7.As seen in Figure 7, the multimedia filtration system is capable of removing COD value upto 80%.

Table 4: COD values of municipal wastewater of Rajshahi City

Location	**Before treatment**	**After treatment**	**% of Removal**
Fultola	5.9	3	49.15
Dorgapara	14	7.7	45
Padma Garden	13.6	6.9	49.26
Shuvo petrol pump	5	1	80

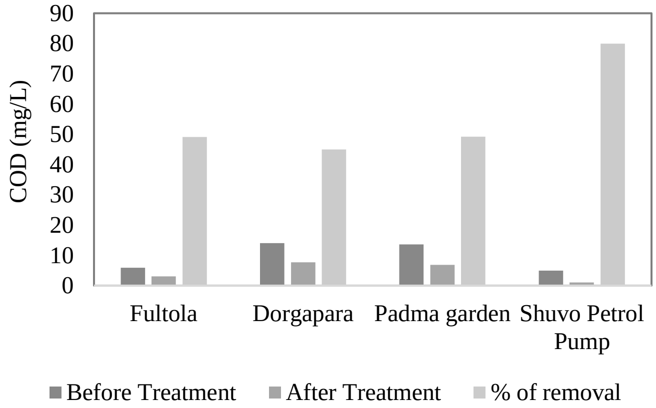


Figure 7: Variation of COD and % removal at study locations

3.5 Total Suspended Solid and Total Dissolved Solid

Total solid is the term applied to the material residue left in the vessel after evaporation of the sample. Total suspended solids (TSS) give a measure of the turbidity of the water. Total dissolved solid (TDS) is nothing but the dissolved in organic impurities present in the sample, it is calculated by subtracting the total suspended solid from total solid. The maximum permissible limit of total suspended solid (TSS) is 100 mg/L for direct discharge into natural water bodies and 200 mg/l for use in irrigation (IS: 2490, part-I-1981). The maximum permissible limit of Total Dissolved Solid (TDS) is 2000mg/l. The results for TDS and TSS are shown in the Tables 5-6 and Figures 8-9.As seen in Figures 8-9, the multimedia filtration system is capable of removing TDS and TSS value upto 47.88% and 47.06% respectively. The TDS and TSS value for all study locations were found within the permissible limit required for irrigation and safe disposal (Table 5-6).

Table 5: Values of Total Dissolved Solid (TDS) municipal wastewater of Rajshahi City

Location	Before treatment	After treatment	% of Removal	MPL for irrigation	MPL for discharge
Fultota	740	425	42.56	2000	2000
Dorgapara	670	350	47.76	2000	2000
Padma garden	710	370	47.88	2000	2000
Shuvo Petrol pump	510	390	23.53	2000	2000

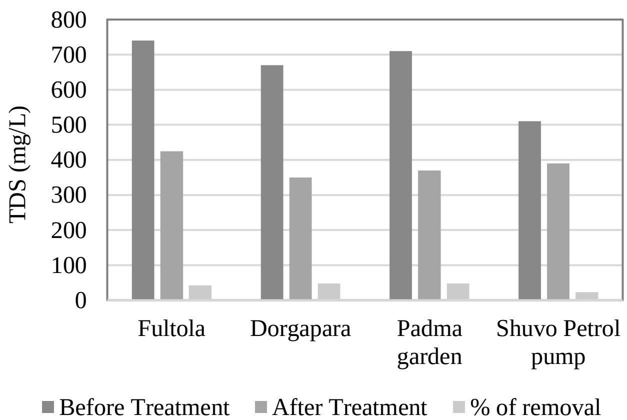


Figure 8: Variation of TDS and % removal at study locations

Table 6: Values of Total Suspended Solid of municipal wastewater of Rajshahi City

Location	**Before treatment**	**After treatment**	**% of Removal**	**MPL for irrigation**	**MPL for discharge**
Fultola	160	85	46.87	200	100
Dorgapara	170	90	47.06	200	100
Padma Garden	140	80	42.85	200	100
Shuvo Petrol pump	240	140	41.67	200	100

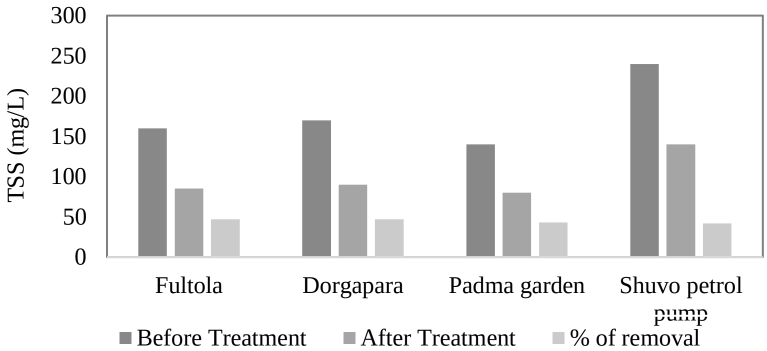


Figure 9: Variation of TSS and % removal at study locations

3.6 Organic Content

Organic content refers to the large pool or carbon-based compounds found within natural and engineered, terrestrial and aquatic environment. It is matter composed or organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment. The maximum permissible limit of total organic content is 250 mg/l for natural discharge and 200 mg/l for irrigation. The results obtained are shown in the Table 7 and graphically presented in Figure 10. As seen in Figure 10, the multimedia filtration system is capable of removing organic content value upto68.75%. The organic content value for all study locations were found higher than maximum permissible limit. However, after filtration organic content have reached within the permissible limit required for irrigation and safe disposal (Table 7).

Table 7: Total Organic Content values of municipal wastewater of Rajshahi City

Location	**Before treatment**	**After treatment**	**% of Removal**	**MPL for irrigation**	**MPL for discharge**
Fultola	800	250	68.75	200	250
Dorgapara	640	223	65.15	200	250
Padma Garden	530	195	63.20	200	250
Shuvo petrol pump	405	156	61.48	200	250

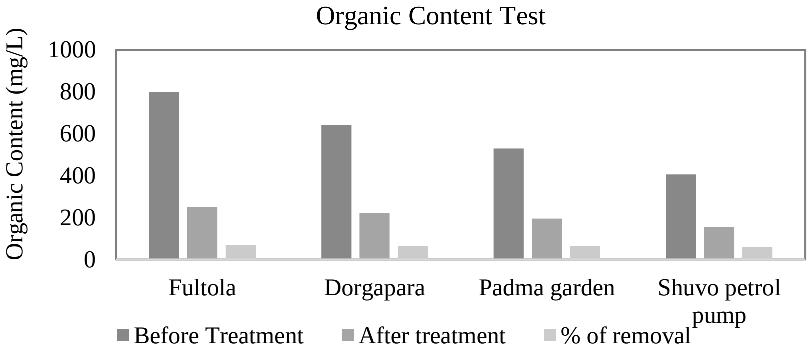


Figure 10**:** Variation of organic content and % removal at study locations

4. MATHEMATICAL EQUATION

$$Q=AV \tag{1}$$

Where, Q= Discharge water, A= Cross sectional area. V= Velocity of water

Here, cross sectional area was A=26.1 mm^2 and Q= 0.4 l/hr, Then discharging velocity, V=15.032 m/hr

5. CONCLUSION

The wastewater of Rajshahi city contains high amount of organic content. However, multimedia filtration system removed successfully up to 68.75% organic content from wastewater and returned within the permissible limit. In addition, the filtration system was found very effective for removing COD value upto 80%.

The multimedia filtration system removed total suspended solid and total dissolved solid from wastewater up to 47.06% and 47.88% respectively and meets with discharge water quality standards. All other parameters such as pH, turbidity and conductivity were found under permissible limit and don't bear any harmful effect.

Based on the study results, it can be concluded that the developed multimedia filtration system is very effective for reducing variety of pollutants concentration from wastewater. Treated wastewater can be reused for various purposes such as irrigation, toilet flushing, car washing, gardening, firefighting, etc.

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REFERENCES

Crini, G., & Lichtfouse, E. (2019), Advantages and disadvantages of techniques used for wastewater treatment. Environmental Chemistry Letters, *Springer Verlag*, 2019, 17 (1), pp.145-155.
Indian Standard Drinking water specification: 2490, part-I-1981
Sagara, J. (2000). Study of Filtration for point of use drinking water treatment in Nepal. Massachusetts Institute of technology, 2000.
Priyadarsini, L., (2013). Development of low cost water Purification Technique. Rourkela, 2013.

Osterdahl, M. (2015). An inventorying study of slow sand filters purification rates in rural areas in Colombia. Colombia, 2015, pp-43.

Grace, M. A., Healy, M. G., & Clifford, E. (2016). Performance and surface clogging in intermittently loaded and slow sand filters containing novel media. *Journal of Environmental Management 180 (2016), 102-110.*

Hasan, M. K., Shahriar, A., & Jim, K. U., (2019), Water pollution in Bangladesh and its impact on public health. *Heliyon*, 2019, 5, e02145

Emara, M. M., AbdElaziz, F., & Elbarbary, Y. H., (2016). Physico-Chemical Studies for boiler Water treatment and its impact on the Quality of final industrial Product. *International Journal of Scientific and Research Publications, 2016, volume-6.*

Ratnoji, S. S., & Singh N. (2014). A study of coconut shell-activated carbon for filtration and its comparison with sand filtration.*International Journal of Renewable Energy and Environmental Engineering ISSN 2348-0157, Vol. 02, No. 03.*,2014, pp.1-4.

Statistics and Facts, Water sense US EPA, 2018, Retrieved from http://www.epa.gov/watersense/statistics-and-fact

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ASSESSMENT OF SEASONAL WATER QUALITY VARIATIONS OF HIGHLY POLLUTED RIVERS IN BANGLADESH USING FEWS BANGLADESH SYSTEM

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ABSTRACT

Regular monitoring and systematic analysis of river water quality data is a prerequisite for the development of effective pollution prevention strategies to protect the rivers around the world. This study endeavours to assess the pollution status of two important rivers in Bangladesh by using a new water quality information system, FEWS-Bangladesh. FEWS-Bangladesh is a customised version of the Delft-FEWS software developed by Deltares. In this syudy, monthly water quality data of the rivers Buriganga and Shitalakhya at 12 monitoring stations for the 2002-2017 period were collected from the Department of Environment (DoE) and Bangladesh Water Development Board (BWDB). Later, available data of significant water quality parameters of the rivers were imported into FEWS Bangladesh system. The study has found that FEWS-Bangladesh is an effective tool which allows for a wide range of analyses of water quality data. This includes an assessment of spatial and temporal variations of water quality using time series graphs and spatial maps displayed by the system. Data show that during the dry season (November to April), the Buriganga and Shitalakhya rivers are extremely polluted with very low dissolved oxygen (DO) values and significantly high biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) levels than Bangladesh Water Quality Standards (ECR, 1997). In addition, high fluctuation of the BOD_5 and COD values in both the Buriganga and Shitalakhya Rrivers are observed between the dry and wet seasons. The pollution level is found relatively higher at the middle portion of the Buriganga river (Kamrangirchar, Sadarghat, Dholaikhal area), as compared to both the upstream and downstream portions. In case of Shitalakhya river, the stations at the lower reach is found more polluted than the upper reach. Water quality of these rivers appears to be deteriorating with time.This study not only investigates the recent pollution conditions of two major rivers around Dhaka city but also highlights the needs to improve the existing water quality monitoring and information systems through wider use of the FEWS-Bangladesh system and to take action in order to improve water quality of the contaminated rivers in Bangladesh.

Keywords: *Water quality, FEWS Bangladesh system, Delft-FEWS, Time series, Spatial map.*

1. INTRODUCTION

With increasing pollution load from domestic and industrial sources, quality of surface water and groundwater is becoming a major concern, particularly in developing countries like Bangladesh (Uddin et al., 2015). Bangladesh is a deltaic land crisscrossed by numerous rivers; the land is also consistently nourished by their water flows (Matin, 2005).Therefore, river water is one of the vital natural resources of this country, being used for drinking and domestic purposes, irrigation, survival of aquatic life, and development of industries. Dhaka city, the capital of Bangladesh, is surrounded by a circular river system, which includes the Turag River, the Buriganga River, the Dhaleswari River, the Balu Rriver, the Shitalakhya River, and the Tongi Khal (Rahman and Hossain, 2007). However, due to the lack of proper waste management, these rivers continuously receive untreated domestic and industrial wastewater. As a result, water quality of the rivers surrounding Dhaka has significantly degraded. Previous studies show that the water of the rivers Buriganga, Shitalakhya, Turag, and Balu are extremely polluted, particularly during the dry season (Kamal, Malmgren-Hansen and Badruzzaman, 1999); (Karim et al., 2000), (Magumdar, 2005); (Ahmed & Badruzzaman, 2007). The polluted water of these rivers has not only destroyed aquatic ecosystems but also poses health hazards to the dwellers of the city. Reversing the declining trend of the rivers around Dhaka city has become a national priority to ensure the multifaceted use of river water as a resource.

The impact of pollution on the water quality of rivers depends on several factors, including types, sources, quantity of pollution discharged, as well as characteristics of the river in question (e.g., discharge). Successful improvement of surface water quality relies on the development of effective and feasible pollution control strategies that require a good understanding of the extent of pollution (Alam, Badruzzaman & Ali, 2012). In this regard, designing a good monitoring network to regularly observe the temporal and spatial variation of the important water quality parameters is essential for assessing the pollution status of the rivers. Although a handful of organizations in Bangladesh i.e. Department of Environment (DoE), Bangladesh Water Development Board (BWDB), and Dhaka Water Supply and Sewerage Authority (Dhaka WASA) collect monitoring data on the water quality of rivers, these data are not systematically stored or analysed to provide an insight to the full extent of pollution and its impact, such as the identification of pollution hot spots and locations where water quality standards are exceeded (UNDP, 2016). On this backdrop, this study uses a new water quality information system, called FEWS-Bangladesh, to assess the temporal and spatial trends of water quality in two major rivers around Dhaka city: the Buriganga River and the Shitalakhya River.

2. DELFT-FEWS AND THE FEWS-BANGLADESH SYSTEM

Delft-FEWS is an open data handling platform which has been developed by Deltares, an independent institute for applied research in the fields of water and the subsurface in the Netherlands. Essentially, Delft-FEWS comprises of modules that can be configured for building a hydrological forecasting system and can be customised to meet the specific requirements of a designated organization (Werner et. al., 2013). Initially developed for flood, drought and seasonal forecasting, FEWS is now widely used for analysis of water quality and other environmental data because of its unique characteristics concerning data importing, processing and model connections. In addition to its role as a flood forecasting tool, Delft-FEWS has also been extended for use as a water quality forecasting tool in the Netherlands, Singapore and South-Korea; as a groundwater scenario management tool in the National Groundwater Modelling System in England and Wales, as well as in Colombia and Canada; as a drought forecasting system in areas such as the River Po, Italy; and as a Water Information System for a number of Water Boards in the Netherlands (Werner et.al., 2013). It is a freely available software that handles large amounts of data efficiently, provides for consistent data quality, standardised work processes, visualization and reporting (Delft-FEWS Detares Nederlands, 2015). FEWS-Bangladesh is a customised system, tailor-made to fit DoE and Dhaka WASA's needs. It has been developed to be used as a water quality information system, allowing users to import, visualise, analyse and report on water quality of the rivers of Bangladesh. The system was developed as part of the "Innovative monitoring and reporting for Sustainable Water quality of the Meghna River (ISWAM)" project and was also applied in the project "Strengthening Monitoring and Enforcement in the Meghna River for Dhaka's Sustainable Water Supply", both led by Deltares in Bangladesh (Deltares Public Wiki, 2018).

3. METHODOLOGY

This section provides a description of the methods followed in the study.

3.1 Description of Study Area

Dhaka, the capital and largest city of Bangladesh, is located in central Bangladesh, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 306.38 square kilometres (118.29 sq mi). As part of the Bengal plain, the city is bounded by four rivers: Buriganga, Turag, Dhaleshwari, and Shitalakhya. The Buriganga River is one of the most important rivers for Dhaka. It originates from the Dhaleshwari River and is a tide-influenced river flowing west and then south of Dhaka. It is only 27 km long and its average width and depth are 400 m and 10 m, respectively. Its catchment area is 253 km^2. Most of the industries in Dhaka are located along the Buriganga and they release their untreated wastewater directly into this river. The river also receives domestic wastewater and pollution inputs from numerous non-point sources. The Shitalakhya River is a tributary of the Brahmaputra River. The length, average width and depth of this river are 110 km, 300 m, and 21 m, respectively. It flows by the eastern side of Dhaka District and falls into the Dhaleshwari River at Madanganj, near Narayanganj. The river joins the Balu River at Demra, a small tributary flowing from the north of greater Dhaka. Approximately 20 km downstream of Demra, the Shitalakhya River joins the Dhaleshwari River. The intake point of the largest surface water treatment plant in Dhaka, the Saidabad Water Treatment Plant, is along the Shitalakhya River.

3.2 Data Collection

Water quality data of the Buriganga and Shitalakhya Rivers were collected from DoE and BWDB.

DoE is a government department under the Ministry of Environment Forest and Climate Change, which is responsible for the protection of the environment. DoE conducts monthly monitoring of the water quality of 27 rivers at 63 locations for basic parameters: pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Total Dissolved Solids (TDS) and Electrical Conductivity (EC), as well as periodic monitoring of chloride (Cl^-), turbidity and alkalinity (UNDP, 2016). The BWDB is a government agency under the Ministry of Water Resources that is responsible for surface water and groundwater management in Bangladesh. BWDB monitors temperature, DO, pH, BOD_5, turbidity, iron (Fe), Cl^-, EC and TDS at 29 stations, twice monthly (UNDP, 2016).

The locations of the monitoring stations and the period of data collection at each of the two selected rivers are presented in Table 1 and illustrated in Figures 1 and 2.

3.3 Water Quality Parameters Considered

This study considered selected physical and chemical parameters to assess the state of water quality of the rivers. The parameters were selected primarily based on data availability from both the BWDB and DoE, and the importance of the parameters as water quality indicators. EC and TDS are physical parameters of interest in this study. DO, BOD_5, COD, and are considered in this study. DO is a key water quality indicator as it is essential for the survival of fish and other aquatic organisms. The trend in DO may be regarded as an indicator of the overall trend in water quality (Luo et al., 2011). BOD_5 is a measure of biodegradable organics present in water, while COD is a measure of both biodegradable and non-biodegradable organics present in water (Davies, Abolude & Ugwumba, 2008).

Table 1: Monitoring stations along the studied rivers with parameters and data collection period.

	Site ID	Site Description	Latitude	Longitude	Prameters	Period (years)
Buriganga River	BG-100	Dhaka Mill Barrak	23.67	90.44	DO, BOD_5 and COD	2001-2012
	BG-101	Mirpur Bridge	23.79	90.33		2015-2017
	BG-102	Hazaribagh	23.60	90.44		2015-2017
	BG-103	Kamrangir Char	23.71	90.35		2015-2017
	BG-105	SadarGhat	23.70	90.41		2015-2017
	BG-106	Bangladesh China Friendship Bridge	23.68	90.42		2015-2017
	BG-107	Dholaikhal	23.70	90.40		2015-2017
	BG-108	Pagla	23.66	90.45		2015-2017
Shitalakhya River	SL-100	Narayonganj	23.66	90.52		2001-2012
	SL-101	Demraghat.	23.72	90.50		2015-2017
	SL-102	Ghorashal Fertilizer Factory	23.90	90.63		2015-2017
	SL-103	Near ACI Pharmaceuticals.	23.63	90.51		2015-2017

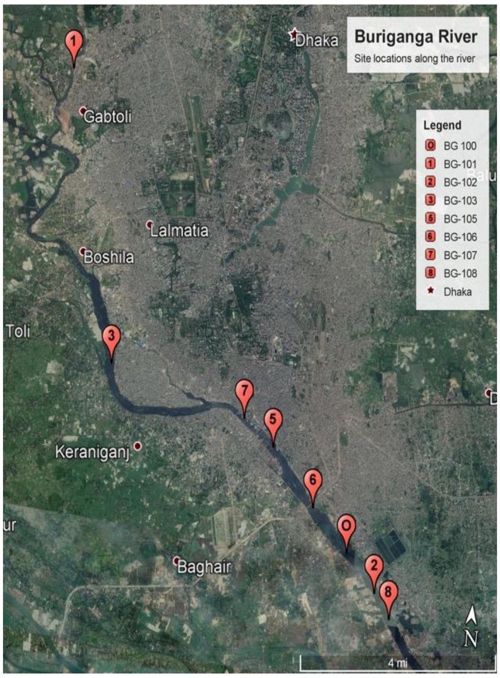


Figure 1: Locations of monitoring stations along the Buriganga River.

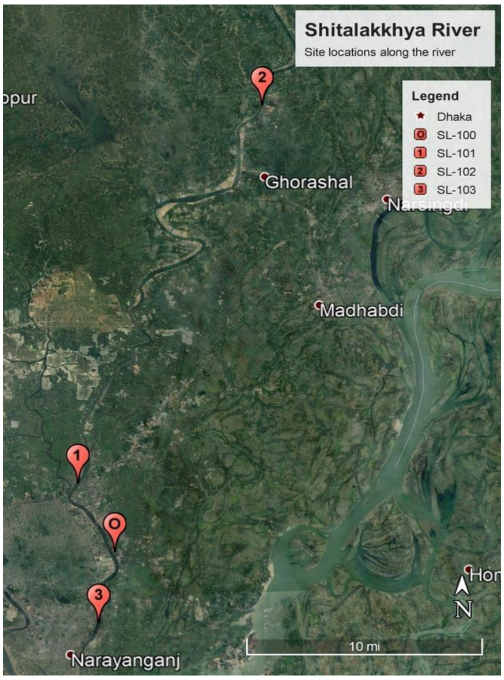


Figure 2: Locations of monitoring stations along the Shitalakhya River.

3.4 Water Quality Data Analysis Using FEWS-Bangladesh System

After collecting the required data from DoE and BWDB, FEWS-Bangladesh was used to analyse the data and generate important water quality information about the studied rivers. The steps followed in analysing data using FEWS-Bangladesh are presented in a flow chart illustrated in Figure 3:

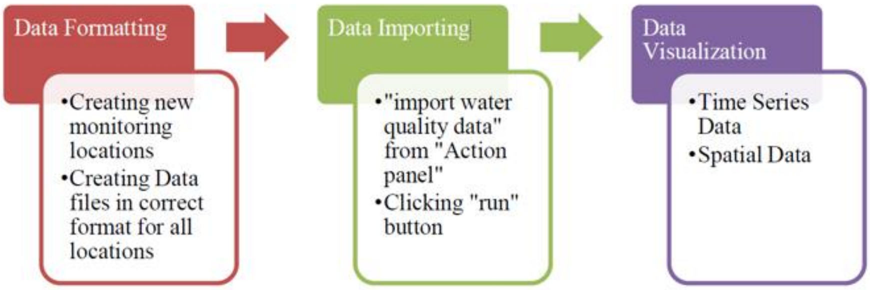


Figure 3: Flow chart for analysing data using FEWS Bangladesh system.

The flow chart in Figure 3 shows that a three-step procedure was followed in data analysis. Firstly, the information about the studied monitoring stations were added into the system and the collected data from all these stations were organised in the specified format of the system. Secondly, the formatted data files were imported to the system. Finally, the imported data were visualised in the display of the system as time series and spatial data.

4. RESULTS AND DISCUSSION

This section presents the water quality status of the Buriganga and Shitalakhya Rivers based on the analysis of the available data using the FEWS-Bangladesh System.

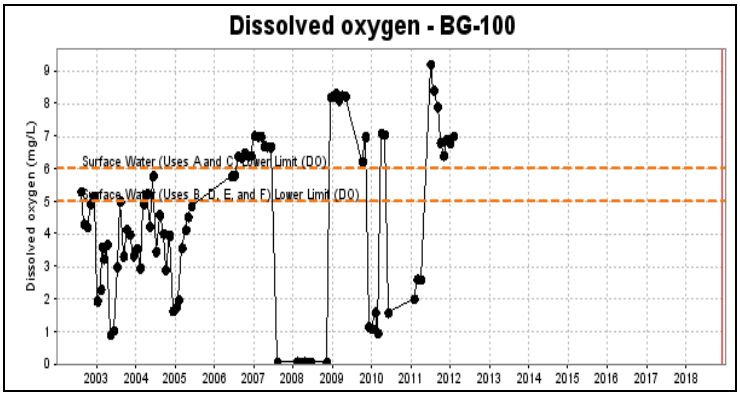
4.1 Water Quality Assessment of Buriganga River

Water quality data of Buriganga River were collected from 8 different monitoring stations of DOE and BWDB (locations of the stations are shown in Table 1).

4.1.1 Dissolved Oxygen (DO)

Figure 4 demonstrate the time series of monthly measured values of DO at two monitoring stations along the Buriganga River.

(a)



(b)

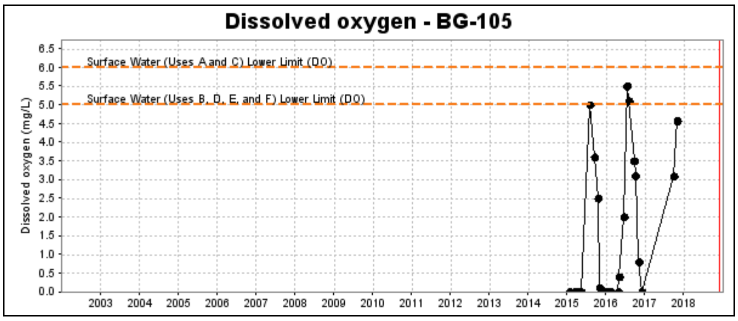


Figure 4: Time series of monthly DO concentration (mg/L) of Buriganga River at stations (a) BG-100 from 2002 to 2012 and (b) BG-105 from 2015 to 2017

Figure 4(a) shows that for the 2002-2012 period, the concentration of DO at the BG-100 station of the Buriganga River remained significantly low during pre-monsoon season (January to April) and post monsoon (October-December) season fluctuating within a range 0.06-3.0mg/L, whereas, during the monsoon season (May-September) the DO concentration was found relatively higher in the range of 4.0-9.00 mg/L. DO at BG-105, shown in Figure 4(b), indicates that during recent years (2015-2017), DO has almost always been below 5 mg/L, reaching a minimum DO level near zero during the dry season (November to April). During the wet season (May to October), DO remained within the range 2.18-5.20 mg/L. The trend of DO concentration between 2015-2017 was found to be similar for the six other stations along the Buriganga River. In addition to time series graphs of individual locations, the spatial distribution of water quality was observed by displaying all of the imported data in a single map produced by the FEWS-Bangladesh System. For instance, Figures 5 and 6 present the spatial variation of DO concentration at eight different monitoring locations along the Buriganga River in the months of February and October 2016, respectively. As discussed earlier, at all the monitoring stations, DO was found to be relatively low in dry season as compared to wet season**.**

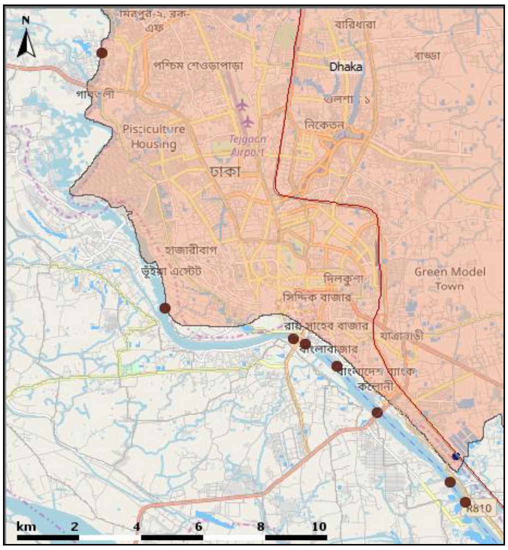


Figure 5: Spatial variation of DO levels (mg/L) along the Buriganga River (dry season).

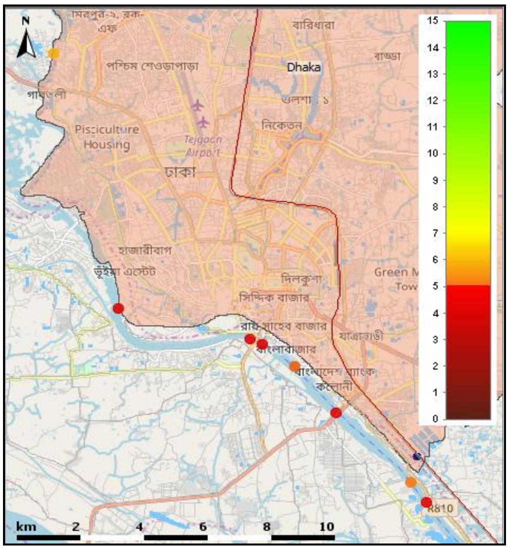


Figure 6: Spatial variation of DO levels (mg/L) along the Buriganga River (wet season).

In Figure 5, the stations are marked with dark red colour, indicating a DO level between 0-2.0 mg/L in February 2016 (pre-monsoon season), whereas in Figure 6, the same stations are marked with red or orange colour indicating a DO level between 3.0-6.0 mg/L in October 2016 (monsoon season). Figures 5 and 6 indicate that stations at the middle reach of the river are more contaminated (DO level below 5.0 mg/L) in both the pre-monsoon and monsoon seasons, compared to the stations at the upstream and downstream ends of the river. It should be mentioned that the scale of a particular parameter was selected in FEWS Bangladesh system configuration based on environmental regulations in Bangladesh (e.g. red is below water quality standards, orange is above water quality standards).

4.1.2 BOD_5 and COD

Figures 7, 8 and 9 present the monthly average **BOD_5** level observed at eight monitoring locations along the Buriganga River in 2016. BOD_5 levels at the monitoring locations varied between a range of 10-50 mg/L in the pre-monsoon period (stations marked with red colour in Figure 7). As expected, BOD_5 levels decreased during the monsoon and remained within a range 3.0-4.0 mg/L (stations marked with light green colour in Figure 8), which increased to a level between 4.5-7.0 mg/L in the post-monsoon period (stations marked with yellow/orange colour in Figure 9). Furthermore, from the time series and spatial variation of BOD_5 along the Buriganga River, significantly higher BOD_5 levels (above 30 mg/L) were found at BG-102 (Hazaribagh), BG-103 (Kamrangichar), BG-105 (Sadarghat) and BG-106 (Near Bangladesh China Friendship bridge) stations, which suggest that these locations are more polluted with biodegradable organic matter from sewage or other discharges. The overall BOD_5 level (>2.00mg/L, below standard water quality) of the Buriganga River is an indication of poor water quality throughout the year (ECR Schedule-3(A), 1997).

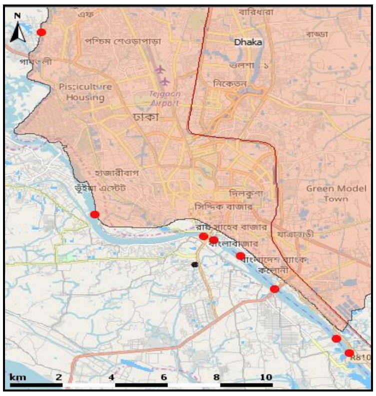


Figure 7: Spatial variation of BOD5 along the Buriganga River (pre-monsoon).

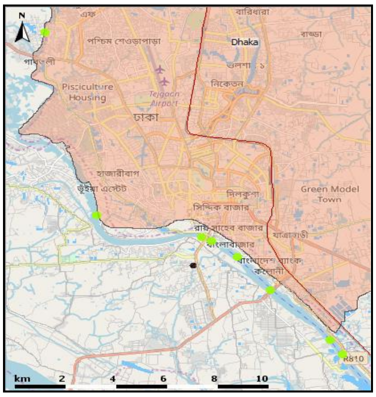


Figure 8: Spatial variation of BOD5 along the Buriganga River (monsoon).

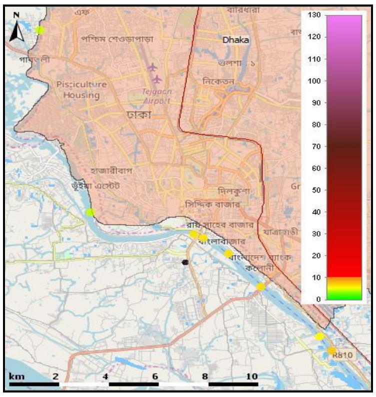


Figure 9: Spatial variation of BOD5 along the Buriganga River (post-monsoon).

Figures 10 and 11 demonstrate that COD levels in the Buriganga River at all of the monitoring stations were considerably high in the pre-monsoon period, fluctuating with a range of 40-80 mg/L (stations marked with red colour in Figure 10) and then decreased to 10-20 mg/L during the monsoon season (stations marked with yellow colour in Figure 11). Significantly higher COD levels (above 70 mg/L) were observed at stations located in the middle part of the river, indicating higher level of pollution.

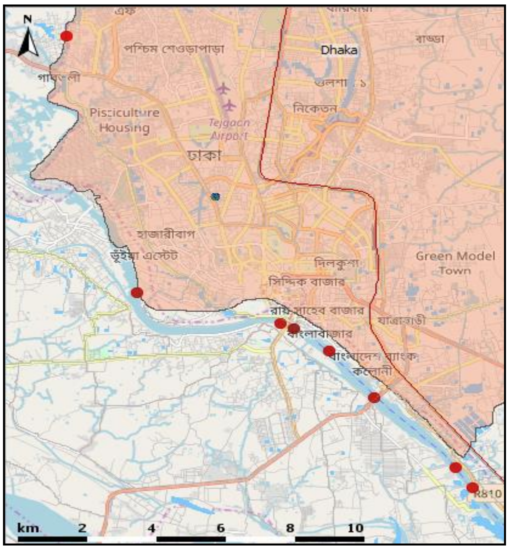


Figure 10: Spatial variation of COD levels along the Buriganga River (pre-monsoon).

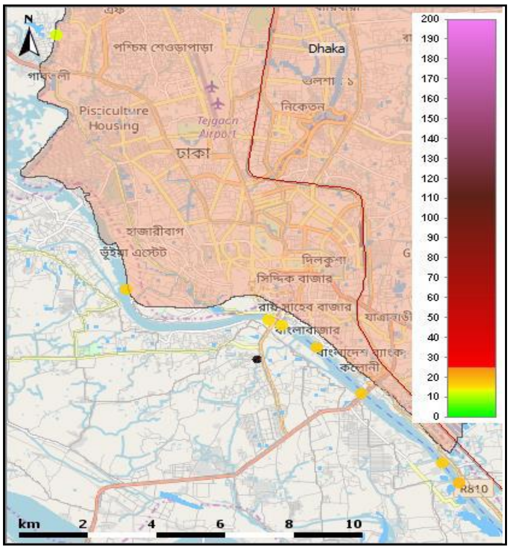


Figure 11: Spatial variation of COD level along the Buriganga River (monsoon).

4.2 Water Quality Assessment of Shitalakhya River

Water quality data of Shitalakhya River were collected from 4 different monitoring stations of DOE and BWDB (locations of the stations are shown in Table 1).

4.2.1 Dissolved Oxygen (DO)

Figures 12 and 13 illustrate the spatial variation of DO concentrations observed at the monitoring stations along the Shitalakhya River in May and October 2016, respectively. It is seen that DO levels fluctuated between 2.0-4.0 mg/L at the outset of monsoon, which increased to a level between 5.0-6.0 mg/L after the monsoon in 2016. DO levels at the lower reach of the Shitalakhya River most often remained below 5 mg/L; the DO level fluctuated between 3.2-7.0 mg/L at the upper reach of the river. The average DO level of the Shitalakhya River is an indication of poor water quality of the river year-round (ECR Schedule-3(B), 1997].

Figure 12: Spatial variation of DO along the Shitalakhya River (dry season)

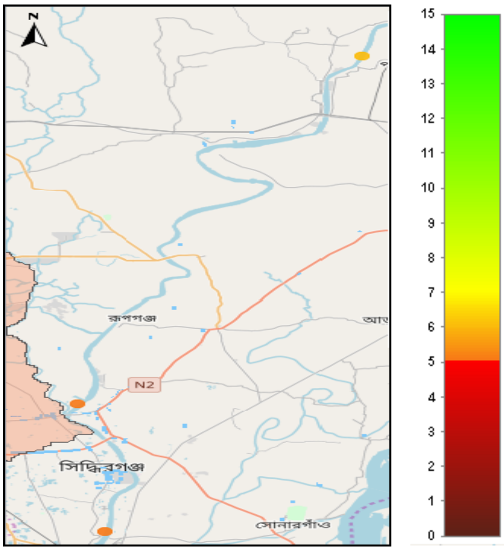


Figure 13: Spatial variation of DO along the Shitalakhya River (wet season)

4.3 BOD_5 and COD

From the spatial variation of BOD_5 at the monitoring locations along the Shitalakhya River in the months of February and September 2016, presented in Figures 14 and 15, it is seen that BOD_5 levels varied between a range 15-30 mg/L in the pre-monsoon season, decreasing to 0.8-1.10 mg/L in the monsoon period. BOD_5 levels in the Shitalakhya River during the dry season (>10 mg/L, the maximum value for a surface water body according to Bangladesh standards) limits its use for any purpose (ECR Schedule-3(A), 1997).

Figure 14: Spatial variation of BOD along the Shitalakhya River (dry season)

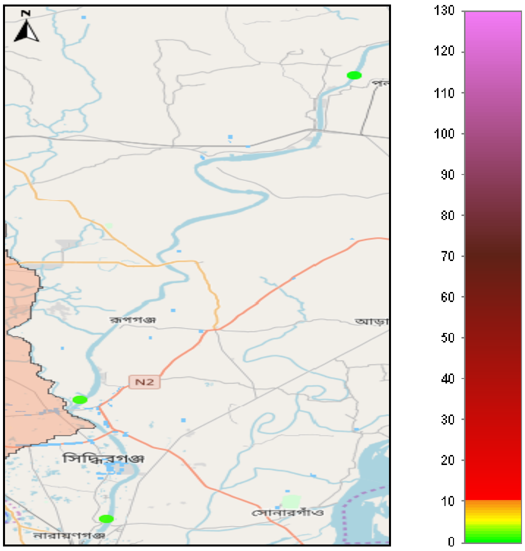


Figure 15: Spatial variation of BOD along the Shitalakhya River (wet season)

Figures 16 and 17 show that like BOD_5, COD levels in the Shitalakhya River at all the monitoring locations are considerably higher in the pre-monsoon period, fluctuating within a range 30-60 mg/L (stations marked with red colour in Figure 16); COD values then decreased to 16-30 mg/L during the monsoon season (stations marked with orange and red colour in Figure 17).

Figure 16: Spatial variation of COD along the Shitalakhya River (dry season)

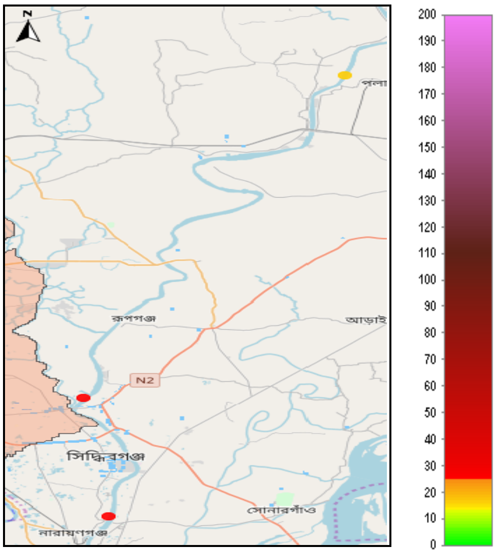


Figure 17: Spatial variation of COD along the Shitalakhya River (wet season)

5. CONCLUSIONS

This research focused on the assessment of water quality of the Buriganga and the Shitalakhya Rivers using FEWS-Bangladesh system with an insight to the effectiveness of the FEWS-Bangladesh System as an innovative technique to handle and interpret monitoring data in order to generate useful water quality information about the rivers in Bangladesh. It has been found that, the FEWS-Bangladesh System is an effective water quality information system, since it displays both raw water quality data, as well as daily, quarterly, monthly and yearly averages as time series and in a spatial display. The system can be configured to display the data in a wide range of formats, as needed. It is thus possible to easily identify locations with higher pollution levels using the spatial display available in the system.

The water quality status of the Buriganga River, flowing from the west to the south of Dhaka, has deteriorated significantly in recent years. High fluctuation of BOD_5 and COD values in both the Buriganga and Shitalakhya River were observed between the dry and wet seasons. The Buriganga River has been found to be polluted throughout the year, with significantly lower DO levels and higher BOD_5 and COD values than the acceptable level of a good raw water source for water supply. In addition, pollution is severe in the middle portion of the river (Kamrangirchar, Sadarghat, Dholaikhal area), as compared to both the upstream and downstream portions. In the case of the Shitalakhya River, water quality at the monitoring stations in the upper reach of the river was found to be better during the wet season, but not during the dry season. However, at the stations in the lower reach of the river, the BOD_5 level was found to be within the acceptable limit (according to Bangladesh standard) during the wet season, whereas DO levels were below the standard during both the dry and wet seasons.

The study recommends that governmental agencies in Bangladesh involved in the monitoring of river water quality should adopt innovative technologies like the FEWS-Bangladesh System to display and systematically analyse and report on monitoring data. This will eventually help the policy makers to undertake effective pollution control and prevention strategies to protect the rivers in Bangladesh.

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REFERENCES

Ahmed T. and Badruzzaman A.B.M. (2007), Effect of Thermal Effluent on Water Quality of Shitalakhya river. Journal of Civil Engineers, The Institution of Engineers, Bangladesh, 35(1), 59-70.

Alam, M., Badruzzaman, A. and Ali, M. (2012). Water Quality Response to Reductions in Waste Loading of Sitalakhya River, Bangladesh. Journal of Water and Environment Technology, 10(1), pp.31-46.

Bangladesh Potable Water Quality Standard [ECR, 1997, Schedule-3(B)] and WHO (2004) Guideline Values

Davies, O. A., Abolude, D. S. and Ugwumba, A. A. (2008). Phytoplankton of the lower reaches of Okpoka creek, Port Harcourt, Nigaria. Journal of Fisheries International. Vol. 3. Issue 3. pp 83-90.

Deltares Nederlands (2015) Retrieved from https://www.deltares.nl/app/uploads/2015/01/ Delft-FEWS_brochure-2017.pdf.

Deltares Nederlands (2018). Retrieved from https://oss.deltares.nl/web/delft-fews/implementations

Deltares Public Wiki. (2018). Retrieved from https://publicwiki.deltares.nl/pages/viewpage.action?pageId=127633757

Kamal, M., Malmgren-Hansen, A. and Badruzzaman, A. (1999). Assessment of pollution of the river Buriganga, Bangladesh, using a water quality model. Water Science and Technology, 40(2), pp.129-136.

Karim, M., Badruzzaman, A., Sekine, M. and Ukita, M. (2000). Assessment of nutrients and dissolved oxygen in a river system in Bangladesh using a water quality model. Doboku Gakkai Ronbunshu, (664), pp.97-107.

Luo, P., He, B., Takara, K., Razafindrabe, B., Nover, D. and Yamashiki, Y. (2011). Spatiotemporal trend analysis of recent river water quality conditions in Japan. Journal of Environmental Monitoring, 13(10), p.2819.

Magumdar.T.K. (2005), Assessment of Water quality in the Peripheral rivers of Dhaka city, M. Engineering Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka.

Rahman, S. and Hossain, F. (2007). Spatial Assessment of Water Quality in Peripheral Rivers of Dhaka City for Optimal Relocation of Water Intake Point. Water Resources Management, 22(3), pp.377-391.

Standards for Inland Surface Water [ECR 1997, Schedule 3(A)]

Uddin, M., Alam, M., Mobin, M. and Miah, M. (2015). An Assessment of the River Water Quality Parameters: A case of Jamuna River. Journal of Environmental Science and Natural Resources, 7(1).

UNDP (2016). Report on Scoping Study on Environmental Health and Water Quality in Rivers and Ecologically Critical Areas in Bangladesh (p. 77).

Werner, M., Schellekens, J., Gijsbers, P., van Dijk, M., van den Akker, O. and Heynert, K. (2013). The Delft-FEWS flow forecasting system. Environmental Modelling & Software, 40, 65-77.

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EVALUATION OF DRINKING WATER QUALITY IN TERMS OF WATER QUALITY INDEX FOR FARIDPUR SADAR UPAZILA

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ABSTRACT

The quality of drinking water plays a vital role in public health. In this study, the quality of drinking water at Faridpr Sadar Upazila was evaluated by the water quality index (WQI). As the local people mainly rely on groundwater as a source of drinking water, eight groundwater stations were selected for sample collection within the locality. The water quality index was assessed using two widely used methods: Canadian Council of Ministers of the Environment (CCME) WQI and Weighted Arithmetic Index Method (WAM). To assess WQI, nine input parameters were used; which are pH, turbidity, nitrate, temperature, dissolved oxygen (DO), total dissolved solids (TDS), iron, arsenic and biochemical oxygen demand (BOD_5). According to the CCME WQI method, WQI varied from 65.1 to 82.1 and by the weighted arithmetic index method, the value of WQI varied between 20.4 and 151.1. The study revealed that, by both methods, WQI indicates that water of the maximum stations is not up to the mark and a sample of only one station (S3 sample from Faridpur Chowdhury Bari) was found to be excellent or good for drinking purpose. Besides the above findings, BOD5 was the parameter, which was found to cross the acceptable limit for all the stations. Moreover, while comparing the result of WQI by both methods, it was found when low acceptance ranged parameters (i.e. Arsenic, BOD, Iron, etc.) dominate, water is categorized in a wider range in the WAM WQI method than by CCME WQI method. This because weights are assigned to each parameter according to their acceptance range. However, it is expected that this paper may assist in raising awareness among policymakers and local people on the quality of the drinking water of the study area.

Keywords: *Water quality, Water quality index, Weighted arithmetic method, CCME method, Faridpur.*

1. INTRODUCTION

Water is a vital natural element that is a prerequisite for the proper functioning of the ecosystem. Being a two-third portion of the earth along with covering 75% of the human body, the role of water in our earth becomes evident. As it plays a vital role in maintaining every life form ensuring the stability of the earth system, access to clean water has become one of the six sustainable development goals of the United Nations (DISLEY, 2013). Water quality is not only essential for the functioning of the environment but also plays a crucial role in maintaining the health of human life in every sphere including drinking, agriculture, forestry, industrial activities, recreation, and others. Among all kinds of human diseases, around 80% are caused by water (Ramakrishnaiah et al., 2009). For maintaining the health of these sectors, ensuring sustainable quality of groundwater is very important as in Bangladesh majority of the water sources lie underground (Bodrud-Doza et al., 2016; Biswas et al., 2014). Unfortunately, population growth along with increased agricultural activity, rapid urbanization, and industrialization along with geogenic contamination, there has been a drastic change in both quantity and quality of groundwater in Bangladesh (Islam et al., 2017). Bangladesh is now facing serious health hazards due to water pollution (Alam, 2009). Assessment of the quality of drinking water has become a necessity for protecting public health. For evaluating water quality index (WQI) is considered as the most effective method as it the capability to integrate a wide range of information into a simpler form (Akhter et al., 2016). Moreover, water quality indices have become a convenient tool for water managers and policymakers for anticipating the quality and potential use of an aquifer system (Bozdağ et al., 2015). Many types of water quality indices have been developed to assess water quality for different purposes taking into consideration different types of parameters.

Even though in recent times, different types of studies and assessments were carried out in different regions of Bangladesh to evaluate the quality of aquifers (Shahidullah et al., 2000; Rahman et al., 2012; Bhuiyan et al., 2010; Hossen et al., 2019), most of them were focused on quality of irrigation water or evaluation of heavy metal pollution. However, some studies were found on the evaluation of water quality for drinking purpose (Saha et al., 2018; Rahaman et al., 2019), where only a few elaborated works focus on small administrative units so that the people of that area can identify the best water source available within their region. The present study targets to evaluate the suitability of aquifers for the drinking purpose of Faridpur Sadar Upazila of Bangladesh in the form of water quality index in two different methods which are: Weighted Arithmetic method and Canadian Council of Ministers of the Environment (CCME) WQI method. The aim was to provide necessary information to the local people and the policy makers so that they can mark the best source available and during an emergency, they can determine the level of treatment for alternate sources.

1.1 Study area

For investigating the water quality index, a small administrative unit of Bangladesh, Faridpur Sadar was chosen (Figure-1). It is an Upazila under Faridpur district and lies between 23°29' and 23°34' north latitudes and 89°43' and 89°56' east longitudes. The total number of households is 103535 with a population of 469410 and the population density is 1137 per sq. km (Bangladesh Bureau of Statistics[BBS], 2011) It has a total area of about 412.86 square km where a riverine area is 10.44 sq. km. Kumar river runs beside the Upazila town. The area is currently facing several water related problems including arsenic contamination and presence of salinity, iron, and manganese in groundwater, non-availability of suitable aquifer and lowering of water table (Department of Public Health Engineering[DPHE], 2012) Moreover, infiltration of wastewater into the groundwater is resulting from mismanagement of waste from garbage and small scale industries. As, the local people of the area mainly rely on groundwater, thus groundwater needs to be evaluated carefully in terms of water quality index for drinking.

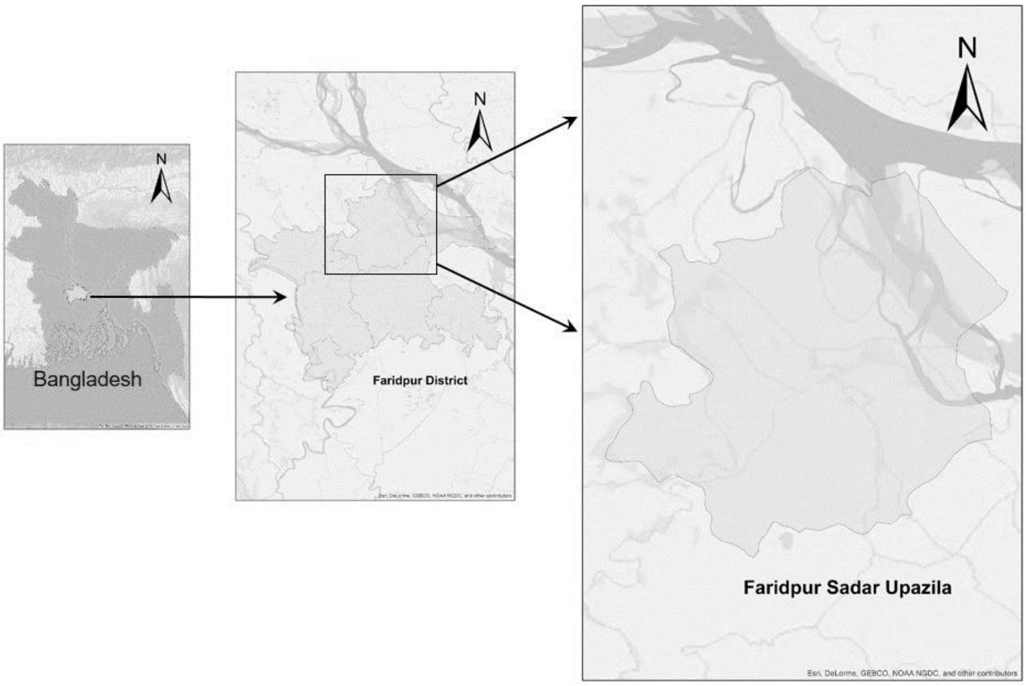

Figure-1: Map of study area

2. METHODOLOGY

2.1 Collection of samples and testing of parameters

A total of eight sampling points in the Faridpur Sadar were selected. Four samples were collected from each sampling point. The samples were collected only during the post-monsoon period (November-2017) as change of water quality along with time was not the prime focus of the study. A portable global positioning system (GPS) meter was used to record the geographical location of the sampling stations. The sampling points are shown in Figure 2.

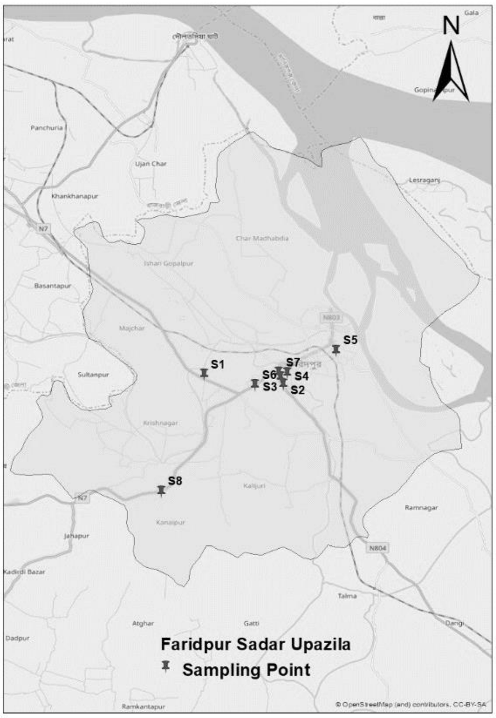

Figure-2: Sampling points in Faridpur Sadar

A total of nine parameters were selected to test WQI (table-1). The parameters are- pH, turbidity, nitrate, temperature, dissolved oxygen (DO), total dissolved solids (TDS), iron, arsenic and biological oxygen demand (BOD). Among these parameters, temperature and pH were measured immediately at the sampling points using a thermometer and digital pH meter. The other parameters were evaluated at the laboratory after carrying the samples to the laboratory.

The GPS location of the sampling points along with the sample names of the locations are presented in table-1:

Table-1: Sampling location and name along with latitude and longitude

Location	Latitude	Longitude	Sample Name
Faridpur dhaka highway	23.598094	89.790735	S1
Faridpur vanga highway	23.593173	89.830853	S2
Faridpur chowdhury bari	23.596809	89.829397	S3
Faridpur Ambika Road	23.598832	89.83297	S4
Faridpur Tepakhola	23.610315	89.857498	S5
Faridpur municipal water supply	23.592767	89.816582	S6
Goalchamot near bus stand	23.599045	89.828608	S7
Knaipur Bazar	23.539072	89.769213	S8

From table-1, calculation of WQI was done by two widely used methods: Weighted Arithmetic Index Method and Canadian Council of Ministers of the Environment (CCME) WQI method.

2.2 Assessment of Water Quality Index (WQI)

Evaluation of water quality from the value of the individual parameter is difficult not only for common people but also for policymakers (Akoteyon et al., 2011). To overcome this complexity, WQI is the most effective tool (Tyagi et al., 2013). Water quality index is a method that summarizes several numbers of water quality parameters into a simple term, which indicates a certain level of water quality (Katyal, 2011). It means WQI is capable of transforming a bulk of information into a simplified, logical and single form. Horton first measured water quality index during the mid-twentieth century by using ten water quality variables where the index weight ranged from 1 to 4. From then, various modifications along with newer approaches to calculate WQI have been developed to evaluate water quality for different purposes (Brown et al., 1970). Among them, to evaluate the quality of water for drinking purpose, the most successful attempt till now appears to be the weighted arithmetic method index developed by Brown et al (1972) which was originally developed by Horton and British Columbia Ministry of Environment, Lands and Parks names as Canadian Council of Ministers of the Environment (CCME) WQI. These two methods are widely used among the researchers (Tyagi et al., 2013) to evaluate WQI. In this study, Weighted Arithmetic water quality index method and CCME WQI method were used for evaluating water quality index.

2.2.1 Calculation of WQI by Weighted Arithmetic Method

The weighted arithmetic water quality index method is widely used for evaluating the quality of groundwater for human consumption. It is one of the most convenient methods for calculating WQI because it classifies water quality by using the most commonly used water quality parameters. Moreover, it also requires less number of parameters compared to other water quality parameters. This method is very useful for communicating with the public and policymakers. The calculation of WQI by weighted arithmetic method involves the following steps:

2.2.1.1 Calculation of quality rating scale (Qi) for each parameter:

If there are i number of water quality parameters, the quality rating scale Qi corresponding to the i^{th} parameter indicates the relative value of this value in polluted water with respect to its standard permissible value. The value of Qi is calculated by equation (1).

$$Qi = 100 \times \frac{Vi - Vo}{Si - Vo} \tag{1}$$

Where,

Q_i= Quality rating scale for i^{th} parameter
V_i= Estimated concentration of i^{th} parameter in the sample
S_i= Recommended standard value for i^{th} parameter
V_o= Ideal value of the i^{th} parameter in the pure water
Here, for all the parameters ideal value, V_o is taken as zero except for pH=7.0 and DO= 14.6 mg/L.

2.2.1.2 Calculation of unit weight (W_i) for each parameter:

The unit weight (W_i) of each parameter represents the value which is inversely proportional to the recommended standard value of the corresponding parameter. It is calculated by equation (2) as follows:

$$Wi = {}^{K}\!/_{Si} \tag{2}$$

Where,

W_i= Unit weight for i^{th} parameter

K= proportionality constant $= \dfrac{1}{\sum \frac{1}{Si}}$

2.2.1.3 Calculation of WQI

The overall WQI is calculated from the quality rating and the unit weight by equation (3). The equation is as follows:

$$WQI = \sum QiWi \Big/ \sum Wi \tag{3}$$

After calculating the value of WQI, the categorization of water quality according to this method is done by the following table-2:

Table-2: WQI index categorization according to weighted arithmetic method

WQI Value	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

2.2.2 Calculation of WQI by CCME WQI Method

To represent a variety of variables into a single number combining various measurements, the Canadian Council of Ministers of the Environment (CCME) WQI is one of the most effective methods which is universally well-accepted (Damo et al., 2013). The index is established based on a formula developed by the British Columbia Ministry of Environment, Lands, and Parks and modified by Alberta Environment (Canadian Council of Ministers of the Environment, 2001). The prime advantage of this method is it’s adaptability to the different legal requirements for which this method can be applied in different regions with a slight adjustment. The calculation of WQI by CCME method is done by the following equation:

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \tag{4}$$

Equation (4) involves calculation of three factors- Scope (F_1), Frequency (F_2) and Amplitude (F_3). The calculation procedure of these factors are mentioned bellow:

2.2.2.1 Calculation of Scope (F_1)

Scope represents the extent of variables with non-compliance over time. It is calculated by the following equation (5):

$$F_1 = \frac{Number\ of\ Failed\ Variables}{Total\ Number\ of\ Variables} \times 100 \tag{5}$$

2.2.2.1 Calculation of Frequency (F_2)

The percentage of individual tests that failed to meet the objectives is represented by frequency and it is calculated by equation (6).

$$F_2 = \frac{Number\ of\ Failed\ tests}{Total\ Number\ of\ tests} \times 100 \tag{6}$$

2.2.2.1 Calculation of Amplitude (F_3)

Amplitude specifies the amount by which the failed tests did not meet their objectives. It includes three steps of calculation:

Step: 1- Calculation of excursion

The number of times by which an individual concentration value deviates than (or less than, when the objective is a minimum) the objective is called “excursion”. When the test value must not exceed the objective, it is calculated by equation (7) and when the test value must not fall below the objective, it is calculated by equation (8).

$$Excursion_i = \frac{Failedtestvalue_i}{Objective_j} - 1 \tag{7}$$

$$Excursion_i = \frac{Objective_j}{Failedtestvalue_i} - 1 \tag{8}$$

Step: 2- Calculation of Normalized sum of excursion (nse)

The collective total by which the individual test deviated from the objective is named as normalized sum of excursion (nse). It is calculated after calculation total excursions by the equation (9).

$$nse = \frac{\sum excursion\ i}{Number\ of\ tests} \tag{9}$$

Step: 3- Calculation of Amplitude (F_3)

After calculating nse, F_3 is then calculated by an asymptotic function mentioned below:

$$F_3 = \frac{nse}{.01nse + .01} \tag{10}$$

After getting the values of F_1, F_2 and F_3, WQI is calculated by equation (4) and the final score is then categorized based on the following classification mentioned in table-3:

Table- 3: WQI index categorization according to CCME method (Canadian Council of Ministers of the Environment, 2001)

WQI Value	Rating of Water Quality	Description
95-100	Excellent water quality	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
80-94	Good Water quality	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
60-79	Fair water quality	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45-59	Marginal water quality	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0-44	Poor water quality	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3. RESULT

After collection and testing of the water quality parameters, following table-4 was obtained based on which water quality index was calculated following the standards of drinking water quality recommended by Bangladesh Environmental conservation Rule, 1997 (Standard, 1997). The recommended values of the input parameters according to ECR, 1997 is tabulated in table-5.

Table- 4: Estimated concentration of parameters in the sampling points

Sample Name	pH	Turbidity (NTU)	Nitrate (mg/L)	Temp (Degree Celsius)	DO (mg/L)	TDS (mg/L)	Iron (mg/L)	Arsenic (mg/L)	BOD (mg/L)
S1	7.47	6.54	0	23	1.3	477	1.1	0	0.5
S2	7.43	7.28	0	24.63	1.77	696	0.7	0.06	0.6
S3	7.2	6.45	0	23.67	1.4	712	0.9	0	0.17
S4	7.33	7.46	0	23.58	1.33	557	0.7	0.07	0.3
S5	7.39	1.41	0	24.33	1.37	462	0.2	0.03	0.2
S6	7.41	9.83	0	25.1	1.8	724	0.3	0.01	0.43
S7	7.09	12.4	0	25.3	1.63	941	0.6	0.02	0.6
S8	7.32	6.34	0	24.9	1.92	802	1.2	0	0.4

Table- 5: Standard values of the parameters according to ECR, 1997

Parameter Name	Lower Limit	Upper Limit	Unit
PH	6.5	8.5	-
Turbidity	-	10.0	NTU
Nitrate	-	10.0	mg/L
Temperature	20.0	30.0	Degree Celsius
DO	6.0	-	mg/L
TDS	-	1000	mg/L
Iron	0.30	1.0	mg/L
Arsenic	-	0.05	mg/L
BOD	-	0.20	mg/L

3.1 pH in drinking water

pH is the indicator of whether the water is hard or soft. The pH of pure water is 7. When pH value is lower than 7, it is considered as acidic and it may impart metallic taste or contribute to fixture corrosion. When pH value is greater than 7, it is considered to be basic and tastes a bit like baking soda along with leaving deposits on fixtures. For all our samples, pH level fluctuated from 7.09 for S7 to 7.47 for S1, which is found to be satisfactory according to ECR, 1997.

3.2 Turbidity in drinking water

Turbidity is the degree of how much clear a liquid is and how much light is scattered by the sample. It can create both aesthetic and health issues by creating objectionable appearances, tastes, and odors along with interfering during disinfection. According to ECR, 1997, the standard value of turbidity in drinking water is 10 NTU. The concentration of turbidity was found to be satisfactory for all the samples except for S7 and S6 where turbidity was 12.4 NTU and 9.83 NTU respectively.

3.3 Nitrate in drinking water

The nitrate toxicity mainly affects human health by transforming into nitrite that prohibits transport of oxygen to tissues in human body. This phenomena causes cyanosis and at higher concentration asphyxia. Fortunately, in all our samples, there was no trace of nitrate poisoning. In all the samples nitrate concentration was found to be 0 mg/L.

3.4 Temperature in drinking water

Temperature of water effects bio-chemical reactions in aquatic organisms. An increase in temperature of water leads to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies the tastes and odors. The temperature of the samples fluctuated from minimum 23^0c for S1 to maximum 25.3^0c for S7 which are within the guideline of ECR, 1997.

3.5 Dissolved Oxygen (DO) in drinking water

Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophs (Rani et al., 2012). By presence of oxygen demanding wastes in water, oxygen level falls. As, DO makes drinking water tastes better, higher level of DO is desirable. In our samples, the concentration of DO was found to be far below than the recommended lower limit in all samples. In place of recommended value of DO being 6.0 mg/L by ECR, 1997, among all the eight samples, maximum value was found to be only 1.92 mg/L for S8.

3.6 Total Dissolved Solid (TDS) in drinking water

TDS is the measure of total amount of inorganic salts along with small amount of organic matter which are soluble in water (World Health Organization [WHO], 1996). As, higher level of TDS imparts objectionable taste and cause scaling in water pipes and household appliances, maximum level is considered to be 1000mg/L. The maximum value of TDS among the eight samples was found to be 941 mg/L in sample S7. So, the value of TDS can be deduced as satisfactory for all the samples.

3.7 Iron in drinking water

Though presence of iron is not hazardous to health, excessive amount makes it secondary or aesthetic contaminant. Apart from that, iron helps in transport of oxygen in blood which is essential for good health. The iron concentration in the samples were within permissible limit except for sample S1 and S8. In this two samples iron concentration was found to slightly cross the prescribed limit. Where the upper limit of iron concentration is 1mg/L, in this two stations iron concentration were 1.1mg/L and 1.2 mg/L respectively.

3.8 Arsenic in drinking water

Arsenic has been demonstrated to be carcinogenic to human health if it is ingested for a longer period of time. Long term exposure to arsenic increases risk of cancer in skin, bladder, lungs and kidney (Fawell et al, 2011). Among our eight samples, two samples exceeded the permissible limit of arsenic concentration (.05 mg/L). These two samples are S2 and S4 where iron concentration is 0.06mg/L and 0.07 mg/L respectively.

3.9 Biological oxygen Demand(BOD) in drinking water

BOD is the measure of level of pollution in water due to presence of organic matter. So, the higher the BOD, the water us more polluted with the presence of oxygen demanding organisms. In our samples, except for having almost marginal value in sample S3 (0.17 mg/L) and marginal value in sample S5 (0.2 mg/L), all the samples exceeded the permissible limit of BOD. Among these, sample S7 contains highest concentration of BOD which is 0.6 mg/L.

3.10 Result of WQI by Weighted Arithmetic Method

By weighted arithmetic method, total five categories of water qualities were found among eight samples. Among them, one excellent, one good, three poor, one very poor and two samples were found unsuitable for drinking purpose (table-7). The calculation of quality rating scale is mentioned below in (table-6).

Table- 6: Calculation of quality rating scale (Q_i) by Weighted Arithmetic Method

Sample Name	pH	Turbidity	Nitrate	Temperature	DO	TDS	Iron	Arsenic	BOD
S1	31.33	65.40	0.00	30.00	154.65	47.70	110.00	0.00	250.00
S2	28.67	72.80	0.00	46.30	149.19	69.60	70.00	120.00	300.00
S3	13.33	64.50	0.00	36.70	153.49	71.20	90.00	0.00	85.00
S4	22.00	74.60	0.00	35.80	154.30	55.70	70.00	140.00	150.00
S5	26.00	14.10	0.00	43.30	153.84	46.20	20.00	60.00	100.00
S6	27.33	98.30	0.00	51.00	148.84	72.40	30.00	20.00	215.00
S7	6.00	124.00	0.00	53.00	150.81	94.10	60.00	40.00	300.00
S8	21.33	63.40	0.00	49.00	147.44	80.20	120.00	0.00	200.00

Among eight samples, only sample S3, which is from Faridpur chowdhury bari, was found to be of excellent quality. After that, the sample S8 which is from Knaipur Bazar was found to be of C grade which indicates the quality to be good. The samples, S1, S5 and S6 from Faridpur Dhaka highway, Faridpur Ambika Road and Faridpur Tepakhola respectively, were found to be of grade C which is poor water quality. The sample S7 of Goalchamot near bus stand was found to be of very poor water quality. sample S2 and S4 from Faridpur Vanga highway and Faridpur Ambika Road were found as unsuitable for drinking purpose.

Table- 7: WQI by Weighted Arithmetic Method

Location	Sample Name	WQI	Remarks	Category
Faridpur Dhaka highway	S1	52.68	C	Poor water quality
Faridpur Vanga highway	S2	151.11	E	Unsuitable for drinking purpose
Faridpur Chowdhury bari	S3	20.74	A	Excellent water quality
Faridpur Ambika Road	S4	137.90	E	Unsuitable for drinking purpose
Faridpur Tepakhola	S5	66.05	C	Poor water quality
Faridpur municipal water supply	S6	58.25	C	Poor water quality
Goalchamot near bus stand	S7	90.51	D	Very Poor water quality
Knaipur Bazar	S8	43.56	B	Good water quality

3.10 Result of WQI by CCME Method

According to CCME method, two categories of water quality were found among eight samples. Except for sample S3 at Faridpur chowdhury bari, the rest of the samples were found to be fair.

Table- 8: Calculation of WQI by CCME Method

Location	Sample Name	F1	F2	F3	CCME WQI	WQI Category
Faridpur dhaka highway	S1	33.3	33.3	36.7	65.5	FAIR
Faridpur vanga highway	S2	33.3	33.3	33.8	66.5	FAIR
Faridpur chowdhury bari	S3	11.1	11.1	26.7	82.1	GOOD
Faridpur Ambika Road	S4	33.3	33.3	32.9	66.8	FAIR
Faridpur Tepakhola	S5	22.2	16.7	27.3	77.5	FAIR
Faridpur municipal water supply	S6	22.2	22.2	27.9	75.7	FAIR
Goalchamot near bus stand	S7	33.3	33.3	35.4	66	FAIR
Knaipur Bazar	S8	33.3	33.3	27	68.6	FAIR

4. DISCUSSION

From the table-9, it is evident that the water quality of Faridpur Sadar is not satisfactory. According to WAM WQI value, most of the sampling points do not hold any good score. Among the eight sampling locations, six locations have a WQI value of more than 50, which indicates the water quality is not suitable for drinking purposes. Furthermore, out of the six bad scores that are greater than 50, three locations have poor water quality, one location having very poor quality and two marked as fully unsuitable for drinking purpose. Only one water quality at sampling point S3 has excellent water quality and one at S8 has good water quality. The scenario is different when the CCME WQI value is considered. According to CCME WQI, all the results hold satisfactory scores falling under the fair category except for S3, which falls in good water quality. Even though, the arsenic value of sample S2 and S4 crosses the acceptable limit, according to CCME method, they are fair, similar to other samples which do not cross the acceptable limit of arsenic. This interrupts to discern for which parameter the water quality fluctuates and which is the most deleterious parameter.

Table- 9: Location specific WQI by Weighted Arithmetic and CCME Method

Location	**Sample Name**	**WQI by Weighted Arithmetic Method**		**WQI by CCME Method**	
		WQI Value	Category	WQI Value	Category
Faridpur dhaka highway	S1	52.68	Poor water quality	65.5	FAIR
Faridpur vanga highway	S2	151.11	Unsuitable for drinking purpose	66.5	FAIR
Faridpur chowdhury bari	S3	20.74	Excellent water quality	82.1	GOOD
Faridpur Ambika Road	S4	137.90	Unsuitable for drinking purpose	66.8	FAIR
Faridpur Tepakhola	S5	66.05	Poor water quality	77.5	FAIR
Faridpur municipal water supply	S6	58.25	Poor water quality	75.7	FAIR
Goalchamot near bus stand	S7	90.51	Very Poor water quality	66	FAIR
Knaipur Bazar	S8	43.56	Good water quality	68.6	FAIR

While, in CCME method water quality index falls only in two categories (i.e. good & fair), in WAM index same numbers can be categorized into five classes which becomes more convenient in comparing the quality of different sources.

Table- 10: Unit Weight (W_i) assigned to parameters by Weighted Arithmetic in descending order

Parameter	**Weightage (Wi)**
Arsenic	0.754186
BOD	0.188547
Iron	0.037709
DO	0.006285
PH	0.004436
Turbidity	0.003771
Nitrate	0.003771
Temp	0.001257
TDS	0.000038

In WAM, weights are given to each parameter according to their acceptance range. The parameter which has a low range of acceptance gets the highest weight. On the contrary, parameter having the highest acceptance range gets the lowest scores. In this case, as arsenic has the lowest acceptance range (0.05 ppm), it got the highest weight of 0.754186. On the other hand, TDS having the highest acceptance range (1000 ppm) has the lowest weight of 0.000038 (table-10). This means that a slight change in the value of the higher weight parameter (i.e. Arsenic, BOD, Iron, etc.) will affect more on the index value than the same amount of change in the lowest weight parameters. In our cases, it can be seen that the value of the higher weightage parameters differs much from one sampling point to another compared to lower weight parameters. This change in value has a great impact on the water quality index value. Therefore, in WAM, the WQI value differs much at different sampling locations.

On the other hand, in the CCME Method, no such weight is assigned to the parameters. The scope, frequency, and amplitude are only considered calculating WQI value. Having all the parameters the same weight, a small change in the value of one parameter (which got higher weightage in WAM, i.e. Arsenic, Iron, BOD) does not have the same impact as like as WAM.

From the WQI values, it can be inferred that the poorest category of WQI at sample S4 was due to the presence of the highest concentration of arsenic and at sample S2 was due to high concentration of both arsenic and BOD. The abundance of iron and BOD made sample S7 holding very poor water quality. The higher concentration of BOD with the lowest amount of DO at sample S1, the marginal value of BOD and arsenic concentration at sample S5 and a higher concentration of BOD at sample S6, categorized them as a poor category. Here, interestingly, in sample S1 though there is no presence of arsenic, a higher concentration of BOD and iron classified the water quality as poor. Subsequently, the absence of arsenic in sample S8 rated it to be good and the absence of arsenic and the lowest concentration of BOD at S3 rated it to be excellent.

5. CONCLUSIONS

From the above study, it can be concluded that both natural lithology and anthropogenic activities are contaminating the groundwater in Faridpur Sadar. As among eight samples, only one sample was found to be excellent according to the WAM WQI method and fair according to the CCME method, the majority of the groundwater sources need some degrees of treatment before consuming it and protection also needed to halt prevailing and further contamination. The study hopes that the policymakers will find the result as a reference while planning programs for the welfare for the community people and the quantification of water quality along with the parameters will help the local people to choose the better source available and raise awareness among them.

REFERENCES

Akoteyon, I. S., Omotayo, A. O., Soladoye, O., & Olaoye, H. O. (2011). Determination of water quality index and suitability of urban river for municipal water supply in Lagos-Nigeria. European Journal of Scientific Research, 54(2), 263-271.

Akter, T., Jhohura, F. T., Akter, F., Chowdhury, T. R., Mistry, S. K., Dey, D., & Rahman, M. (2016). Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study. Journal of Health, Population and Nutrition, 35(1), 4.

Alam, G. J. (2009). Environmental pollution of Bangladesh—it's effect and control. Pulp and Paper, 51, 13-7.

Bangladesh Bureau of Statistics. (2011). District Statistics 2011 Faridpur District. Dhaka, Bangladesh:

Bhuiyan, M. A., Islam, M. A., Dampare, S. B., Parvez, L., & Suzuki, S. (2010). Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of northwestern Bangladesh. Journal of Hazardous Materials, 179(1-3), 1065-1077.

Biswas, R. K., Roy, D. K., Islam, A. R. M. T., Rahman, M. M., & Ali, M. M. (2014). Assessment of drinking water related to arsenic and salinity hazard in Patuakhali district, Bangladesh. Int J Adv Geosci, 2(2), 82-85.

Bodrud-Doza, M., Islam, A. T., Ahmed, F., Das, S., Saha, N., & Rahman, M. S. (2016). Characterization of groundwater quality using water evaluation indices, multivariate statistics and geostatistics in central Bangladesh. Water Science, 30(1), 19-40.

Bozdağ, A. (2015). Combining AHP with GIS for assessment of irrigation water quality in Çumra irrigation district (Konya), Central Anatolia, Turkey. Environmental earth sciences, 73(12), 8217-8236.

Brown, R. M., McClelland, N. I., Deininger, R. A., & Tozer, R. G. (1970). A Water Quality Index- Do We Dare.

Canadian Council of Ministers of the Environment. (2001). Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0, User's Manual. Canadian Environmental Quality Guidelines.

Damo, R., & Icka, P. (2013). Evaluation of Water Quality Index for Drinking Water. Polish Journal of Environmental Studies, 22(4).

Department of Public Health Engineering.(2012). Union wise water technology mapping [Faridpur Circle].Dhaka, Bnagladesh: Author.

DISLEY, Y. P. (2013). Sustainable development goals for people and planet. NATURE, 495, 21.

Fawell, J. K., & Mascarenhas, R. (2011). Arsenic in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. Guidelines for Drinking-water Quality, 24.

Hossen, M. A., Rafiq, F., Kabir, M. A., & Morshed, M. G. (2019). Assessment of Water Quality Scenario of Karnaphuli River in Terms of Water Quality Index, South-Eastern Bangladesh. American Journal of Water Resources, 7(3), 106-110.

Islam, A. T., Shen, S., Bodrud-Doza, M. D., & Rahman, M. S. (2017). Assessing irrigation water quality in Faridpur district of Bangladesh using several indices and statistical approaches. Arabian Journal of Geosciences, 10(19), 418.

Katyal, D. (2011). Water quality indices used for surface water vulnerability assessment. International journal of environmental sciences, 2(1).

Rahaman, M. F., Ali, M. S., Arefin, R., Mazumder, Q. H., Majumder, R. K., & Jahan, C. S. (2019). Assessment of drinking water quality characteristics and quality index of Rajshahi city, Bangladesh. Environment, Development and Sustainability, 1-15.

Rahman, M. S., Molla, A. H., Saha, N., & Rahman, A. (2012). Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. Food Chemistry, 134(4), 1847-1854.

Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. Journal of Chemistry, 6(2), 523-530.

Rani, J., Kannagi, A., & Shanthi, V. (2012). Correlation of total heterotrophic bacterial load in relation with hydrographical features of Pazhayakayal estuary, Tuticorin, India. Journal of environmental biology, 33(4), 769.

Saha, R., Dey, N. C., Rahman, S., Galagedara, L., & Bhattacharya, P. (2018). Exploring suitable sites for installing safe drinking water wells in coastal Bangladesh. Groundwater for Sustainable Development, 7, 91-100.

Semiromi, F. B., Hassani, A. H., Torabian, A., Karbassi, A. R., & Lotfi, F. H. (2011). Water quality index development using fuzzy logic: A case study of the Karoon River of Iran. African Journal of Biotechnology, 10(50), 10125-10133.

Shahidullah, S. M., Hakim, M. A., Alam, M. S., & Shamsuddoha, A. T. M. (2000). Assessment of a Groundwater Quality in a Selected Area of Bangladesh. Pakistan J. Bio. Sci, 3(2), 246-249.

Standard, B. (1997). The environment conservation rules 1997. Government of the People's Republic of Bangladesh, Dhaka.

Swarnokar, S. C., Hassan, N., Rahman, M., Islam, M. M., & Ara, M. H. (2019). Assessment of Groundwater Quality in a Tidal River Basin of the Ganges Delta in Bangladesh. Journal of Geoscience and Environment Protection, 7(5), 131-151.

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of water quality index. American Journal of Water Resources, 1(3), 34-38.

World Health Organization (WHO). (1996). Guidelines for Drinking Water Quality. 2nd Edn, Vol. 2. Health Criteria and Other Supporting Information. Geneva, Switzerland: World Health Organization.

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REMOVAL OF EXCESSIVE NITROGEN AND PHOSPHORUS CONTENT FROM URBAN WASTEWATER USING LOCAL MICROALGAL BLOOM

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ABSTRACT

Urban wastewater is composed of various organic and inorganic substances which are capable of destroying the ecology of receiving water bodies. Therefore, for the treatment purpose, various efficient conventional processes have been applied so far to remove the easily settleable matter to oxidize the oxidizing compounds. However, this secondary effluent contains excessive inorganic nitrogen and phosphorus content whose biological treatments are rarely found. For this reason, microalgae, which has biodiesel potential, is used in this study for the removal of inorganic nitrogen and phosphorus from the secondary effluent. In this study, algal strains have been collected from locally available natural algal blooms and cultured in BG-11 medium. *Spirullina sp.*, the blue-green algae has been found to be dominant over the other species within the natural bloom. Ten different dosage (0.2-2.5 g/L) of *Spirullina sp.* have been applied to the synthetic wastewater and the removal efficiency of nitrate, ammonia and phosphate have been observed to be about 60%, 30% and 54% respectively. The highest removal efficiency has been found at 2.5 g/L of microalgae dose. Note that a 3-day hydraulic retention time has been kept in this experiment for all algal dosages. Linear forms of Langmuir and Freundlich isotherms have been used for biosorption modelling, and both isotherms fit well with R^2>60% and NRMSE<11% in all cases. Additionally, the separation factor and the adsorption intensity represent the favorability of the biosorption process.

Keywords: *Wastewater treatment, Urban wastewater, Microalgae, Biosorption.*

1. INTRODUCTION

Water is a fundamental necessity for life. Every metabolism inside a body depend on water. However, only 2.66% of the total water resource is freshwater. For this reason, the conservation of freshwater sources has become a priority throughout the world. The qualitative and quantitative threats to water resources have imposed due to man-made pollution. The urban municipal wastewater generally originated from domestic and community uses. An urban city having a population of 5,00,000 and water consumption of 0.2 $td^{-1}capita^{-1}$, produces 85,000 td^{-1} of wastewater approximately (Cai, Park, & Li, 2013). The inorganic component of municipal wastewater contributes greatly to the accumulation of nitrogen and phosphorus in receiving water bodies. The source of nitrogen and phosphorus in municipal wastewater is various household activities (Abdel-Raouf, Al-Homaidan, & Ibraheem, 2012). About 30-50% of the phosphorus originated from human wastes such as feces, urine and waste food. The remaining phosphorus content (about 50-70%) comes from Detergents which are used for laundering of clothes (Barth, Smith, Brunner, & Farrell, 1976). More often these pollutants initiate into the environment without proper treatment (Mouchet, 1986).These anthropogenic activities affect the aquatic ecosystem severely (Mennaa, Arbib, & Perales, 2015). Eutrophication is a common phenomenon causes due to an excess amount of nitrogen and phosphorus. It means a dense population of algae on the water surface (Hutchinson, 1973). Due to eutrophication, the growth of algae and higher forms of plants are accelerated. As a result of eutrophication, oxygen depletion and toxic effect occurs in the receiving water body along with several adverse ecological impacts and decreased lifespan of acquatic organisms (Henze, Harremoes, la Cour Jansen, & Arvin, 2001). The water quality degrades gradually (Commission, 2002). The area of surface water polluted with algal bloom is not suitable for uses such as drinking, irrigation, industry, recreation, or fishing (Carpenter et al., 1998). The toxic effect may enter into the food chain and causes various kind of diseases to human.

Aside from imbalance the aquatic ecosystem, humans and animals who depend on the water of receiving water bodies are facing a greater threat to their health. Exposure to excess amount of Nitrate may cause gastric cancer, impose threats to newborn child and pregnant ladies, and changes the composition of hemoglobin which is responsible for methaemoglobinemia or blue baby syndrome in infant (Ghafari, Hasan, & Aroua, 2008; Mayo & Hanai, 2014). Due to blue baby syndrome, respiratory problems, digestive problems like diarrhea, vomiting, and in extreme cases even death in young children may occur. Nitrate also have carcinogenic, teratogenic and mutagenic properties (Abel, 2014). Ammonia and Phosphorus don not have any direct effect on human or animals. The necessity of removing them from municipal wastewater is protecting the food chain (Klaassen & Amdur, 2013).

Therefore, the necessity of wastewater recycling and energy recovery have arisen for potable water, energy, and food. (de la Noue & de Pauw, 1988). However, it is very difficult to find a solution for the treatment and safe discharge of wastewater. Since the solution involves integrated processes, the technical, economic and financial issues must be considered. Activate sludge process is a very popular conventional method for wastewater treatment. This process shows a higher removal of biodegradable material by using bacteria in primary and secondary treatments of effluent. This apparently clean secondary treated effluent contains a large number of inorganic compounds, like nitrogen and phosphorus. he disposal of large volume of sludge is also troublesome and may lead to secondary pollution (Olguín, 2012). The total cost of wastewater treatment increases for each additional step (Oswald, 1988). For removing nitrates, ammonia and phosphate from wastewater completely, a tertiary treatment process costs four times more than primary treatment process (de la Noue & de Pauw, 1988). Lastly, the conventional treatment processes lead to incomplete utilization of natural resources (Guterstam & Todd, 1990; Phang, 1990).

On the other hand, the capacity of microalgae for inorganic nutrient uptake is very high (Blier, Laliberte, & De la Noüe, 1995; Talbot & De la Noüe, 1993). Therefore, as a potential alternative, wastewater treatment by using microalgae has been proposed as a tertiary treatment process (Olguín, 2003; Sturm & Lamer, 2011). Biological removal of nutrients by means of microalgae offers several advantages over tertiary chemical and physicochemical treatments (De la Noüe & Basseres, 1989; Proulx & De la Noue, 1988). Algal treatment is favorable because of photosynthesis characteristics of algae. During photosynthesis solar energy converts into useful biomasses by combining nutrients such as nitrogen and phosphorus and carbon-di-oxide from the environment (Cai et al., 2013; de la Noue & de Pauw, 1988; Martínez, Sánchez, Jiménez, El Yousfi, & Muñoz, 2000; Tam & Wong, 1995). It is cost effective and environment-friendly method (Pittman, Dean, & Osundeko, 2011; Tang, Vincent, Proulx, Lessard, & De La Noüe, 1997). Microalgae also produce oxygen during photosynthesis process and also have a disinfection effect due to elevated pH (Mara & Pearson, 1986; Martínez et al., 2000). The main challenges for this technology lie in the wastewater composition, microalgae species and the final utilization of biomass yield (Jais, Mohamed, Al-Gheethi, & Hashim, 2017). The harvested microalgae can be used for the production of biofuel, fertilizers, various high-value products like Pharmaceuticals and genetically engineered products (Javanmardian & Palsson, 1991; Mallick, 2002; Mennaa et al., 2015). These include antibacterial, antiviral, antitumor/ anticancer, antihistamine and many other biologically valuable products (Haroun, Sharaf, & Ibrahee, 1995; Ibraheem, 1995). Blue-green algae are a prominent form of microalgae within the natural bloom in freshwater (Cai et al., 2013; Kotak et al., 1993; Smith, 1998). They are also potential for the removal of inorganic nutrients from wastewater (Sawayama, Rao, & Hall, 1998). It is also well established that blue-green algae are capable of reducing nitrate, ammonia and phosphate (Garbisu, Hall, & Serra, 1993; Romero, Coronil, Lara, & Guerrero, 1987).

Nutrients from wastewater generally uptake by algae for their cellular growth. For the growth of organisms, nitrogen is considered as a critical nutrient. Within a cell of any organism, organic nitrogen is found in the form of biological substances. They are- peptides, proteins, enzymes, chlorophylls, energy transfer molecules (ADP, ATP), and genetic materials (RNA, DNA) (Barsanti & Gualtieri, 2014). Microalgae convert inorganic nitrogen into organic nitrogen by the assimilation process. Eukaryotic algae perform the assimilation process by using nitrate, nitrite and ammonium which are the forms of inorganic nitrogen (Cai et al., 2013). Inorganic phosphorus is also very important for microalgae growth and metabolism. It is found in nucleic acids, lipids, proteins, and the intermediates of carbohydrate metabolism. Phosphorus also helps to generation of ATP from adenosine diphosphate (ADP), accompanied by a form of energy input (Martinez, Jimenez, & El Yousfi, 1999).

The efficiency of microalgae for removing nitrogen and phosphorus content from municipal wastewater has been shown in many studies. *Chlorella vulgaris* has an efficiency of removing 86% of inorganic nitrogen and 78% of inorganic phosphorus (Lau, Tam, & Wong, 1997). The study shows 86% and 70% removal of inorganic nitrogen and phosphorus respectively by *Chlorella vulgaris* too (Lau, Tam, & Wong, 1996). For *Natural bloom*, the efficiency is more than 87% and 80% for removing nitrogen and phosphorus respectively (Mennaa et al., 2015). About 97.8% of phosphorus is removed from domestic sewage by algae (Colak & Kaya, 1988). *Spirulina maxima* show the removal of 87% nitrogen and 60% phosphorus at HRT of 4 days (Kosaric, Nguyen, & Bergougnou, 1974). Promising nutrient removal by *Spirulina plantensis* also confirmed (Lodi, Binaghi, Solisio, Converti, & Del Borghi, 2003).

1.1. Knowledge Gap

The theory of wastewater treatment with microalgae has established around 50 years ago. Since then several studies have conducted by using laboratory cultured single microalgae species. A single microalgae strain collected from any laboratory having a controlled atmosphere needs high maintenance. The removal efficiency also decreases due to seasonal temperature variation. However, a complete study using algae only from the local source does not conduct yet. To fill in this gap, the wastewater has been treated in this study with locally available microalgae.

2. METHODOLOGY

Natural-bloom Culture:

Microalgae sample for this study was collected from the natural bloom in pond by the side of university avenue, Shahjalal University of Science and Technology, Sylhet. The collected sample was primarily stored in filtered pond water in a 0.5 L plastic bottle. Naturally grown microalgae may arise sporadically as water blooms in ponds. Generally, a large number of these natural blooms are consist of unicellular blue-green algae (Geitler, 1932). For this reason, the BG-11 cultural medium has been selected to ensure the growth of microalgae. Medium BG-11 is neutral after sterilization. It supports the growth of the algal population in the air (Stanier, Kunisawa, Mandel, & Cohen-Bazire, 1971). The pH of the BG-11 culture medium maintained 7.1 by using 1M NaOH. After adjusting the pH, the solution was autoclaved at 121°C for 15 min. The medium was cooled before adding the collected microalgae sample. The collected microalgae were separated from pond water by filtration. Then the filtrate was added to a sterilized BG-11 medium in three 1L beakers. Continuous air supply had maintained by using air pump. A 16:8 hr light:dark cycle was maintaind throughout the culture condition. pH had measured once a day and maintained as 7.1.

2.3 Growth Rate Measurement

A 10 mL sample from each batch has been collected daily at mid day. Spectrophotometric analyses of the collected samples are done by using a UV spectrophotometer. Optical density has been measured from the absorbance of 680 nm wavelength. The optical density indicates the density of microalgae. Using the optical density (OD_{680}) the growth rate of microalgae is calculated by using the following exponential formula:

$$\text{Growth rate, GR (per day)} = \frac{\ln OD_t - \ln OD_0}{t} \tag{1}$$

where, OD_0 represents the optical density at initial day and OD_t represents optical density measured at day t (L. Wang et al., 2010). After attaining a satisfactory growth rate after 18 days, the mass culture of microalgae has been started. For mass culture, the microalgae were moved from 1L beaker to a large tank. The dimension of the tank is 60 cm × 20 cm. A total 10L BG-11 medium is used for mass culture.

2.4 Synthetic Wastewater Composition

Synthetic wastewater is a chemically derived wastewater. The chemical content of the synthetic wastewater used in this study had chosen to compare the nutrient content of wastewater within Sylhet city and from the literature review. Seven random points had chosen for the collection of wastewater samples. The selection of collecting points was based on: upstream and downstream of canals, location of residential areas and reconnaissance survey. The measured nutrient content of Sylhet city wastewater was compared with the values obtained from the literature review (Table 1). The highest values of nitrate, ammonia and phosphate were selected for chemical content of synthetic wastewater. For the chemical composition of synthetic wastewater, the highest nutrient content was selected from Table 1. The concentration of the nutrients in synthetic wastewater were set as 17mg/L, 100 mg/L and 212 mg/L respectively.

Table 1: Nutrient Content of Wastewater.

Nutrient	**Samples from Sylhet City [mg/L]**							**Concentration in sysnthetic wastewater [mg/L]**
	1	**2**	**3**	**4**	**5**	**6**	**7**	
Nitrate	3.4	2.8	4.3	1.2	1.1	0.4	0.5	17[a]
Ammonia	21.0	4.5	9.6	22.0	1.4	20.1	16.3	100[b]
Phosphate	5.3	3.5	4.5	5.7	0.9	5.4	1.3	212[b]

[a](Cho, Luong, Lee, Oh, & Lee, 2011), [b](Zhou et al., 2012)

3. Experimental Setup

The experiments with synthetic wastewater were done on a laboratory scale. For each dose, three 1L solutions of synthetic wastewater were made. The hydraulic retention time (HRT) for all doses remained constant and it was 3 days. As a light source, two 23W fluorescent lights were used (Figure 1(a)). The fluorescent lights had provided 3600 lumens light intensity continuously for the photosynthesis process. To provide turbulence within the wastewater sample, magnetic stirrer at 350 rpm was used (Figure 1(b)).

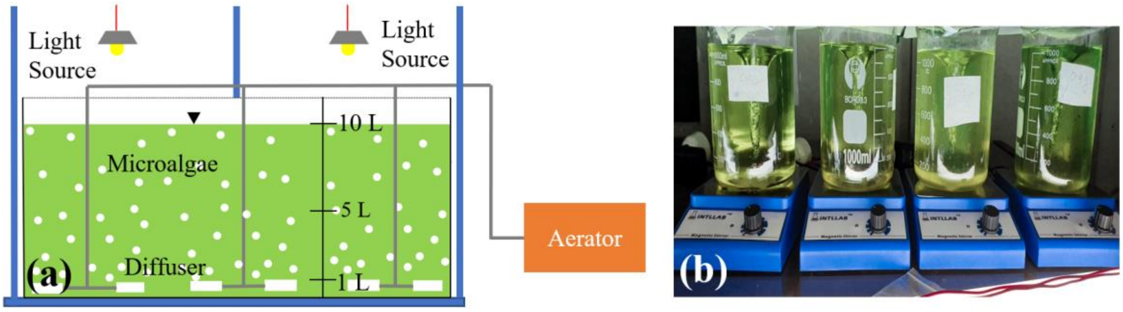

Figure 1: Panel (a) represents the schematic diagram of mass culture of microalgae using 60 cm × 20 cm tank and Panel (b) represents the experimental setup of synthetic wastewater treatment

4. Biosorption Modelling

Nutrient removal by microalgae is a biosorption process. Biosorption is a physicochemical and metabolically-independent process. The significance of biosorption processes in the environment and conventional biotreatment processes is irrefutable. The aim of biosorption modeling is experimental data analyses, understanding process mechanisms, prediction of operational condition changes and optimizing processes (Fomina & Gadd, 2014). For comparison among different types of biosorbents and their capacities of pollutant uptake, the biosorption process can be expressed as an equilibrium isotherm curve (Vijayaraghavan & Yun, 2008). For simple single component models, Langmuir and Freundlich's versions are used widely (Gadd, 2009; Pagnanelli, Esposito, & Vegliò, 2002). In the Langmuir isotherm model, monolayer adsorbate adsorption is occurred at or before a relative pressure of unity is reached (Liu, Luo, Ding, & Luo, 2019). No further sorption can take place when the layer is filled. This causes the surface to be saturated where the maximum adsorption is achieved (Boparai, Joseph, & O'Carroll, 2011). The Freundlich equilibrium isotherm is an empirical exponential equation. It assumes that due to the increase of Adsorbate concentration, the concentration of Adsorbate on the adsorbent surface also increases (Hamdaoui & Naffrechoux, 2007; Liu et al., 2019). Freundlich isotherm describes the surface heterogeneity. The exponential distribution of active sites and their energies are also expressed by Freundlich equilibrium isotherm model (Ayawei, Ekubo, Wankasi, & Dikio, 2015; C. Wang, Hu, Chen, & Wu, 2005). For biosorption modelling, Langmuir (Langmuir, 1916) and Freundlich (Freundlich, 1906) isotherm models were used in this study.

5. RESULT AND DISCUSSION

Growth rate and nutrient removal by *Spirulina sp.*

The microalgae species had been identified from microscopic photograph after two months of culture. The dominant algae found in the culture was *Spirulina sp.* The growth rate of microalgae was measured in terms of OD_{680}. From the growth rate curve, the behavior of microalgae in cultural medium can be stated (Figure 2(a)). No lag phase was observed throughout the curve which indicated the well adaptation of microalgae in cultural medium. An exponential growth phase had observed after 8 days of culture. The exponential growth phase was remain for 1 day, and thereafter a comparatively stationary growth phase had achieved.
Removal of nitrate, ammonia and phosphate from municipal wastewater is a vital issue for saving the natural water source from pollution. This study was conducted in an aim of reducing maximum

amount of nutrient enrichments within 3 days of HRT. Figure 2(b) shows that the maximum reduction in nitrate, ammonia and phosphate was about 66%, 30% and 54% respectively when the algal dose was 2.5 g/L.

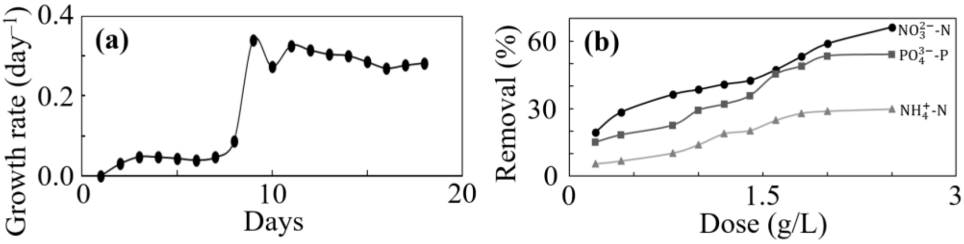

Figure 2: Growth Rate of *Spirulina sp.* and its efficiency to remove nutrients from wastewater

Calibration results

Langmuir isotherm model expresses the monolayer adsorption on adsorbent. The essential characteristics of the model is expressed by the dimensionless constant R_L. For all three nutrients, the values of R_L are within the range $0<R_L<1$ (Table 2). Therefore, the biosorption of the nutrients can be considered as favorable and the values of R^2 and NRMSE also represents the data are well fitted in the model (see Figure 3(a-b)).

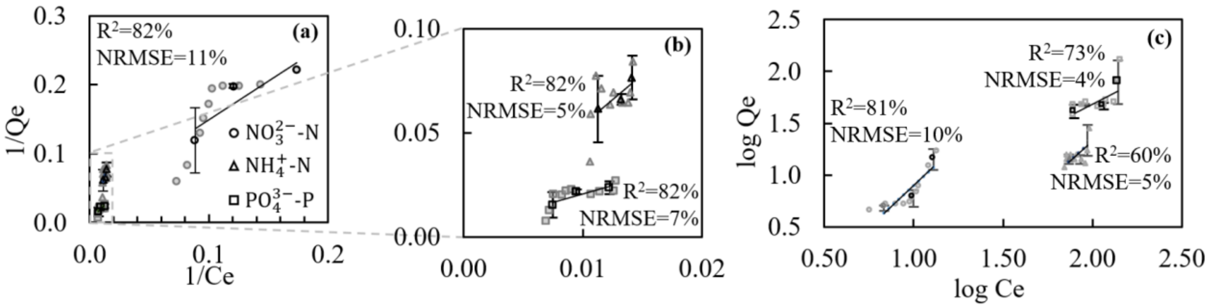

Figure 3: Graphical representation of Langmuir and Freundlich Isotherm Models. Panel (a) and (b) represents Langmuir model, where Panel (a) includes all three nutrients and Panel (b) represents the magnified section of Panel (a). Panel (c) represents Freundlich model.

Freundlich isotherm model supports the surface heterogeneity. The parameters K_F and 1/n from this model express the adsorption capacity (L/mg) and adsorption intensity respectively. Figure 3(c) shows the values of R^2 and NRMSE are around 60-80% and 3-10% respectively which represents the sound goodness of fit of the modelled data. The values of 1/n for all nutrients are seen to be greater than unity (Table 2), which symbolizes the increment of absorption coefficient with the increment of solution concentration. As a result, hydrophobic surface characteristics increase after monolayer. Again, the value of 1/n within the range of 1-10 expresses the favorability of the biosorption for all components.

Table 2: Calibrated values of both Langmuir and Freundlich model parameters.

Parameters	**$1/Q_m$**	**K_L**	**R_L**	**$logK_F$**	**1/n**
Nitrate	0.036	0.033	0.64	-0.71	1.61
Ammonia	0.006	0.001	0.89	-1.73	1.53
Phosphate	0.004	0.003	0.79	-0.24	1

6. CONCLUSION

Municipal wastewater possess a huge amount of nutrient load. Untreated nutrient content pollute the receiving water bodies and causes eutrophication which is harmful for human, animals and aquatic ecosystem. To solve the situation, this study has been conducted to find out the efficiency of microalgae in case of nutrient removal. The compatibility of natural bloom culture in BG-11 media also showed here. Among the species of natural bloom, Spirulina sp. has become dominant. Though Spirullina sp. is a Prokaryotic cell, it is able to do the photosynthesis process just like the Eukaryotic microalgae. However, the debate of cyanobacteria being Prokaryotic or Eukaryotic is still exiting.

In this study, Spirullina sp., a blue-green algae is used for treatment purpose. This blue-green algae has shown a promising removal efficiency of nitrate, ammonia and phosphate. However, around 30%, 70% and 40% of nitrate, ammonia and phosphate respectively could not be removed by Spirullina sp. These results has been obtained for 3-day HRT and 2.5 g/L algal dose. The feasibility of this biosorption treatment has confirmed by the Langmuir and Freundlich isotherm models. In both cases, the separation factor and the adsorption intensity have been found to below unity. Therefore, not only the favorable adsorption of nitrate, ammonia and phosphate has established but also well goodness of fit of both models have established by blue-green algae Spirulina sp.

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REFERENCES

Abdel-Raouf, N., Al-Homaidan, A., & Ibraheem, I. (2012). Microalgae and wastewater treatment. Saudi journal of biological sciences, 19(3), 257-275.

Abel, P. D. (2014). Water pollution biology: CRC Press.

Ayawei, N., Ekubo, A., Wankasi, D., & Dikio, E. (2015). Adsorption of congo red by Ni/Al-CO3: equilibrium, thermodynamic and kinetic studies. Oriental Journal of Chemistry, 31(3), 1307-1318.

Barsanti, L., & Gualtieri, P. (2014). Algae: anatomy, biochemistry, and biotechnology: CRC press.

Barth, E., Smith, J., Brunner, C., & Farrell, J. (1976). Process design manual for phosphorus removal. US Environ. Protection Agency Report EPA, 625, 1-76.

Blier, R., Laliberte, G., & De la Noüe, J. (1995). Tertiary treatment of cheese factory anaerobic effluent with Phormidium bohneri and Micractinum pusillum. Bioresource Technology, 52(2), 151-155.

Boparai, H. K., Joseph, M., & O'Carroll, D. M. (2011). Kinetics and thermodynamics of cadmium ion removal by adsorption onto nano zerovalent iron particles. Journal of Hazardous Materials, 186(1), 458-465. doi:https://doi.org/10.1016/j.jhazmat.2010.11.029

Cai, T., Park, S. Y., & Li, Y. (2013). Nutrient recovery from wastewater streams by microalgae: status and prospects. Renewable and Sustainable Energy Reviews, 19, 360-369.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological applications, 8(3), 559-568.

Cho, S., Luong, T. T., Lee, D., Oh, Y.-K., & Lee, T. (2011). Reuse of effluent water from a municipal wastewater treatment plant in microalgae cultivation for biofuel production. Bioresource Technology, 102(18), 8639-8645. doi:https://doi.org/10.1016/j.biortech.2011.03.037

Colak, O., & Kaya, Z. (1988). A study on the possibilities of biological wastewater treatment using algae. Doga Biyoloji Serisi, 12, 18-29.

Commission, E. (2002). Commission Decision 2002/657/EC of 12 August 2002 implementing Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results. Off J Eur Comm, 221, 8-36.

De la Noüe, J., & Basseres, A. (1989). Biotreatment of anaerobically digested swine manure with microalgae. Biological wastes, 29(1), 17-31.

de la Noue, J., & de Pauw, N. (1988). The potential of microalgal biotechnology: A review of production and uses of microalgae. Biotechnology Advances, 6(4), 725-770. doi:https://doi.org/10.1016/0734-9750(88)91921-0

Fomina, M., & Gadd, G. M. (2014). Biosorption: current perspectives on concept, definition and application. Bioresource Technology, 160, 3-14.

Freundlich, H. (1906). Over the adsorption in solution. J. Phys. Chem, 57(385471), 1100-1107.

Gadd, G. M. (2009). Biosorption: critical review of scientific rationale, environmental importance and significance for pollution treatment. Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology, 84(1), 13-28.

Garbisu, C., Hall, D. O., & Serra, J. L. (1993). Removal of phosphate by foam-immobilized Phormidium laminosum in batch and continuous-flow bioreactors. Journal of Chemical Technology & Biotechnology, 57(2), 181-189.

Geitler, L. (1932). Cyanophyceae. Kryptogramenflora von Deutschland, Osterreich und der Schweiz, 14, 130-148.

Ghafari, S., Hasan, M., & Aroua, M. K. (2008). Bio-electrochemical removal of nitrate from water and wastewater—a review. Bioresource Technology, 99(10), 3965-3974.

Guterstam, B., & Todd, J. (1990). Ecological engineering for wastewater treatment and its application in New England and Sweden. Ambio, 19(3), 173-175.

Hamdaoui, O., & Naffrechoux, E. (2007). Modeling of adsorption isotherms of phenol and chlorophenols onto granular activated carbon: Part I. Two-parameter models and equations allowing determination of thermodynamic parameters. Journal of Hazardous Materials, 147(1), 381-394. doi:https://doi.org/10.1016/j.jhazmat.2007.01.021

Haroun, B., Sharaf, A., & Ibrahee, I. (1995). Evaluation of natural products in some common Egyptian marine algae. J. Union, Arab. Biol., 2 (B), 137–153. Paper presented at the 2nd International Conference.

Henze, M., Harremoes, P., la Cour Jansen, J., & Arvin, E. (2001). Wastewater treatment: biological and chemical processes: Springer Science & Business Media.

Hutchinson, G. E. (1973). Marginalia: Eutrophication: The scientific background of a contemporary practical problem. American scientist, 61(3), 269-279.

Ibraheem, I. (1995). Phytochemical studies on some common algae of El-Sukhna and Abu-Qir Gulf. M. Sc. Thesis, Al-Azhar Univ., Fac. of Sci. Cairo, Egypt,

Jais, N. M., Mohamed, R. M. S. R., Al-Gheethi, A. A., & Hashim, M. K. A. (2017). The dual roles of phycoremediation of wet market wastewater for nutrients and heavy metals removal and microalgae biomass production. Clean Technologies and Environmental Policy, 19(1), 37-52. doi:10.1007/s10098-016-1235-7

Javanmardian, M., & Palsson, B. O. (1991). High-density photoautotrophic algal cultures: Design, construction, and operation of a novel photobioreactor system. Biotechnology and Bioengineering, 38(10), 1182-1189.

Klaassen, C. D., & Amdur, M. O. (2013). Casarett and Doull's toxicology: the basic science of poisons (Vol. 1236): McGraw-Hill New York.

Kosaric, N., Nguyen, H., & Bergougnou, M. (1974). Growth of Spirulina maxima algae in effluents from secondary waste-water treatment plants. Biotechnology and Bioengineering, 16(7), 881-896.

Kotak, B. G., Kenefick, S. L., Fritz, D. L., Rousseaux, C. G., Prepas, E. E., & Hrudey, S. E. (1993). Occurrence and toxicological evaluation of cyanobacterial toxins in Alberta lakes and farm dugouts. Water Research, 27(3), 495-506.

Langmuir, I. (1916). The constitution and fundamental properties of solids and liquids. Part I. Solids. Journal of the American chemical society, 38(11), 2221-2295.

Lau, P., Tam, N., & Wong, Y. (1996). Wastewater nutrients removal by Chlorella vulgaris: optimization through acclimation. Environmental technology, 17(2), 183-189.

Lau, P., Tam, N., & Wong, Y. (1997). Wastewater nutrients (N and P) removal by carrageenan and alginate immobilized Chlorella vulgaris. Environmental technology, 18(9), 945-951.

Liu, L., Luo, X.-B., Ding, L., & Luo, S.-L. (2019). 4 - Application of Nanotechnology in the Removal of Heavy Metal From Water. In X. Luo & F. Deng (Eds.), Nanomaterials for the Removal of Pollutants and Resource Reutilization (pp. 83-147): Elsevier.

Lodi, A., Binaghi, L., Solisio, C., Converti, A., & Del Borghi, M. (2003). Nitrate and phosphate removal by Spirulina platensis. Journal of Industrial Microbiology and Biotechnology, 30(11), 656-660. doi:10.1007/s10295-003-0094-5

Mallick, N. (2002). Biotechnological potential of immobilized algae for wastewater N, P and metal removal: A review. Biometals, 15(4), 377-390. doi:10.1023/a:1020238520948

Mara, D., & Pearson, H. (1986). Artificial freshwater environment: waste stabilization ponds. Biotechnology, 8, 177-206.

Martinez, M., Jimenez, J., & El Yousfi, F. (1999). Influence of phosphorus concentration and temperature on growth and phosphorus uptake by the microalga Scenedesmus obliquus. Bioresource Technology, 67(3), 233-240.

Martínez, M. E., Sánchez, S., Jiménez, J. M., El Yousfi, F., & Muñoz, L. (2000). Nitrogen and phosphorus removal from urban wastewater by the microalga Scenedesmus obliquus. Bioresource Technology, 73(3), 263-272. doi:https://doi.org/10.1016/S0960-8524(99)00121-2

Mayo, A. W., & Hanai, E. E. (2014). Dynamics of nitrogen transformation and removal in a pilot high rate pond.

Mennaa, F. Z., Arbib, Z., & Perales, J. A. (2015). Urban wastewater treatment by seven species of microalgae and an algal bloom: biomass production, N and P removal kinetics and harvestability. Water Research, 83, 42-51.

Mouchet, P. (1986). Algae reactions to mineral and organic micropollutants, ecological consequences and possibilities of industrial-scale application: a review. Water Research, 20(4), 399-412.

Olguín, E. J. (2012). Dual purpose microalgae–bacteria-based systems that treat wastewater and produce biodiesel and chemical products within a Biorefinery. Biotechnology Advances, 30(5), 1031-1046.

Olguín, E. J. (2003). Phycoremediation: key issues for cost-effective nutrient removal processes. Biotechnology Advances, 22(1-2), 81-91.

Oswald, W. J. (1988). Micro-algae and wastewater treatment. Microalgal biotechnology, 305-328.

Pagnanelli, F., Esposito, A., & Vegliò, F. (2002). Multi-metallic modelling for biosorption of binary systems. Water Research, 36(16), 4095-4105.

Phang, S.-M. (1990). Algal production from agro-industrial and agricultural wastes in Malaysia. Ambio, 415-418.

Pittman, J. K., Dean, A. P., & Osundeko, O. (2011). The potential of sustainable algal biofuel production using wastewater resources. Bioresource Technology, 102(1), 17-25. doi:https://doi.org/10.1016/j.biortech.2010.06.035

Proulx, D., & De la Noue, J. (1988). Removal of macronutrients from wastewaters by immobilized microalgae. Moo-Young (ed.), Bioreactor Immobilized Enzimes and Cells. Fundamentals and Applications. Elsevier Applied Science Publ. Ltd., Essex.

Romero, J., Coronil, T., Lara, C., & Guerrero, M. G. (1987). Modulation of nitrate uptake in Anacystis nidulans by the balance between ammonium assimilation and CO2 fixation. Archives of Biochemistry and Biophysics, 256(2), 578-584. doi:https://doi.org/10.1016/0003-9861(87)90615-1

Sawayama, S., Rao, K., & Hall, D. (1998). Nitrate and phosphate ion removal from water by Phormidium laminosum immobilized on hollow fibres in a photobioreactor. Applied Microbiology and Biotechnology, 49(4), 463-468.

Shi, J., Podola, B., & Melkonian, M. (2007). Removal of nitrogen and phosphorus from wastewater using microalgae immobilized on twin layers: an experimental study. Journal of Applied Phycology, 19(5), 417-423. doi:10.1007/s10811-006-9148-1

Smith, V. H. (1998). Cultural eutrophication of inland, estuarine, and coastal waters. In Successes, limitations, and frontiers in ecosystem science (pp. 7-49): Springer.

Stanier, R. Y., Kunisawa, R., Mandel, M., & Cohen-Bazire, G. (1971). Purification and properties of unicellular blue-green algae (order Chroococcales). Bacteriological reviews, 35(2), 171-205. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/4998365

Sturm, B. S., & Lamer, S. L. (2011). An energy evaluation of coupling nutrient removal from wastewater with algal biomass production. Applied Energy, 88(10), 3499-3506.

Talbot, P., & De la Noüe, J. (1993). Tertiary treatment of wastewater with Phormidium bohneri (Schmidle) under various light and temperature conditions. Water Research, 27(1), 153-159.

Tam, N. F., & Wong, Y.-S. (1995). Wastewater treatment with microorganisms: Commercial Press (HK) Limited.

Tang, E. P., Vincent, W. F., Proulx, D., Lessard, P., & De La Noüe, J. (1997). Polar cyanobacteria versus green algae for tertiary waste-water treatment in cool climates. Journal of Applied Phycology, 9(4), 371-381.

Vijayaraghavan, K., & Yun, Y.-S. (2008). Bacterial biosorbents and biosorption. Biotechnology Advances, 26(3), 266-291.

Wang, C., Hu, X., Chen, M.-L., & Wu, Y.-H. (2005). Total concentrations and fractions of Cd, Cr, Pb, Cu, Ni and Zn in sewage sludge from municipal and industrial wastewater treatment plants. Journal of Hazardous Materials, 119(1), 245-249. doi:https://doi.org/10.1016/j.jhazmat.2004.11.023

Wang, L., Min, M., Li, Y., Chen, P., Chen, Y., Liu, Y., . . . Ruan, R. (2010). Cultivation of green algae Chlorella sp. in different wastewaters from municipal wastewater treatment plant. Applied biochemistry and biotechnology, 162(4), 1174-1186.

Zhou, W., Min, M., Li, Y., Hu, B., Ma, X., Cheng, Y., . . . Ruan, R. (2012). A hetero-photoautotrophic two-stage cultivation process to improve wastewater nutrient removal and enhance algal lipid accumulation. Bioresource Technology, 110, 448-455. doi:https://doi.org/10.1016/j.biortech.2012.01.063

IMPACTS OF RELOCATION OF TANNERY INDUSTRIES ON THE RIVER SYSTEM OF DHAKA

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ABSTRACT

Bangladesh is a low lying riverine country located in South Asia. Buriganga and Dhaleshwari are two of the major rivers for Dhaka, the capital of Bangladesh. Buriganga has become a dying river due to the indiscriminate disposal of effluents from various industries, especially from tannery industries situated at Hazaribagh, which is close to Buriganga. To improve the water quality of Buriganga, the tannery industries along with a new Common Effluent Treatment Plant (CETP), were established at Savar in 2016, on the bank of Dhaleshwari River. The main objective of this study is to assess the impacts on the water quality of the selected sample locations for these two rivers due to the relocation of tannery industries from Hazaribagh to Savar, by comparing with previous data. For Buriganga river sampling locations were Rayerbazar, Chadnighat and Bangladesh China Friendship Bridge (B.C.F.B) and for Dhaleshwari, three points namely upstream, downstream and mixing point were selected as sampling locations. The water quality parameters which were studied during different seasons were - pH, BOD_5, COD, Colour, TDS, Chloride, Chromium, EC, Phosphate, Nitrate, Hydrogen sulfide, Ammonia. The analysis showed that except the Rayerbazar (where tannery industries used to discharge the wastewater previously) location, water quality parameters haven't improved in other two locations of Buriganga. The reason is the presence of other industries on the bank of Buriganga River that are polluting the river on a regular basis. For Dhaleshwari River, present study result shows overall degradation of water quality in comparison with the previous data, especially Chloride, TDS, Chromium were at alarming level. The data from wet season was better for both the rivers as expected.

Keywords: *Tannery, Relocation, Pollution, River, Analysis.*

1. INTRODUCTION

Bangladesh, located in South Asia, is blessed with about 700 rivers including tributaries flowing through the country constituting a waterway of total length around 24,140 kilometers. Dhaka, the capital of Bangladesh, is located on the northern bank of the river Buriganga and surrounded by other rivers, namely, the Turag to the west, the Tongi Khal to the north and the Balu to the east. The rivers surrounding Dhaka are giving advantage to it and essential for the survival of the mega city as these provide drainage system, drinking water, different kinds of fishes and also waterways for traveling. The city has many industries, built with limited planning, that discharge large amounts of untreated effluent into the adjacent rivers (Turag, Buriganga, and Balu). The water quality of these rivers is in a very critical condition (Akbor et al.2017; Hadiuzzaman et al. 2006). Monsoon flood caused by the overflow of rivers inundates about one-third of Bangladesh (Bala et al. 2009). The pollution levels showed a seasonal pattern of change with high pollution during dry season and low pollution during wet season (Islam et al. 2015; Mohiuddin et al. 2011).

Generally, rivers surrounding Dhaka are being polluted by the discharge of untreated industrial effluent, urban wastewater, agrochemicals, sewage water, storm runoff, solid waste dumping, oil spillage, sedimentation and also encroachment. Although there are certain laws and regulations to control industrial pollution, its monitoring system is generally weak (Islam et al. 2017). Estimation reveals that there are over 7,000 industries in Dhaka metropolitan area located mostly in three clusters, namely, Hazaribagh, Tejgaon, and Dhaka- Narayanganj- Demra dam area (Roy, 2009). However, among all these industries the tannery industries situated at Hazaribagh and Rayerbazar were one of the main polluters of the Buriganga. As the tanneries were located on the bank of the Buriganga, this river has been the disposal point of effluent all along from the beginning of the operation of these industries, where both liquid and solid wastes were produced.

Several regulatory measures and policies are being considered and implemented by the government to protect the river Buriganga from pollution. One of the most significant initiatives is relocating the tannery industries from Hazaribagh to the Savar Tannery Industrial Estate on the bank of Dhaleshwari river. Almost 115 tanneries are now operating at Savar Tannery Estate. As wastewater from the tannery industries was of the major sources of Buriganga river water pollution, it was expected that with the relocation of the tannery industries the water quality of Buriganga River would improve to some extent. In Savar, the effluent from new tannery estate is discharging into Dhaleshwari River. Though the effluent is to be treated before being discharged into the Dhaleshwari, but it can be postulated that the water quality of the river will degrade to some extent than previous.

Before the relocation of tannery industries, many studies were carried out to assess the water quality of these two rivers, specially of Buriganga river. But after the relocation there were very few studies on the water quality of Buriganga and almost no elaborate study with proper data on the water quality of Dhaleshwari. Islam (2018) found that the DO level has not improved to a large extent in 2018, even after relocation of many tannery industries from Hazaribagh. Islam (2018) also predicted only minor increase (about 0.2 mg/L) in DO, even if all the BOD load from tannery industries have been removed. So, this research was conducted not only to document the current water quality scenario of these rivers but also to assess the impact of relocation on the water quality of these major two rivers.

The main objective of this study was to assess the impacts on the water quality of Buriganga and Dhaleshwari rivers due to the relocation of tannery industries from Hazaribagh to Savar. Some specific objectives were also set for this study. The specific objectives are noted as below:

- To assess the water quality of Buriganga river over a considerable time.
- To study the impacts on water quality of Dhaleshwari river due to disposal of treated wastewater from CETP of Savar Tannery Estate.

- To study the seasonal and temporal variation of water quality parameters of both the rivers Dhaleshwari and Buriganga.

Keeping the objectives of this research in mind, at first field surveys were conducted at locations (Hazaribagh and Savar CETP area) to assess the present situation of the tannery estate, their wastewater disposal location, the surrounding environment etc. This survey facilitated in selecting the sampling locations also. Sampling of water from the rivers were performed on monthly basis. Laboratory analysis of the collected samples was carried out to characterize the river water quality.

2. METHODOLOGY

2.1 Sample Collection

There were total six sampling locations – three in Buriganga River and three in Dhaleshwari River. All but one location was regularly sampled. Sample collection, at the mixing point of the Rayerbazar canal and Buriganga River, was done only for two months, one during dry season and the other during wet.

2.1.1 Buriganga River Sample Location

Three locations were selected for the Buriganga river. The sampling locations were Rayerbazar (RB), Chadnighat (CG) and Bangladesh China Friendship Bridge (B.C.F.B). The Rayerbazar (RB) location was the mixing point of the Rayerbazar canal and Buriganga River. Table 1 shows the geographical co-ordinates of the Buriganga river sampling locations.

Table 1: Information on the sampling locations of Buriganga River

ID	Sampling Location	Latitude	Longitude
RB	Rayerbazar	23° 44' 26.7" N	90° 21' 6.84" E
CG	Chadnighat	23° 42' 35.64" N	90° 23' 29.58" E
BCFB	Bangladesh-China Friendship Bridge	23° 41' 21.696" N	23° 41' 21.696" E

2.1.2 Dhaleshwari River Sample Location

Three locations were selected as sampling locations for the Dhaleshwari river. The sampling locations were Mixing point-where the treated effluent of CETP was discharged in the river (MIX), Downstream of mixing point (DW) and Upstream of mixing point (UP). Table 2 shows the geographic co-ordinates of the Dhaleshwari river sampling locations.

Table 2: Information on the sampling locations of Dhaleshwari River

ID	Sampling Location	Latitude	Longitude
UP	Upstream of mixing point	23° 46' 58.2996" N	90° 14' 24.9" E
MIX	Mixing point of CETP outlet and Dhaleshwari River	23° 46' 34.104" N	90° 14' 18.06" E
DW	Downstream of the mixing point	23° 46' 17.904" N	90° 14' 13.668" E

2.1.3 Sampling Frequency

It was decided to collect water samples once a month from the selected sites to observe the monthly variation of water quality (October-July) and seasonal variation of water quality (Dry Season- and Wet Season). The water samples were usually collected from 10AM to 1PM. The date of collection was randomly chosen.

2.2 Parameter Selection

Water quality parameters were chosen based on tannery wastewater characteristics (Mahmood, 2008). Total 17 parameters were tested of the collected water samples. 10 of them were tested on every month as the samples were collected. 4 extra parameters were tested only on two months-February and July. Remaining 3 were tested once only on February.

The following Tables 3, 4 and 5 show which parameters were tested and the frequency of each parameter tested.

Table 3: Parameters tested regularly

1. pH	2. Colour	3. Chloride (Cl^-)	4. Chromium (Cr)
5.Chemical Oxygen Demand (COD)	6.Bio-chemical Oxygen Demand (BOD)	7.Total Dissolved Solids (TDS)	8.Electrical Conductivity (EC)

Table 4: Parameters tested on two months only

1.Ammonia as $NH_3 – N$	2.Nitrate as $NO_3 – N$
3.Hydrogen Sulphide (H_2S)	4.Phosphate as $PO_4 – P$

Table 5: Parameters tested only on February

1.Cadmium (Cd)	2. Lead (Pb)	3.Copper (Cu)

3. RESULT

An extensive sample collection campaign including river water sampling and collection from point sources were conducted to analyze surface water quality parameters of Buriganga and Dhaleswari rivers. Sampling of Dhaleshwari river was done from October 2017 to July 2018. Sampling of Buriganga river was done from November 2017 to July 2018. Temporal variation was determined using the dataset throughout the whole sampling time. Seasonal variation was measured using dataset of dry season (October 2017 to April 2018) and wet season (May 2018 to July 2018). This Chapter presents an assessment of the water quality of Buriganga and Dhaleswari rivers based on the test result of parameters, with particular focus on the possible impact of tannery industry relocation.

3.1 Buriganga River Seasonal Variation

In Figure 1 it can be seen that the COD value in respective sampling location is higher in dry season than in wet season. In Figure 2 it can be inferred that the BOD value is also higher in dry season than wet season as it is correlated to COD values. Figure 3 also shows the same result that dry season values are higher for Chloride than wet season. The only anomaly in these four graphs can be seen in Figure 4 which shows the seasonal variation for Chromium. Unlike the other parameters the value of chromium is not always higher in dry season. Only Rayerbazar sampling location has a higher dry season value than wet season, and the other two sampling points has rather unusual higher wet season values than dry season.

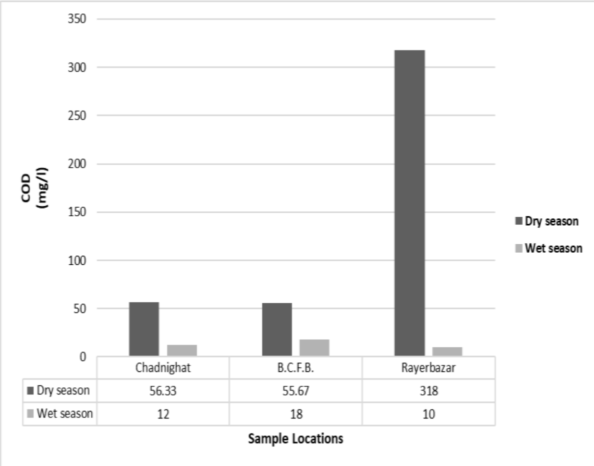

Figure 1: Seasonal Variation of COD Buriganga

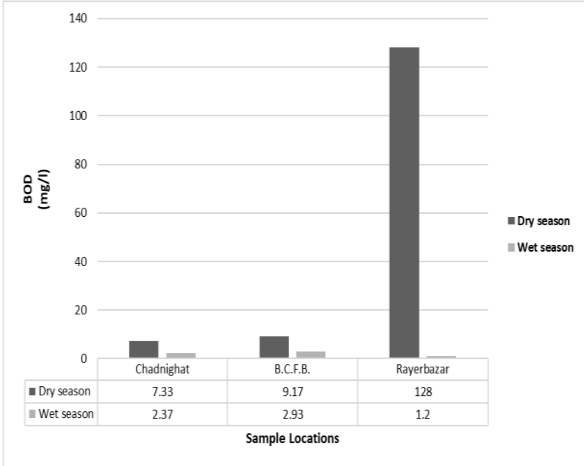

Figure 2: Seasonal Variation of BOD_5 Buriganga

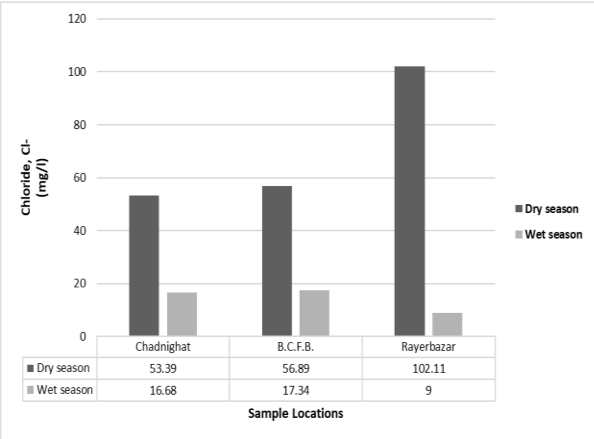

Figure 3: Seasonal Variation of Chloride Buriganga

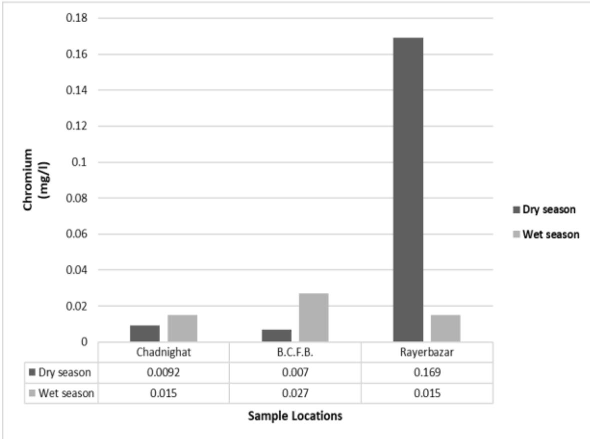

Figure 4: Seasonal Variation of Chromium Buriganga

3.2 Dhaleshwari River Seasonal Variation

In figure 5 the analysis of COD value was usual for Upstream and Downstream sampling points. On the other hand, the COD value for mixing point was higher in wet season than dry season which is unusual. Figure 6 shows the seasonal variation of BOD value, which also exhibits the same discrepancy in mixing point sampling location as COD value. The BOD value in dry season for mixing point sampling location was lower than the value in wet season, which is very unusual. In Figure 7 and Figure 8 it can also be seen that the same anomaly is present for both the parameters Chloride and Chromium, where the value in wet season of Mixing point sampling location is higher than the value in dry season.

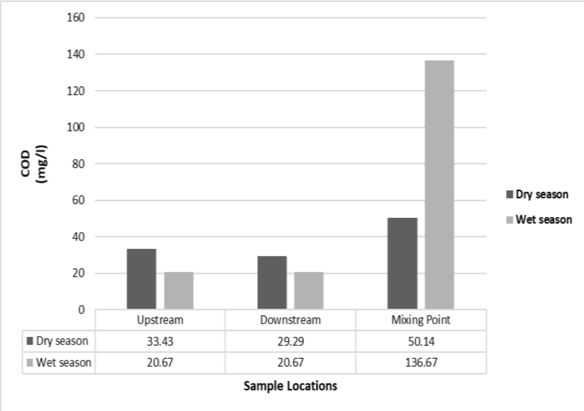

Figure 5: Seasonal Variation of COD Dhaleshwari

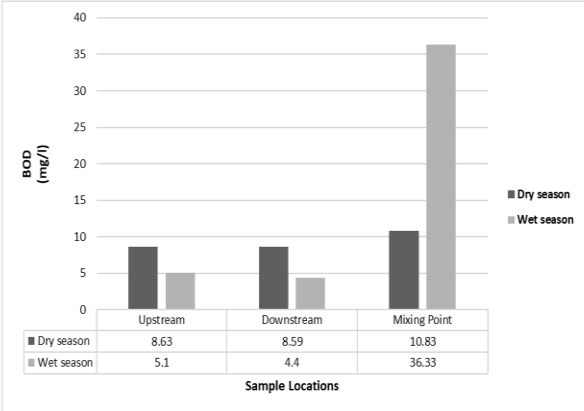

Figure 6: Seasonal Variation of BOD_5 Dhaleshwari

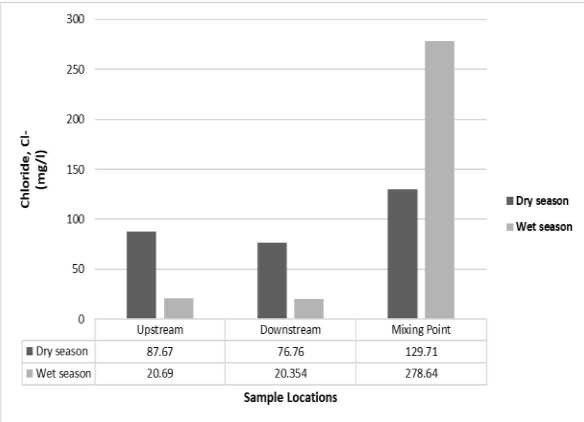

Figure 7: Seasonal Variation of Chloride Dhaleshwari

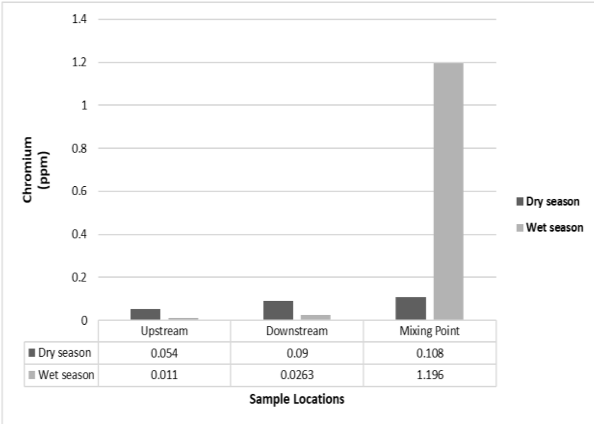

Figure 8: Seasonal Variation of Chromium Dhaleshwari

3.3 Findings

3.3.1 Comparison of Water Qualities with Different Standards

The following table 6 shows the comparision of Buriganga and Dhaleshwari river water quality with USEPA Surface Water Parameter Quality, Surface Water Standard (ECR, 1997) and EU Directive or National Regulations (2001).

Table 6 : Comparison of water quality of Buriganga and Dhaleshwari with different standards

Water Quality Parameter	Range		USEPA Surface Water Parameters	Surface Water Standard (ECR, 1997)	EU Directive or National Regulations (2001)
	BURIGANGA	DHALESHWARI			
Ammonia (mg/L)	5.37-5.92	4.17-10.45	-	-	4
BOD_5 (mg/L)	4.9-64.6	6.50-23.58	-	≤ 3	7

Water Quality Parameter	Range		USEPA Surface Water Parameters	Surface Water Standard (ECR, 1997)	EU Directive or National Regulations (2001)
	BURIGANGA	DHALESHWARI			
Cadmium (ppm)	<MDL*	<MDL*	0.0018	-	0.005
COD (mg/L)	34.17-164	24.98-93.41	-	-	40
Chloride (mg/L)	35.04-55.6	54.18-204.18	860	-	250
Chromium (ppm)	0.012-0.092	0.03-0.65	0.57	-	0.05
Color (Pt.Co)	108.92-192.5	46.25-121.75	-	-	150
Copper (ppm)	0.012	0.08	-	-	1
Electric Conductivity (mS/cm)	0.51-0.58	0.76-1.43	-	-	1
Lead (Pb) (ppm)	<MDL*	<MDL*	0.065	-	0.05
Nitrate (mg/L)	0.5-0.85	0.35-6.85	-	-	50
pH	7.14-7.2	7.35-7.48	-	6.5-8.5	5.5-9
Phosphate (mg/L)	0.53-3.14	0.96-1.3	-	-	0.7

*MDL= Minimum Detection Level, for Cadmium=0.001 ppm, for Lead=0.01 ppm

From this table 6 it can be noticed that COD and BOD value of both rivers exceed the standard in a considerable extent. This signifies that river health of both Buriganga and Dhaleshwari is poor. Chromium in Buriganga River satisfies the standard but in Dhaleshwari River it exceeds the limit which indicates the presence of tannery effluent in Dhaleshwari river. Other heavy metals Pb, Cu, Cd and pH, Chloride, Nitrate do not cross the standard limit. Ammonia and Phosphate value exceed the limit to some extent. EC value exceeds the limit in Dhaleshwari river in non significant amount but does not exceed in Buriganga River. Colour exceeds the standard in Buriganga but is within limit in Dhaleshwari river.

3.3.2 Buriganga River Water Quality

The following table 7 shows the comparison between Buriganga River water quality parameters studied in this research and previous study by DoE.

Table 7: Comparison of Present Studies of Buriganga River with Previous Studies

Concentration at different Sampling Location	B.C.F.B		Chadnighat		Rayerbazar	
	Present Study	Findings from previous studies (DoE,2014)	Present Study	Findings from previous studies (DoE,2014)	Present Study	Findings from previous studies (Chakraborty et al, 2013)
Parameters						
pH	7.14	7.22	7.2	7.25	7.15	8.6
EC (mS/cm)	0.58	0.73	0.56	0.75	0.51	3.28

Concentration at different Sampling Location	B.C.F.B		Chadnighat		Rayerbazar	
	Present Study	Findings from previous studies (DoE,2014)	Present Study	Findings from previous studies (DoE,2014)	Present Study	Findings from previous studies (Chakraborty et al, 2013)
TDS (mg/l)	300	363.5	300.25	372.58	291.5	2200
COD (mg/l)	36.84	57.35	34.17	59.55	164	3470
BOD (mg/l)	6.05	13.64	4.85	18.86	64.6	750
Chloride (mg/l)	37.12	34.04	35.04	36.06	55.56	800
Chromium (ppm)	0.02	-	0.01	-	0.09	8.34
NO_3-N (mg/L)	0.85	-	0.5	-	0.53	8
PO_4 (mg/L)	1.3	-	1.19	-	0.96	2.01

The following observations can be inferred from table 7:

- **Rayerbazar-** There is a decrease of TDS by 7 times compared to the findings from previous data. The extent of decrease of Chloride is by 14 times and that of Chromium is by about 90 times. Significant decrease of COD, BOD, NO_3-N and PO_4 is observed. The tannery relocation effect is clearly reflected by the decrease of Chloride and Chromium values, which is supported by the other parameters at this location.
- **Chadnighat and B.C.F.B. –** EC, TDS and Chloride values does not show any remarkable change. COD and BOD values have significantly dropped indicating the improvement of water quality.

So, the water quality of Rayerbazar shows significant improvement due to tannery relocation. But overall water health of Buriganga has not improved much in downstream.

3.3.3 Dhaleshwari River Water Quality

The following observations can be inferred from table 8-

The average value of **BOD** has changed from 13.2 mg/L to 12.31 mg/L. Average **TDS** value has changed to 506.64 mg/L from 310 mg/L. Average **Chloride** value has drastically increased to 102.3 mg/L from 20 mg/L. Average of **EC** value has increased from 0.66 mS/cm to 1.02 mS/cm. The average value of **pH** has changed from 7.78 to 7.43.

These changes in water quality parameters signify the degradation of water quality of the river Dhaleshwari due to the relocation of tannery industries on the bank of this river.
The following table 8 shows the comparison between Dhaleshwari River water quality parameters studied in this research and previous study by DoE.

Table 8 : Comparison of Present Studies of Dhaleshwari River with Previous DoE Studies

Parameters	Concentration at Different Sampling Location (Average of 10 Months)					Findings from previous studies (DoE, 2014)
	Upstream	Mixing	Downstream	Range	Average	
pH	7.48	7.46	7.35	7.35-7.48	7.43	7.78
Colour (pt.Co)	48.92	121.75	46.25	46.25-121.75	72.31	-
EC (mS/cm)	0.87	1.43	0.76	0.76-1.43	1.02	0.66
TDS (mg/L)	372.74	793.77	353.41	353.41-793.77	506.64	310

Parameters	Concentration at Different Sampling Location (Average of 10 Months)					Findings from previous studies (DoE, 2014)
	Upstream	Mixing	Downstream	Range	Average	
COD (mg/L)	27.05	93.41	24.98	24.98-93.41	48.48	-
BOD (mg/L)	6.87	25.58	6.5	6.50-23.58	12.31	13.2
Chloride (mg/L)	54.18	204.18	48.56	54.18-204.18	102.3	20

4. CONCLUSION

The main focus of this study was to assess the impacts on the water quality of river Buriganga and river Dhaleshwari due to the relocation of tannery industry from Hazaribagh to Savar.

4.1 Seasonal Variation

Buriganga River

- **COD-** In **Dry** season, the average COD values were 318 mg/L, 55.67 mg/L and 56.33 mg/L and in **Wet** season, the average COD values were 10 mg/L, 18 mg/L and 12 mg/L at Rayerbazar, B.C.F.B and Chadnighat respectively.
- **BOD_5-** In **Dry** season, the average BOD_5 values were 128 mg/L, 9.17 mg/L and 7.33 mg/L and in **Wet** season, the average BOD_5 values were 1.2 mg/L, 2.93 mg/L and 2.37 mg/L at Rayerbazar, B.C.F.B and Chadnighat respectively.
- **TDS**- In **Dry** season, the average TDS values were 454 mg/L, 424.67 mg/L and 436.5mg/L and in **Wet** season, the average values were 129 mg/L, 175.33 mg/L and 164 mg/L at Rayerbazar, B.C.F.B and Chadnighat respectively.
- **Chloride-** In **Dry** season, the average Chloride values were 102.11 mg/L, 56.89 mg/L and 53.39 mg/L and in **Wet** season, the average values were 9 mg/L, 17.34 mg/L and 16.68 mg/L at Rayerbazar, B.C.F.B and Chadnighat respectively
- **Chromium**- In **Dry** season, the average Chromium values were 0.169 mg/L, 0.007 mg/L and 0.0092 mg/L and in **Wet** season, the average values were 0.015 mg/L, 0.027 mg/L and 0.015 mg/L at Rayerbazar, B.C.F.B and Chadnighat respectively.

From the observation it can be concluded that the overall water quality parameters have improved during the wet season compared to the dry season as expected.

Dhaleshwari River

- **COD-** In **Dry** season, the average COD values was 33.43 mg/L, 29.29 mg/L and 50.14 mg/L and in **Wet** season, the average values were 20.67 mg/L, 20.67 mg/L and 136.67 mg/L at upstream, downstream and mixing point respectively.
- **BOD_5-** In **Dry** season, the average BOD_5 values were 8.63 mg/L, 8.59 mg/L and 10.83 mg/L and in **Wet** season, the average values were 5.1 mg/L, 4.4 mg/L and 36.33 mg/L at upstream, downstream and mixing point respectively.
- **TDS**- In **Dry** season, the average TDS values were 559.14 mg/L, 521.14 mg/L and 353.41 mg/L and in **Wet** season, the average values were 186.33 mg/L, 185.67 mg/L and 913.67 mg/L at upstream, downstream and mixing point respectively.
- **Chloride**- In **Dry** season, the average Chloride values were 87.67 mg/L, 76.76 mg/L and 129.71 mg/L and in **Wet** season, the average values were 20.69 mg/L, 20.35 mg/L and 278.64 mg/L at upstream, downstream and mixing point respectively.
- **Chromium-** In **Dry** season, the average Chromium values were 0.054 mg/L, 0.09 mg/L and 0.108 mg/L and in **Wet** season, the average values were 0.011 mg/L, 0.026 mg/L and 1.19 mg/L at upstream, downstream and mixing point respectively.

From the observation it can be concluded that the overall water quality parameters have improved during the wet season compared to the dry season as expected.

4.2 Comparison with Water Quality Standards

4.2.1 Buriganga River:

- COD & BOD_5 values exceed the standard.
- Colour exceeds the standard.

This signifies that overall health of Buriganga river is not quite satisfactory. It also interprets that there are still many soucres of pollution near buriganga river such as- industries discharging untreated effluent, discharging of municipal waste and many undetected sources.

4.2.2 Dhaleshwari River:

- COD & BOD_5 values exceed the standard.
- Chromium value exceeds the limit.
- EC value exceeds the limit.

These indicate the poor health of river Dhaleshwari.

4.3 Comparison with Previous Studies

4.3.1 Buriganga River:

- **Rayerbazar-** TDS, COD, BOD_5, Chloride, Chromium, NO_3-N and PO_4 values have dropped significantly which clearly shows the positive effect of tannery relocation.
- **Chadnighat and B.C.F.B. –** COD and BOD_5 values have dropped but EC, TDS and Chloride values do not show any remarkable change. So, the water health of Buriganga has not improved much in downstream after the tannery relocation.

These results show that relocation of tannery industries has significant improving effect on Rayerbazar location but has little effect on other part of Buriganga. To effectively improve the overall water health of Buriganga, this only relocation may not work, more adequate steps are necessary as well.

4.3.2 Dhaleshwari River

- BOD_5 value has increased a bit.
- TDS value has increased almost two times.
- Chloride value has increased almost five times.

These major increases clearly indicate the degradation of water quality of Dhaleshwari river. as a result of relocation of tannery industries.

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REFERENCES

Akbor, M. A., Uddin, M. K., & Ahsan, M. A. (2017). Investigation of Water Quality Parameters at Different Points in the Buriganga River, Bangladesh. *Journal of Environmental Science and Natural Resources*, 10(1), 75-80.

Bala, S. K., Islam, A. S., Chowdhury, J. U., Rahman, M. R., Haque, M. A., Khan, M. S. A., & Salehin, M. (2009). Performance of flood control works around Dhaka city during major floods in Bangladesh. In 2nd international conference on water & flood management (ICWFM-2009).

Chakraborty, Chandan & Ahmed, Sobur & Huq, Md Mazaharul & Tabassum, Taslima & Ashraf, Ali & Siddiqui, (2013). Assessment of Level of Water Pollution Dis-charged From Hazaribagh: A Critical study. International Journal of Scientific and Engineering Research. 4. 2318.

DoE (2014). River Water Quality Report 2014, Natural Resource Management Section, Department of Environment, ISSN: 2226-1575.

ECR (1997). The Environment Conservation Rules, 1997, Government of the People's Republic of Bangladesh, Ministry of Environment and Forest, Notification-Date, 12 Bhadra 1404/27 August 1997.

EU Directive or National Regulations (2001). Parameters of Water Quality: Interpretation and Standards. Environmental Protection Agency, Ireland.

Hadiuzzaman M., Baki A. B. M., Khan S.M., (2006). Pollution status and trends in water quality of the Shitalakhya and Balu rivers. The Journal of Noami Volume 23 Number 2 December 2006.

Islam, M., Uddin, M., Tareq, S., Shammi, M., Kamal, A., Sugano, T. & Kuramitz, H. (2015). Alteration of water pollution level with the seasonal changes in mean daily discharge in three main rivers around Dhaka City, Bangladesh. Environments, 2(3), 280-294.

Islam, S. M. D., & Azam, G. (2015). Seasonal variation of physicochemical and toxic properties in three major rivers; Shitalakhya, Buriganga and Turag around Dhaka city. Bangladesh. J. Bio. Environ. Sci, 7(3), 120-131.

Islam, M. S., Akbar, A., Akhtar, A. Y. S. H. A., Kibria, M. M., & Bhuyan, M. S. (2017). Water Quality Assessment Along With Pollution Sources of the Halda River. Asia. Soci. J, 43, 61-70.

Islam, R. (2018). Effects of relocation of tannery industries from Hazaribagh on water quality of Buriganga river. M.Sc. Engg, Thesis, Department of Civil Engineering, BUET, Dhaka.

Mahmood, S. O. (2008). Chemical Treatment Options for Tannery Wastewater, M.Sc. Engg, Thesis, Department of Civil Engineering, BUET, Dhaka.

Mohiuddin KM, Ogawa Y, Zakir HM, Otomo K, Shikazono N (2011). Heavy metals contamination in water and sediments of an urban river in a developing country. Int J Environ Sci Technol 8(4):723–736

Roy M., (2009). Planning for sustainable urbanisation in fast growing cities: mitigation and adaptation issues addressed in Dhaka, Bangladesh Habitat Int., 33 (3) (2009), pp. 276 – 286.

US EPA (1991). Maximum contaminant level goals and national primary drinking water regulations for lead and copper; final rule. US Environmental Protection Agency. Federal Register, 56(110):26460– 26564.

US EPA (1995). Effect of pH, DIC, orthophosphate and sulfate on drinking water cuprosolvency. Washington, DC, US Environmental Protection Agency, Office of Research and Development (EPA/600/R-95/085).

IMPACTS OF BRICKFIELDS ON ENVIRONMENT AND ASSESSMENT OF ENVIRONMENTAL LAWS: A CASE STUDY OF PABNA SADAR UPAZILA IN BANGLADESH

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ABSTRACT

Building Structures and major construction works are booming in both the urban and rural areas in Bangladesh. Brick is an essential construction material for building structures. To meet the excessive demand of bricks, there are many brickfields are growing sporadically here and there at the fringe zones and rural areas. The purpose of this study is to investigate environmental impacts of brickfields and assess the environmental legal guidelines in Bangladesh. Pabna Sadar Upazila has been selected as the study area because of its rapidly changing population density, socioeconomic phenomena and industrial and environmental concerns. At present, 45 brickfields are located in the study area. This study is based on randomly selected respondents' perception on change of any resource or condition of environment and assessment of Brick manufacturing and Brickfield Establishment Act 2013 and Environment Conservation Rule 1997. Primary data is collected in three ways such as reconnaissance Survey, questionnaire survey, interviews, FGD and photography. All these data were collected to the selected community members living near the brickfields. The sources of secondary data were high-resolution satellite images in Google Earth, BBS, official documents and so on. Impacts on soil fertility, agricultural production, vegetation, fish culture, health status were assessed on the answer of respondents. Different types of software tools like Microsoft Excel program, SPSS have been helped to analyze data digitally and utilized to produce this paper. From the study, it was found that most of the brickfields of the study area were located near agricultural lands and residential areas those were responsible for loss of agricultural production, fish cultivation, local community's health problems and violation of environmental laws specifically Brick Burning Acts in great extent. Improving technology, development of policy and proper regulations of this act may be the best recommendation for the betterment of urban and rural environment.

Keywords: *Brickfields, Agriculture, Aquaculture, Environmental pollution, Environmental laws.*

1. INTRODUCTION

The population of Bangladesh is 158.9 million with a growth rate of 1.37 and a total number of establishments are 78, 18,565. The population density of Bangladesh is 1,106 per km (BBS, 2015). This vast amount of population and growing economic sectors lead the construction sectors in the country. The demand for building materials is very high at the moment of Bangladesh because of a large number of government projects as well as individual usage (The Daily Star, 2019). Rapid urbanization, industrialization and construction of buildings in Bangladesh use bricks from several past decades. This has reinforced brick manufacturing industry a fastest growing sector (Saha & Hossain, 2016). UNDP reported that Bangladesh manufactures 1,200 crore of bricks each year for the rapid urbanization rate (7-8%) in medium and large cities (UNDP, 2011). There are approximately 6637 traditional and modern brickfields are currently operating brickfields in Bangladesh. According to the report of the Bangladesh Centre for Advance Studies (BCAS), only 735 of these brickfields follow the new regulations. According to the BCAS, 1,745 of the brickfields in Bangladesh begin operations before obtaining a license (Ahmed, 2019). Nearly 90 percent of the brick-makers have not updated their production process in keeping with new environmental regulations on the fuel (Faisal, 2016). Nearly 23 billion bricks are produced annually in traditional brickfields of Bangladesh by mining an estimated 3350 million cubic feet of soft clay, and burning 5.67 million tons of coal and 3 million tons of firewood (DoE, 2017). In absence of natural sources of stones and climate consideration, bricks are mostly used in the country. In traditional brickfields, bricks are produced from clay and then fired in the kiln. But brick kilns location in agricultural lands, low quality wooden for burning of bricks, improper fixed chimneys and the violation of laws to conserve environment is leading this sector into a major cause of agricultural productivity decline, pollution of environments and hazards towards human health (Guttikunda & Khaliquzzaman, 2014).

Pabna is the oldest district in Bangladesh under the Rajshahi division. Many old architectural symbols like Pabna Mental Hospital, Hardinge Bridge, Jor-bangla temple and so on that are made by brick. There are 96 brickfields in Pabna district. Among of them, 76 brickfields are illegal. Without the license, workers of these industries used fuel as wood and tire for the production of brick. Most of the brickfields are located near agricultural fields and adjacent of roads (Desh Rupantor, 2019).

A few articles were found on impacts of brickfields and no specific papers that have been found on the assessment of environmental laws in Pabna Sadar Upazila. It is assumed that the following gaps of the research should be filled to reach the goal of this research. That's why Pabna Sadar Upazila is selected as the study area. The resulting conclusion will be helpful for policymakers and responsible authority toward defining adaptive measures and taken steps against on illegal actions of brickfield owners. This study is analysed based on the changes of environmental aspects what the respondents observed before and after establishment of brickfields around them and location of brickfields and burning process of bricks are assessed on the basis of field observation, gazette of Brick Manufacturing and Brick Kiln Establishment Act 2013, Brick Manufacturing and Brick Kiln Establishment Act 2019 and Environmental Conservation Rule 1997. The objectives of this research are:

1. To find out negative or positive effects of brickfields on soil fertility, agriculture, aquaculture, vegetation and health status of residents if the study area based on field observation and answer of the respondents.
2. To evaluate the environmental laws and their post-construction environmental effect.

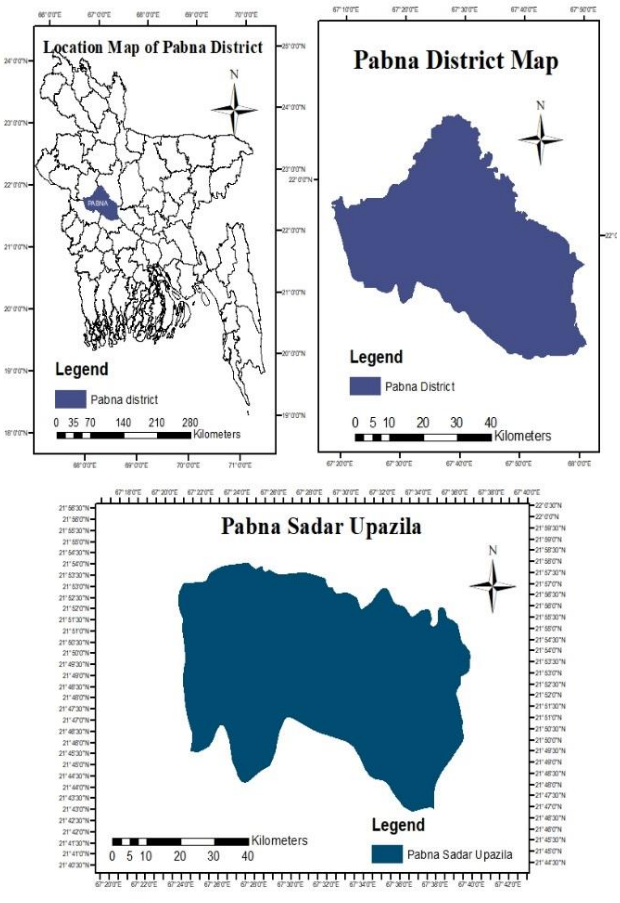
2. LITERATURE REVIEW

"Brick" means sand or cement or any building materials manufactured by the soil in brick kiln and "Brickfields" are those places where latest technology, reducing fuel air pollution rules according to laws of Environment Conservation Rule, 1997 (DoE, 2017). Based on the production process, brickfields can be classified in several ways. Fixed chimney kiln (FCK) has an oval shape in which the chimney is located at the centre and the bricks are fired in the space around the chimney, between the central part of the kiln and the outer wall. It is a continuous moving-fire kiln in which the fire burns continuously and moves in a closed circuit through the bricks stacked in the trench. Usually, solid fuels such as coal, wood, saw dust, and agriculture residues are used in FCBTKs (BRICKGURU, 2017). The improved zigzag kiln is a modified traditional zigzag "Hawa bhatta" kiln taken in Bangladesh to demonstrate this technology. It is an elliptically shaped kiln with well insulated permanent side walls and roofs and arched firing chambers to allow easy air flow. After sun drying, bricks are loaded manually into the firing chambers. Air required for the combustion process is forced from it reaches the line to be fired, it is previous firing zone thus reducing firing time hour (English Booklet, n.d.). A Hybrid Hoffman Kiln is a rectangular shaped annular circuit with an arched roof covered with a shade to protect it from rains. It has a firebrick lining on the inside surface. The thick walls of the kiln and good insulation minimize heat loss to the surrounding (DoE, 2017). The tunnel kiln is considered to be the most advanced brick making technology. In a Tunnel Kiln, green bricks produced by mixing powdered fuel with clay are loaded on cars and then pushed in the kiln, a horizontal tunnel (DoE, 2017).

3. MATERIALS AND METHODS

3.1 Study Area Profile

Pabna Sadar Upazila, a small administrative unit, situated in Pabna district under Rajshahi division which is positioned between 23°53' and 24°05' north latitudes. It is covered with an area of 439.30 square kilometre and the total population is 590914 (Community Report: Pabna, 2013). This Upazila consists of 1 municipality, 15 wards, 46 mahallas, 10 unions, and 291 villages. Main sources of income of the study area are agriculture 38.77 percent among all occupation types. Natural resources sand, coal have been found in this Upazila (Daily Sun, 2018). Figure 1 shows the location of the Pabna Sadar Upazila in the context of Pabna district and Bangladesh.



Map 1: Location of the Study Area [Source: Author, 2019]

3.2 Sampling and Data Collection

Primary data were collected by Field Observation, Questionnaire Survey, Focus Group Discussions and interviews of the people. For the questionnaire survey, a total of 348 people were selected randomly in the study area. However, all respondents were later divided into two groups. The owners and workers of brickfields are in category-1 who were engaged in the brick manufacturing process and the workers were the most vulnerable to health hazards because of direct involvement with brickfield activities. None of them is in below 18 in age. The people who were living within 1 kilometre of the brickfields are in category-2. Each category consisted of 174 respondents in the study area. They were involved in farming, aquaculture, household and different types of activities. Local knowledgeable persons including assistant director and other officials of the Department of Environment, Forests and Climate Change in Pabna district, community representatives, and teachers were interviewed individually to know their perception about this study. Two FGD were conducted with the workers of brickfields to identify the brick kiln technology, chimney height, fuel and brick manufacturing process. Impacts of brickfields were assessed in terms of changes in soil fertility, agricultural production, vegetation, fish production, health status and air quality based on how respondents found these after the construction of brickfields. Secondary data were collected from newspapers, journals, reports and web browsing.

3.3 Data Processing and Analysis

Data were analysed and produced graphs by SPSS (Statistical Package for Social Science) software and Microsoft Excel and GIS (Geographic Information System) is used for map preparation for showing the existing location of brickfields and 1km area from it for environmental law assessment.

4. DATA ANALYSIS AND RESULTS

4.1 Impacts on Soil Fertility

According to the survey report, 68% of the respondents' answered that the felt adverse effects on soil fertility due to the brickfields. On the other hand, 13% of the respondents complained about moderate effect, 6% answered minor effect and 13% felt no effect on soil fertility because of brickfields that show in figure 1. The brick kiln workers remove topsoil for brick production. It has a direct impact on soil fertility and land degradation. The negative impact of topsoil removal is the reduction of agricultural output and increases the cost of replacing the nutrients lost (Bisht and Neupane, 2015). Burning of the soil decreases the soil pH and make it acidic. It has serious impacts on soil physical, biological and chemical properties resulting in sharp declination in soil fertility and productivity (Pariyar, 2013).

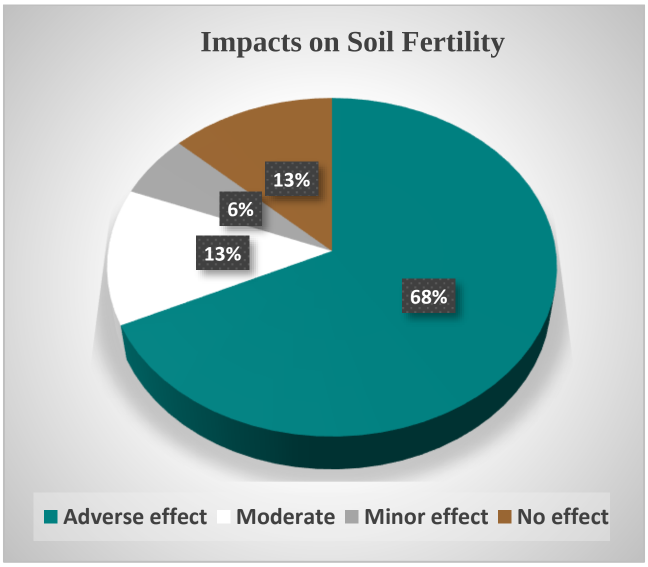


Figure 1: Impact on soil fertility [Source: Field Survey, 2019]

4.2 Impacts on Agricultural Production

Most of the brickfields were situated near the agricultural lands. 23% of the respondents opined that they felt adverse effects of brickfields on agricultural production. Half (50%) of the respondents complained about moderate effect, 27% of the respondents answered minor effect and none of the respondents answered no effect on agricultural production (figure 2). Some people who were lived around the brickfields said that production of crops had been declined after construction of brickfields. Agricultural lands had become unsuitable for producing any crops due to over-exploitation of its topsoil (Jerin et. al, 2016). For this reason, farmers are now applying high doses of chemical fertilizers, which have harmful consequences to the environment. Majority of the respondents said that black smoke of brick kilns is responsible for the reduction of crop production.

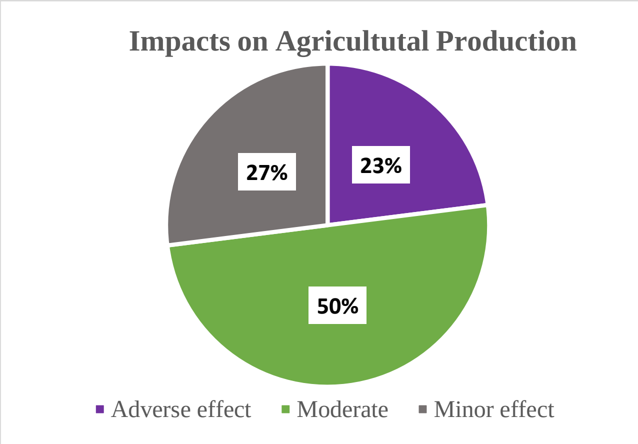


Figure 2: Impact on Agricultural production [Source: Field Survey, 2019]

4.3 Impacts on Vegetation

Result shows that 48% of the respondents opined that they felt adverse effects on vegetation, especially on fruits and vegetable plants within 1 km of brickfield. Among of the respondents who were the residents around brickfields, 16% respondents opined that brickfield had a moderate effect, 23% commented on minor effect and 13% felt no effect on vegetation (figure 3). Many of the residents said that the plant buds died due to the emission of black smoke of brick kiln i. e. mango tree, litchi tree flowering trees and so on and sometimes plants do not grow properly. They also noted that fruits production is reduced after the establishment of brickfields in the study area. In some residential areas surrounding brickfields, it is directly observed that leaves were covered with black smokes.

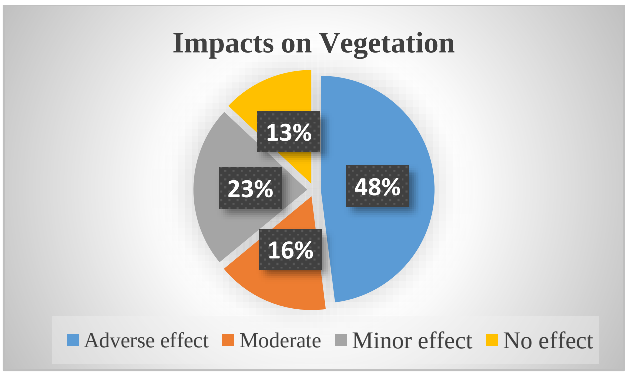


Figure 3: Impact on vegetation [Source: Field Survey, 2019]

4.4 Impacts on Aquaculture

Majority of the respondents in category-2 said (36%) that, "brickfields had no effect on fish production and aquatic plant production" and 17% of the respondents said about the adverse effect, 21% commented on moderate effect and 26% respondents said that they felt minor effects on aquaculture after establishment of brickfields (figure 4). In Hemayetpur, Dapunia and Dogachi union of Pabna Sadar

Upazila, most of the brickfields are located near water bodies. According to the respondents' fish cultivation were hampered in nearby water bodies due to water pollution.

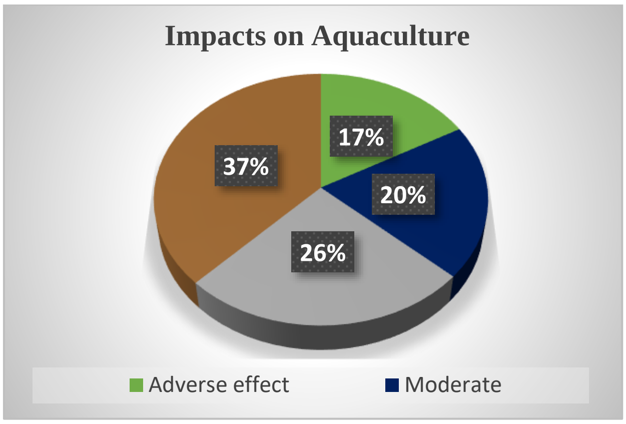


Figure 4: Impacts on aquaculture [Source: Field Survey, 2019]

4.5 Air Pollution

A study was found that the concentrations of particulate matter (PM) in the air around the brick kilns zones are three times higher than the offseason of brick kilns (Raut, 2003). Brickfields are important contributors to the emission of greenhouse gases in Bangladesh as they burn huge amounts of coal and wood fuel. The main reason for poor emission from brick kilns is the poor quality of coal and uses of biomass mainly firewood. FCKs are not energy efficient and consequently, pollutants are being emitted by a greater rate. The main pollutants which are emitted from the brickfields are particulate matter (PM), some hazardous gases like CO_2, CO, NO_X, NO and SO_2. The PM concentration appears to be low but it is expected to have long term massive impact on global environments as well as on human health. The particulate matter consists of dust, smoke, fumes, and fly ash (Daraina et. al, 2013). At present, 45 brickfields where a fixed kiln chimney, 44 Hawa-Bhatta and a hybrid Hoffman brickfield located in the study area (Department of Environment, Forests and Climate Change of Pabna District, 2019). According to the respondents of category-1, the chimney height of some brickfields is less than 120 feet. It is another cause of air pollution.

4.6 Health Status of Respondents

In Bangladesh, most of the brickfields are situated near the residential area and many people work in the brickfields daily in the brick production period. A health survey clearly showed that people who are living near brick kilns are more likely to suffer from illnesses caused by air pollution, comparing those who are living in areas without the kilns. School children nearby brick kilns were had the worse condition of health and they were suffered for higher prevalence of upper respiratory tract infections like pharyngitis and tonsillitis (Joshi and Dudani, 2008). It was also found that brick field workers suffered from discomfort in different parts of the body, especially in the lower back, knees and upper extremities (Das, 2014). Another study of brickfield impacts on human health showed that residents who were working in the brickfields suffering from eye irritation, respiratory problems and skin diseases (Jerin et. al, 2016).

This study is divided into two parts i. e. category-1 and category-2. Table 1 shows the types of disease that were found in both category respondents due to the brickfields.

Table 1: Health status of respondents

Types of disease	Category-1	Category-2
Respiratory problems	13	6
Skin disease	8	12
Respiratory problems and skin disease	17	24
Eye irritation	6	7
Respiratory problems and Eye irritation	10	5

Types of disease	Category-1	Category-2
Respiratory problems, skin disease and eye irritation	21	23
Others	1	4
No problem	24	19
Total	**100**	**100**

[Source: Field Survey, 2019]

4.7 Assessment of Environmental Act related with brickfields

- According to the section-4 of Brick Manufacturing and Brick Kiln Establishment Act-2013, "brick manufacturing is prohibited without taking a license from the Deputy Commissioner of the district" (DoE, 2017). But the assistant director of the Department of Environment, Forests and Climate Change in Pabna district complained that most of the brickfields have not any license from deputy commissioner or other legal documents from the Department of Environment.

- In section 5(1) of this act, any person can't cut earth from ponds, canals, marshes, creeks, lakes, rivers, wetlands, sandbars or other areas without permission from appropriate authorities. 5(2)-Requires permission from the appropriate authority for the collection of soil for brick manufacturing from haor-baors, ponds, canals, beels, river beds, chars and fallow land. From the field investigation, most of the brickfields are located adjacent to the agricultural field. According to the residents of Hemayetpur union, owners of brick industry dug canals and ponds to use soil in brick production. This activity is an example of violation of this act.

- According to the rules, there are three types of brick kilns are allowed for the burning of bricks i. e. improved zigzag kiln, Hybrid Hoffman kiln and Tunnel Kiln. According to the survey data, a fixed kiln chimney was found in the study area which is not allowed. The chimney height of some brick kilns is within 110-115 feet. M/S MCA Brickfield's chimney height is 115 feet. But the chimney height of zigzag kiln should be 120 feet in height according to the act (DoE, 2017).

- According to the Brick Manufacturing and Brick Kiln Establishment Act-2013 "Fuel wood cannot be used in brick kilns for burning bricks" (DoE, 2017). But workers of brickfield said that they use wood, tire for burning of bricks.

- According to the section 8(a), establishment of brick kilns within the boundary of residential, commercial or preserved area, municipality or Upazila headquarters, forest, orchard, wetland, sanctuary, agricultural land, ecologically critical area and degraded air shed is prohibited and according to section 8(b), establishment of brick kilns in the following distance or places is totally banned namely: (a) within 1 kilometers distance from the boundary of prohibited areas, (b) within 2 kilometers distance from boundary of public forest, (c) within half kilometers distance from the foot of the hill or hillock, (d) within 1 kilometers distance from any special structure, railways, educational institutions, hospitals and clinics, research institutions or any other similar place or institution, and (f) with half kilometers distance from Upazila, union or rural roads made by Local Government Engineering Department (LGED) (DoE, 2017).
  But figure 5 shows the location of brickfields where most of the brickfields are located near the residential area and agricultural lands. The population of the ward no. 9 of Dogachi Union of Pabna Sadar Upazila is 3000. In this ward 3 brickfields are located near educational institutions, agricultural land within 1 km. As a result, people especially children and old man are suffering from many respiratory diseases (Pabna Samachar, 2019). It was directly observed that in Hemayetpur and Dapunia union, brickfields are located with near half kilometer from the Local Government Engineering Department (LGED) road.

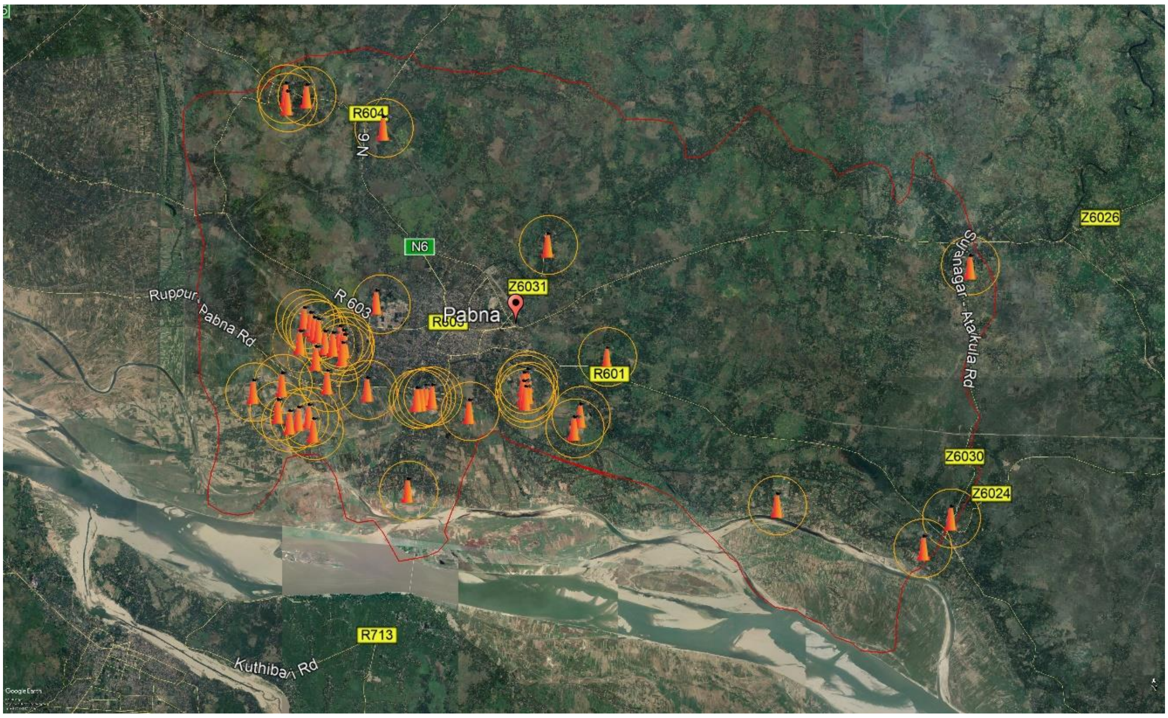


Figure 5: Location of brickfields in Pabna Sadar Upazila [Source: Author, 2019]

- In Section 7(a), waste disposal and gaseous emissions emission will be in a limit according to environment conservation rules of 1997. The Department of Environment (DoE) published a gazette by named "Environment Conservation Rule, 1997" where includes the standard unit of emission that can produce different brick kiln that is in table-2 (DoE, 1997).

Table 2: Standard measurement of parameters of different types of brick kiln

Nature	Parameter	Unit	Ideal measurment
Zigzag or FCK	Total particles	$Mg\backslash Nm^3$	400
Vertical saft brick kiln\Tunnel kiln	Total particles	$Mg\backslash Nm^3$	250
Hybrid Hoffman Klin\Tunnel kiln (fuel: coal)	Total particles	$Mg\backslash Nm^3$	250
Hybrid Hoffman Klin\Tunnel kiln (fuel: gas)	Total particles	$Mg\backslash Nm^3$	100

[Source: Environmental Conservation Rule, 1997]

The brick manufacturing season is November to April. In every season, approximate 7 million bricks in average are produced in every brickfield. 1 million bricks are burnt in each round and 180 ton coal is needed for each round. 1 short ton (2,000 pounds) of coal can be generated about 5,720 pounds (2.86 short tons) of carbon dioxide. From the study, it can be easily identified that these brickfields generate a huge amount of CO_2 that is the main culprit of global warming. From field investigation, questionnaire survey and interviews of the assistant director of the Department of Environment, Forests and Climate Change in Pabna district, these brickfields are produced an excess amount of gaseous particulates that is too much from an ideal measurement. But, they don't pay any compensation for it.

5. CONCLUSIONS

From the study it was found that most of the brickfields of the study area were located near agricultural lands, ponds and residential areas those were responsible for decrease of soil fertility, loss of agricultural production, fish cultivation and local community's health problems in great extent. Most of the brickfields didn't follow the acts and they have no licence from the deputy commissioner which is totally illegal. Besides, brick fields were considered as the principle reason of land degradation, health problem and air pollution in rural areas of Pabna Sadar Upazila.

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REFERENCES

Ahmed, A. (2019, September 17). *Daily Sun*. Retrieved from Air Pollution from Brick Kilns and Alternative Solutions: https://www.daily-sun.com/post/424375/2019/09/18/Air-Pollution-from-Brick-Kilns-and-Alternative-Solutions

BBS, (2015). *Bangladesh Statistics 2017*. Dhaka: Bangladesh bureau of statistics. Retrieved from Bangladesh Statistics 2017.

Bisht, G., & Neupane, S. (2015). Impact of Brick Kilns' emission on soil quality of agriculture fields in the vicinity of selected Bhaktapur Area of Nepal. Applied and Environmental Soil Science. http://doi. org/10.1155/2015/409401.

BRICKGURU. (2017). Retrieved from What is a Fixed Chimney Bull's Trench Kiln (FCBTK)?: ttps://www.brickguru.in/web/brickguru/knowledge-briefs?arturl=kb09-what-is-a-fixed-chimney-bull-s-trench-kiln-fcbtk-

Community Report: Pabna. (2013) Dhaka: Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh.

Daraina k. M. et. al. (2013). Brick Manufacturing Practice in Bangladesh: A Review of Energy Efficacy and Air Pollution. *Journal of Hydrology and Environment Research, 1*(1), 60-69.

Daily Sun. (2018, August 04). Retrieved from Pabna Sadar: https://www.daily-sun.com/post/327228/2018/08/05/Pabna-Sadar

Das, B. (2014). Assessment of occupational health problems and physiological stress among the brick field workers of west bengal, India. *International Journal of Occupational Medicine and Environmental Health, 27*(3), 413-425.

Department of Environment(DoE). (1997). *Environment Conservation Act 1997.* Dhaka: Ministry of Environment, Forests and Climate Change.

Department of Environment(DoE). (2017). *National strategy for sustainable brick production in Bangladesh.* Dhaka: Ministry of Environment and Forests, Government of the people's republic of Bangladesh.

Department of Environment, Forests and Climate Change. (2019). District Office, Pabna.

Desh Rupantor. (2019, February 9) Retrieved from http://www.deshrupantor.com/desh/2019/02/09/121982

English Booklet (n.d.). *Booklet on New Brick Making Technologies.* The prople's Republic of Bangladesh.

Faisal, A. (2016). *bdnews24*. Retrieved from Brick-makers not following new regulations: https://bdnews24.com/bangladesh/2016/12/15/brick-makers-not-following-new-regulations

Guttikunda, S.K. and Khaliquzzaman, M. (2014). Health benefits of adapting cleaner brick manufacturing technologies in Dhaka, Bangladesh. *Air Quality, Atmosphere & Health, 7*(1), 103-112. Retrieved from https://link.springer.com/article/10.1007%2Fs11869-013-0213-z

Jerin M. K.(2016). Impacts of Brick Fields on Environment and Social Economy at Bagatipara, Natore, Bangladesh. *J. Environ. Sci. & Natural Resources, 9*(2), 31-34.

Joshi, S. K., and Dudani, I. (n.d.). Environmental Health Effects of Brick Kilns in Kathmandu Valley. *Kathmandu University Medical Journal, 6*(1), 3-11.

Pabna Samachar. (2019). Retrieved from https://www.pabnasamachar.com

Pariyar S. K., T. D. (2013). Environment And Health Impact For Brick Kilns In Kathmandu Valley. *NTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, 2*(5) 184-187.

Raut, A. K. (2003). Brick Kilns In Kathmandu Valley: Current Status, Environmental mpacts and Future 0ptions. *Himalayan Journal of Science, 1*(1), 59-51.

Saha, C. K. and Hossain, J. . (2016). Impact of brick kilning industry in peri-urban Bangladesh. *International Journal of Environmental Studies, 73*(4), 491-501. Retrieved from https://www.tandfonline.com/doi/full/10.1080/00207233.2016.1179014

The Daily Star. (2019). Retrieved February 24, 2019, from Construction sector looks to thrive on higher demand: https://www.thedailystar.net/star-infrastructure/news/construction-sector-looks-thrive-higher-demand-1706542

UNDP. (2011, June 20). Retrieved from Eco-friendly brick technique helps build a cleaner Bangladesh: https://www.undp.org/content/undp/en/home/presscenter/articles/2011/06/20/eco-friendly-brick-technique-helps-build-a-cleaner-bangladesh.html

QUALITY ASSESSMENT OF WATER USING WATER QUALITY INDEX METHOD: A CASE STUDY ON THE OLD BRAHMAPUTRA RIVER, JAMALPUR SEGMENT

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ABSTRACT

As a factor Water plays a crucial part in human existence. Because of the huge level of pollution in Bangladesh, the current condition of water quality as the most pollution happened in the river is absolutely essential to assess the scenario. Keeping this in mind the study is intended to determine the water quality index (WQI) and to see through the current status of the overall water quality of the old Brahmaputra river, Jamalpur. Determining different water quality parameters are quite expensive process. For water quality index designation, the National Sanitation Foundation-Water Quality Index (NSF-WQI) method had been used. To do so the required parameters were pH, Turbidity, Total Dissolve solids (TDS), Temperature change, Total Phosphate, Total Nitrates, Dissolve oxygen (DO), Biological Oxygen Demand for 5 days (BOD5) and Fecal coliform. In the months of May 2019 and July 2019, samples were gathered from three distinct locations. All the Parameters had been compared to standard values of the Department of Public Health Engineering (DPHE), Bangladesh. Since WQI is a single value for total water quality, the general features of the river should be more understandable to the public.

The average value of WQI of May’19 was 50.62 and 53.28 was found in the month of July,19 which means the quality of the water is medium.

Keywords: *Water quality index; NSF-WQI; Pollution; Parameters.*

1. INTRODUCTION

Bangladesh is known as the river nation with 700 river figures which is 24140 km (15000 miles) long. (River & Drainage System, n.d.).. Brahmaputra, One of Asia's main rivers. The Brahmaputra split into two branches; the western and the eastern which is formally known as the old Brahmaputra. It covers Mymensingh, Jamalpur, Sherpur and Netrokona district. (Brahmaputra River, n.d.). Water accounts for 71% of the earth's complete surface, with only 3% of fresh water. 75% water forms in glaciers and polar icebergs, 24% water storage and only 1% water are available in rivers, lakes or lakes as fresh water which is appropriate for human use. (Dugan, P.R. 1972). Water contamination is spreading in epidemic form at present owing to a number of reasons, such as industrialization, waste water and sewage, mining activity, marine dumping, accidental leakage of oil, fossil fuel combustion, chemical fertilizers and pesticides, waste from sewerage lines, radioactive wastes, urban growth. Rivers perform an important part in the assimilation or transport of industrial and municipal waste water, manure disposal, and rivers from the river pollution areas, streets and highways. The fluvial regime flowing across Bangladesh consists of the 3rd biggest water supply in the oceans. (Ali, 2002).The water quality index is described as a method that gives the general water quality a composite impact ranking of the various water quality parameters. (Akkaraboyina MK et al. 2012).The water quality index (WQI) is the most significant scheme for certifying water quality in a straightforward manner that can react to modifications in water fundamental features. The National Sanitation Foundation (NSF) has created the WQI Water Quality Index as a normal technique to compare the relative quality of multiple water bodies. (Said et al., 2004). Multiple national and international organization had been developed various WQI methods: Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) etc. (Paun et al., 2016). The water quality index of the old Brahmaputra had been evaluate using National Sanitation Foundation Water Quality Index (NSF-WQI). By taking a look at the parameters measured, the advantages of this method may generally indicate the old Brahmaputra water quality. In numerous developed countries, NSF-WQI was also extensively used for assessing river water quality. NSF-WQI has been developed with reference to the Horton index by Brown, McClelland, Deininger and Tozer since 1970. Different environmental specialists have used NSF-WQI and have demonstrated that this is a credible index to describe environmental quality. (Ott, 1978).

The necessary parameter for developing WQI using NSF-WQI: temperature Change, total dissolved solids (TDS), turbidity, dissolved oxygen (DO), pH, Biological Oxygen Demand (BOD), total nitrate, Total Phosphate, and fecal coliform.

2. METHODOLOGY

2.1 Study Area

The Study had been conducted in the selected points shown in figure-1. Station B was taken at the bottom of Brahmaputra Bridge. The Stations A and C each are taken at a distance of 2 km roughly to the east and west.

Table 1**:** The co-ordinates of water sampling stations.

Serial No.	Stations	Co-ordinates	
		N	E
01	A	24°55'56.0"	89°57'01.6"
02	B	24°55'24.4"	89°58'04.2"
03	C	24°54'47.0"	89°58'57.2"

Figure-1: Station A, B and C. (Source: Google Maps).

2.1.1 Sampling

1.5 litter plastic bottle was used during the collection. For fecal coliform test specialized glass bottle had been used which was wrapped with aluminium foil paper. And the plastic bottle was wrapped with black colour plastic polythene. 7th day of the month of May'19 and July,19 at the time of 9.00 am – 11.00 am the samples were collected from the stations. The samples were preserved at 4°C to maintain its proper quality.

2.2 Water Quality Index Development

Horton in 1965 first categorized water quality. In 1970, a general water quality index was developed by Brown et al. (Tirkey et al., 2013). For calculating the water quality index (WQI), raw analysis results are converted into unit-less sub-index values for the selected water quality variables with different calculated units. (Cude, C. 2001). In theory, the water quality indices consist of sub-index scores given by comparing their calculation in a scale of 0-100 for each quality parameter with a particular parameter rating curve, optionally weighted, and combined into the final index. (Yagow & Shanholtz, 1996)
The equation of developing water quality index,

$$WQI = \sum_{i=1}^{n} w_i I_i$$

Here,
W i = Weight parameter untill i, scale 0-1.0
I i = Value Sub Index for i th (Q-value)
n = The number of water quality parameters

Table 2**:** Weighting factors of the quality parameters of the water. (Thukral et al.,2005).

No.	Parameters	Weighting Factors
01	Dissolved Oxygen (% Saturation)	0.17
02	Temperature	0.10
03	Turbidity	0.08
04	Phosphate	0.10
05	TDS	0.07
06	Nitrate	0.10
07	pH	0.11
08	Fecal Coliform	0.16
09	BOD_5	0.11

Table 3: Water Quality Rating. (Thukral et al.,2005)

No.	WQI range	Quality of Water
01	>90-100	Excellent
02	>70-90	Good
03	>50-70	Medium
04	>25-50	Bad
05	0-25	Very bad

3. RESULT

Table 4,5 and 6 presents the concentrations of the quality parameters and quality index of the stations A, B and C for May'19 and table 7,8 and 9 representing for July'19 respectively.

Table 4: WQI of May'19 at station A

No.	Parameters	Concentration Present	Unit	Bangladesh Standard (For Drinking)	Q-Value	Weighting Factor	WQI
01	DO (%saturation)	12.9	-	-	8.74	0.17	1.49
02	Temperature	28.77	°C	20-30	11.23	0.10	1.123
03	Turbidity	265	NTU	10	5	0.08	0.4
04	Phosphate	0.19	mg/L	6.0	92.4	0.10	9.24
05	TDS	187	mg/L	1000	74.3	0.07	5.201
06	Nitrate	5.8	mg/L	10	61	0.10	6.1
07	pH	8.09	-	6.5-8.5	80.85	0.11	8.89
08	Fecal Coli.	13	N/100ml	0	69.3	0.16	11.09
09	BOD_5	0.86	mg/L	0.2	95.7	0.11	10.53
						∑WQI	54.064
						Quality of Water	Medium

Table 5: WQI of May'19 at station B

No.	Parameters	Concentration Present	Unit	Bangladesh Standard (For Drinking)	Q-Value	Weighting Factor	WQI
01	DO (%saturation)	12.97	-	-	8.79	0.17	1.49
02	Temperature	28.71	°C	20-30	11.29	0.10	1.129
03	Turbidity	243	NTU	10	5	0.08	0.4
04	Phosphate	0.15	mg/L	6.0	94	0.10	9.4
05	TDS	190	mg/L	1000	74	0.07	5.18
06	Nitrate	5.85	mg/L	10	60.75	0.10	6.075
07	pH	8.3	-	6.5-8.5	73.5	0.11	8.085
08	Fecal Coli.	159	N/100ml	0	39.87	0.16	6.38
09	BOD_5	0.83	mg/L	0.2	95.85	0.11	10.54
						∑WQI	48.68
						Quality of Water	Bad

Table 6: WQI of May'19 at station C

No.	**Parameters**	**Concentration Present**	**Unit**	**Bangladesh Standard (For Drinking)**	**Q-Value**	**Weighting Factor**	**WQI**
01	DO (%saturation)	12.9	-	-	8.74	0.17	1.49
02	Temperature	28.96	°C	20-30	11.04	0.10	1.104
03	Turbidity	308	NTU	10	5	0.08	0.4
04	Phosphate	0.21	mg/L	6.0	90.9	0.10	9.09
05	TDS	188.30	mg/L	1000	74.17	0.07	5.19
06	Nitrate	5.23	mg/L	10	63.85	0.10	6.385
07	pH	7.9	-	6.5-8.5	87	0.11	9.57
08	Fecal Coli.	315	N/100ml	0	33.55	0.16	5.37
09	BOD_5	0.89	mg/L	0.2	95.55	0.11	10.51
						∑WQI	49.109
						Quality of Water	Bad

Table 7: WQI of July'19 at station A

No.	**Parameters**	**Concentration Present**	**Unit**	**Bangladesh Standard (For Drinking)**	**Q-Value**	**Weighting Factor**	**WQI**
01	DO (%saturation)	13	-	-	8.8	0.17	1.50
02	Temperature	28.10	°C	20-30	11.89	0.10	1.19
03	Turbidity	252	NTU	10	5	0.08	0.4
04	Phosphate	0.23	mg/L	6.0	88.7	0.10	8.87
05	TDS	73	mg/L	1000	85.7	0.07	6.0
06	Nitrate	5.2	mg/L	10	64	0.10	6.4
07	pH	7.7	-	6.5-8.5	91	0.11	10.01
08	Fecal Coli.	10	N/100ml	0	72	0.16	11.52
09	BOD_5	0.84	mg/L	0.2	95.8	0.11	10.54
						∑WQI	56.43
						Quality of Water	Medium

Table 8: WQI of July'19 at station B

No.	**Parameters**	**Concentration Present**	**Unit**	**Bangladesh Standard (For Drinking)**	**Q-Value**	**Weighting Factor**	**WQI**
01	DO (%saturation)	12.9	-	-	8.74	0.17	1.49
02	Temperature	27.7	°C	20-30	12.3	0.10	1.23
03	Turbidity	283	NTU	10	5	0.08	0.4
04	Phosphate	0.27	mg/L	6.0	84.3	0.10	8.43
05	TDS	76	mg/L	1000	85.4	0.07	5.98
06	Nitrate	4.9	mg/L	10	65.5	0.10	6.55
07	pH	7.7	-	6.5-8.5	91	0.11	10.01
08	Fecal Coli.	130	N/100ml	0	41.9	0.16	6.7
09	BOD_5	0.86	mg/L	0.2	95.7	0.11	10.53
						∑WQI	51.33
						Quality of Water	Medium

Table 9: WQI of July'19 at station C

No.	Parameters	Concentration Present	Unit	Bangladesh Standard (For Drinking)	Q-Value	Weighting Factor	WQI
01	DO (%saturation)	13	-	-	8.8	0.17	1.50
02	Temperature	28.2	°C	20-30	11.8	0.10	1.18
03	Turbidity	377	NTU	10	5	0.08	0.4
04	Phosphate	0.23	mg/L	6.0	88.7	0.10	8.87
05	TDS	76	mg/L	1000	85.4	0.07	5.98
06	Nitrate	5.4	mg/L	10	85.2	0.10	8.52
07	pH	7.8	-	6.5-8.5	90	0.11	9.9
08	Fecal Coli.	350	N/100ml	0	32.5	0.16	5.2
09	BOD_5	0.87	mg/L	0.2	95.62	0.11	10.52
						∑WQI	52.07
						Quality of Water	Medium

3.1 DISCUSSION

The river is slightly alkaline with an average pH concentration of 7.915 and the water is highly turbid as it has an average concentration of 288 NTU. Fecal coliform concentration in both months is low at station A comparing to other stations as several municipal sewerage system opening located near station B and C. The inclusive phosphate (avg. 0.21 mg/L) and nitrate (avg. 5.4) concentration are below of their standards. Low Q-value of sub-indices i.e., DO, temperature, turbidity, fecal coliform is the major reason behind the low value of WQI.

From the results the overall water quality of the Old Brahmaputra can be specified. The highest value was found at station A in July'19 (56.43) which is in a medium criterion and the lowest at station B in May'19 (48.68) is in a bad criterion. The average value of WQI in May'19 was 50.62 and in July'19 the average value was 53.28. So, the overall quality can be summarized as a medium quality of water.

4. ILLUSTRATIONS

Figure 2 and 3 represents the water quality index of the month of May'19 and July' 19 respectively. Axis -X represent stations and Axis -Y represent water quality index.

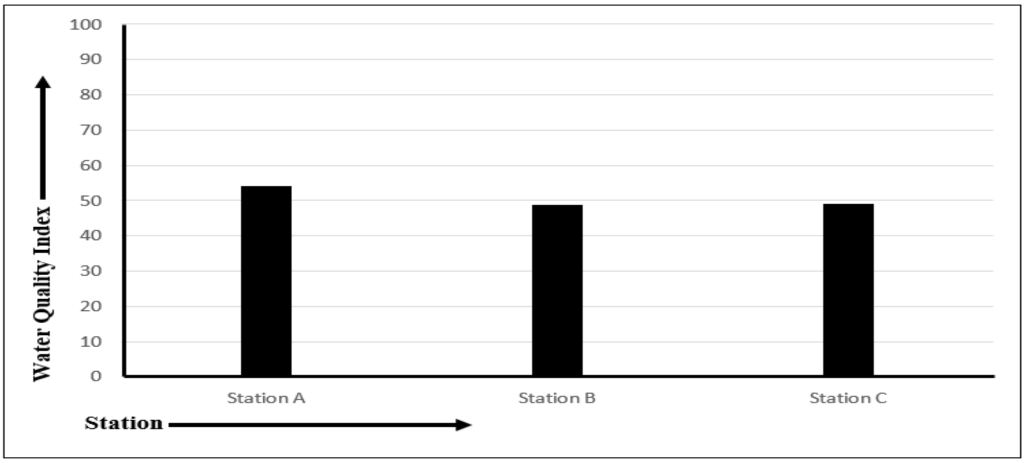

Figure - 2: Water Quality Index of May'19

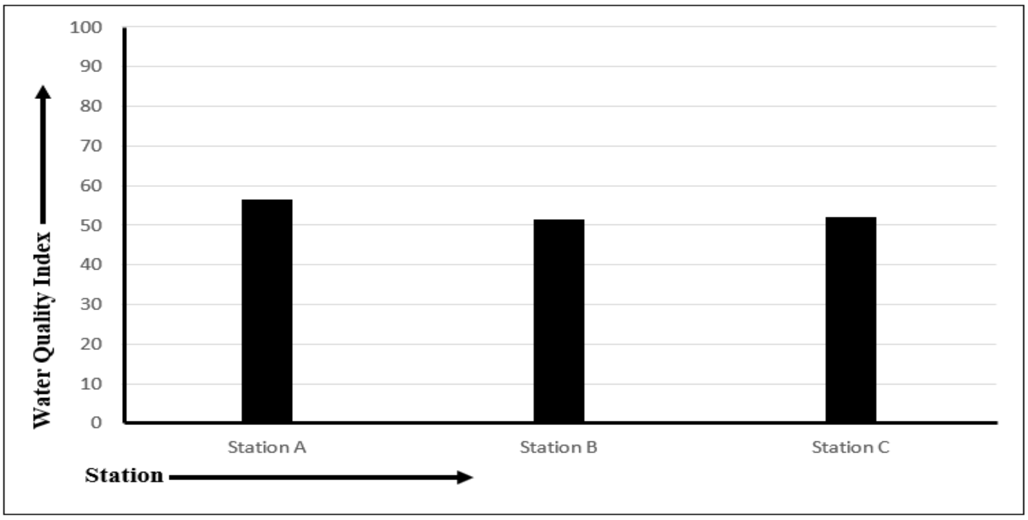

Figure - 3: Water Quality Index of July'19

5. CONCLUSION

The old Brahmaputra River plays a crucial part with work related to irrigation, transport system and drainage system of the whole region. The water quality of this river has been compromised for several reasons. Based on the values of WQI it can be concluded that the water quality is obviously not suitable for drinking. But it can be used for agricultural purposes.

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REFERENCES

River and Drainage System. (n.d.). Retrieved from http://en.banglapedia.org/index.php?title=River_and_Drainage_System

Brahmaputra River. (n.d.). Retrieved from https://en.wikipedia.org/wiki/Brahmaputra_River

Dugan, P.R. (1972). Biochemical Ecology of Water Pollution. Plenum Press London, 159

Ali MA (2002). Public Private Partnership for water resource management in Bangladesh Water. Department of Environment, The Government of Bangladesh.

Akkaraboyina, Mahesh & Raju, B.S.N... (2012). Assessment of water quality index of River Godavari at Rajahmundry. *Universal Journal of Environmental Research and Technology.*

Said, Ahmend & Stevens, David & Sehlke, Gerald. (2004). An Innovative Index for Evaluating Water Quality in Streams. Environmental management. 34. 406-14. 10.1007/s00267-004-0210-y.

Paun, Iuliana & Cruceru, Liliana & Chiriac, Florentina Laura & Niculescu, Marcela & Vasile, Gabriela & Marin, Nicoleta. (2016). Water quality indices - methods for evaluating the quality of drinking water. 395-402. 10.21698/simi.2016.0055.

Ott, Wayne. (1978). Environmental Indices Theory and Practice. Michigan: Ann Arbor Science.

Tirkey, Poonam & Bhattacharya, Tanushree & Chakraborty, Sukalyan. (2013). Water quality indices- important tools for water quality assessment: a review. 1.

Cude, Curtis. (2001). Oregon Water Quality Index: A Tool for Evaluating Water Quality Management Effectiveness. JAWRA *Journal of the American Water Resources Association.* 37. 125 - 137. 10.1111/j.1752-1688.2001.tb05480.x.

Yagow. G., and Shanholtz. V., (1996) Procedures for indexing monthly NPS pollution loads from agricultural and urban fringe watersheds. In Proceedings of Watershed '96 Conference, (accessible in electronic format through Internet at http://www.epa.gov/search97cgi).

Thukral, Ashwani & Bhardwaj, Renu & Kaur, Rajvir. (2005). Water Quality Indices.

INVESTIGATION OF BIOGAS GENERATION FROM KITCHEN WASTE OF BUET CHATTRI HALL

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ABSTRACT

Biogas is a renewable source of natural gas produced by the microbial degradation of organic matter in a process called anaerobic digestion. It can be a good practice for solid waste management. The research work is based on the effectiveness of bio-gas production from residential kitchen waste, collected from BUET Chattri Hall. It is seen that 73% of the kitchen waste is biodegradable, which is high, so it can be a good source of bio gas generation. For proper anaerobic digestion microorganisms have used, collected from the bio-gas plant of Jahangirnagar University, Savar. In last experiment to overcome the lack of balanced nutrition, Urea and DAP fertilizer are used for the nutrition supply like nitrogen and phosphorus. The digestion process of the sample has been observed in two ways- batch feed study, Semi continuous feed study. Four experiments have been done; among them 1st, 2nd, 4th experiment are done as batch feed study and 3rd one is done as semi continuous feed study. Biogas generation rate is found in the range of 0.021 m^3/kg of VS added to 0.069 m^3/kg for batch feed study, 0.0073 m^3/kg of VS added to 0.049 m^3/kg of VS added for batch study with nutrients, 0.029 m^3/kg of VS added to 0.19 m^3/kg of VS added for semi continuous feed study.In experiment one, two and three pH varied from 4 to 6. So, in experiment four we tried to increase pH by adding NaOH and then pH became almost stable in the range from 6.36 to 7.38. From this research, it is seen that gas has been produced successfully but after a certain time gas production has been stopped and consumption of gas is also noticed.

Keywords: *Waste, Biodegradability, Biogas, Anaerobic, Digestion*

1. INTRODUCTION

Waste management is a challenging task and global concern all over the world. Bangladesh is also facing similar adversity as the amount of waste generated from domestic and commercial activities is increasing day-after-day in the large cities including the megacity Dhaka (DoE, 2013). North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) collectively generate about 1.6 million tons of municipal waste per year, which emit approximately 1 million tons of GHG annually. A study by Department of Environment (DoE) revealed that Dhaka's problem regarding solid wastes is worse compared to cities in other developing countries. Everyday a lot of solid waste is producing in the kitchen of a residential area. So, we can try to convert our waste into resource. A very simple method is producing biogas. Most part of our kitchen waste is biodegradable. Hence, it can be a good source of biogas production. Biogas is a renewable source of energy. It can be an important fact of sustainable development. Biogas can be used for lighting, cooking, fuel and the use of biogas will reduce the demand of other energy sources like electricity, natural gas, fossil fuels etc. The residue of anaerobic digestion can be used as good fertilizer, which is also helpful. In most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. In addition, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming. A large fraction of kitchen waste is biodegradable organic material having the high calorific value and nutritive value to microbes and can be efficiently converted to biogas. The proper disposal of kitchen waste of Chattri Hall, BUET will be tried to done in eco-friendly and cost-effective way. Anaerobic digestion (AD) is a promising method to treat the kitchen wastes. Physical and chemical characteristics of the organic wastes are important for designing and operating digesters, because they affect the biogas production and process stability during anaerobic digestion. They include moisture content, volatile solids, nutrient contents, particle size, & biodegradability. The biodegradability of a feed is indicated by biogas production or methane yield and percentage of solids (total solids or total volatile solids) that are destroyed in the anaerobic digestion.

Dr. Anand Karve (ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen waste, leftover food, etc.). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours. Thus, the system developed by Dr. Anand Karve is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system (Karve. A.D, 2007); for that reason, in this research same type of waste is used instead of cow dung, sewerage etc.

Biodegradable waste includes any organic matter in waste which can be broken down into carbon dioxide (CO_2), water (H_2O), methane (CH_4) or simple organic molecules by micro-organisms. The main objective of the study is to investigate quantity of biogas from kitchen waste in reactors. Specific objectives of the study are-

1. To observe the batch feed study and semi continuous feed study.
2. To determine the digestion time or detention time for kitchen waste.
3. To study the effect of nutrients like nitrogen, phosphorus on biogas production.

2. METHODOLOGY

Kitchen waste is collected from Chattri Hall, BUET. After that biodegradable portion of waste is separated and cut into around four-millimetre small pieces and weighted by weighing machine for experiment. To determine the quantity of gas from anaerobic digestion of Residential hall kitchen waste, small gas plant suitable for laboratory use is taken to run the experiment. Four sets of gas collection system are used to measure Biogas. In this research, biodegradable components are used only. Hence, we need to know the percentage of biodegradable components in kitchen waste. To determine the percentage, waste is collected from hall kitchen. Waste is collected for 7 days and then the average percentage of biodegradable kitchen waste is determined.

2.1 Set up of laboratory scale gas plant

In each arrangement, a large glass bottle is used as reactor or digester with an inlet and outlet system. There are two holes bored in the cork, one for gas pipe and another for inlet glass tube. After placing sample, silica gel is used at stopper to make sure that the system is air-tight and no gas can escape from the digester.

Another two bottles are used for gas collection. Gas will be collected over water by water displacement method. Most components of biogas are non-soluble. When gas is not soluble in water, it can be collected over water. A rubber pipe from the reactor is connected with a glass bottle with sufficient amount of water. Another glass bottle with less amount of water is connected with the previous one. A measuring tape is attached to every glass bottle for measuring the amount of gas generated.

A heater is used for measuring the temperature of the system. Which is set to maintain the temperature at 32°C-35°C.

2.2 Waste Sample

For a representative sample, Kitchen waste of Chattri Hall was collected for 7 days. The biodegradable part of the waste was separated. Then each component of waste was separated to know the percentage of it on a weight basis. From 7 days survey, a representative composition of kitchen waste was found. This waste composition was used as the waste sample to digest anaerobically for producing biogas.

2.3 Collection of Microorganisms:

In Jahangir Nagar University, there is a biogas plant based on waste of residential Halls. For experiments, seed was collected from that biogas plant. The liquid of digester is full of microorganism. Hence, the inoculum was carried in a non-toxic container and collected just before starting of the experiment. Because this inoculum cannot be preserved, microorganisms may die for lack of nutrition or food in container.

2.4 Procedure of the experiment:

At first, survey was done in order to finding the ratio of biodegradable waste to non-biodegradable waste for one week. Then composition of biodegradable kitchen was calculated in percentage from the surveyed data. TS (Total Solid) and VS (Volatile Solid) percentage has been determined for the waste representative waste sample.

2.4.1 Batch Feed Study:

Experiment 1:
At first kitchen waste is collected and weighted. At 1st experiment 750gm waste and 1250ml inoculum is used in 1st set up. In another set up only 1250ml inoculum is used.

Experiment 2:
At 2nd experiment 250gm waste, 875 ml inoculum, 875ml water was used in 1st set up. In another set up 500gm waste, 750 ml inoculum, 750ml water was used.

Experiment 4:
At 4th experiment there were four set ups. In 1st set up 750gm waste+20gm Nitrogen+5gm Phosphorus are used (Set 1). In 2nd set up 750gm waste+15gm Nitrogen+3gm Phosphorus are used (Set 2). In 3rd set up 750gm waste+10gm Nitrogen+2gm Phosphorus are used (Set 3). In 4th set up

750gm waste+5gm Nitrogen+1gm Phosphorus are used (Set 4). For proper nutrition, nitrogen requirement is fulfilled from urea fertilizer (CH4N2O) and Phosphorus requirement is fulfilled from DAP [(NH4)2HPO4]. Fertilizers are diluted with water. In 1st set up 750gm waste, 34gm Urea, 25gm DAP,625ml inoculum ,566ml water is used. In 2nd set up 750gm waste, 27gm Urea, 15gm DAP,625ml inoculum, 583ml water is used. In 3rd set up 750gm waste, 18gm Urea, 10gm DAP,625ml inoculum, 597ml water is used. In 4th set up 750gm waste, 9gm Urea, 5gm DAP,625ml inoculum, 611ml water is used.

2.4.2 Semi-Continuous Feed Study:

The 3rd experiment was done by semi continuous feed system, in total four set ups. In 1st set up 1000gm waste, 500ml inoculum, 500 ml water are used. In 2nd set up 750gm waste, 625ml inoculum, 625 ml water are used. In 3rd set up 500gm waste, 750ml inoculum, 750 ml water are used. In 4th set up 250gm waste, 875ml inoculum, 875ml water are used. Data of gas generation is recorded at 24-hour interval. By assuming 20 days Hydraulic Retention Time (HRT);50gm,37.5gm ,25gm ,12.5gm sludge is removed and same amount of waste is fed semi continuously (three- and four-days interval in a week) in four set up respectively. In spite of daily feeding, waste is fed at three- and four-day's interval to avoid difficulties.

2.4.3 Data Recording:

Volume of gas in each 24-hour period was recorded. The recording of data was continued until the gas exhausted. pH is measured for every experiment by pH paper.

3. RESULT AND ANALYSIS:

The result of seven days survey is- biodegradable waste is 73% and non-biodegradable waste is 27%. The highest and lowest amount of waste is generally found on Saturday and Thursday respectively. Biodegradable waste part included- rice, potato, cauliflower, gourd, papaya, pumpkin, point-gourd where percentage of rice is the highest.

The value of TS is 33% and value of VS is 20.7%, determined from the average of three solid waste sample testing. From TS and VS value, we can understand the biodegradability property of solid waste since higher percentage of volatile solid indicates higher the percentage of biogas production.

In the 1st experiment, at first gas produced from solid waste and inoculum and gas produced from only inoculum is measured. Later, Gas produced from only solid waste is calculated by subtracting the previous values. The total amount of produced gas from 1st experiment is shown below:

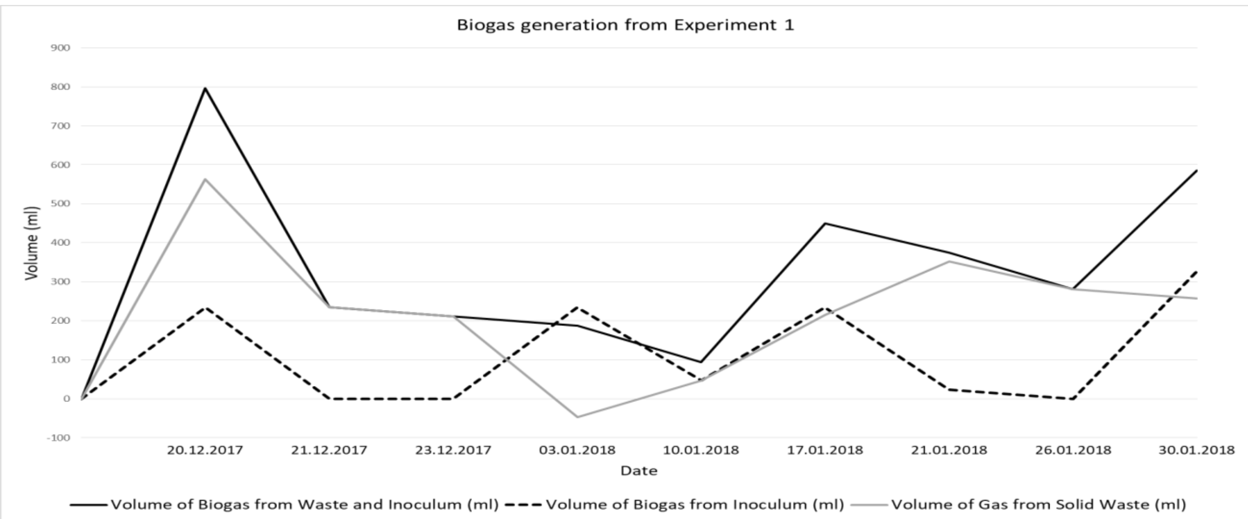

Figure 3.1: Bio-Gas generation from 1st experiment

From the graph it can be observed that at first gas production was high and the peak value is achieved in second day. Then the gas production decreased and after about ten days gas production started to increase. Gas is produced up to fifty-one days and then production of gas is exhausted. Temperature of the experiment is maintained around 32°C-35°C by a heater.

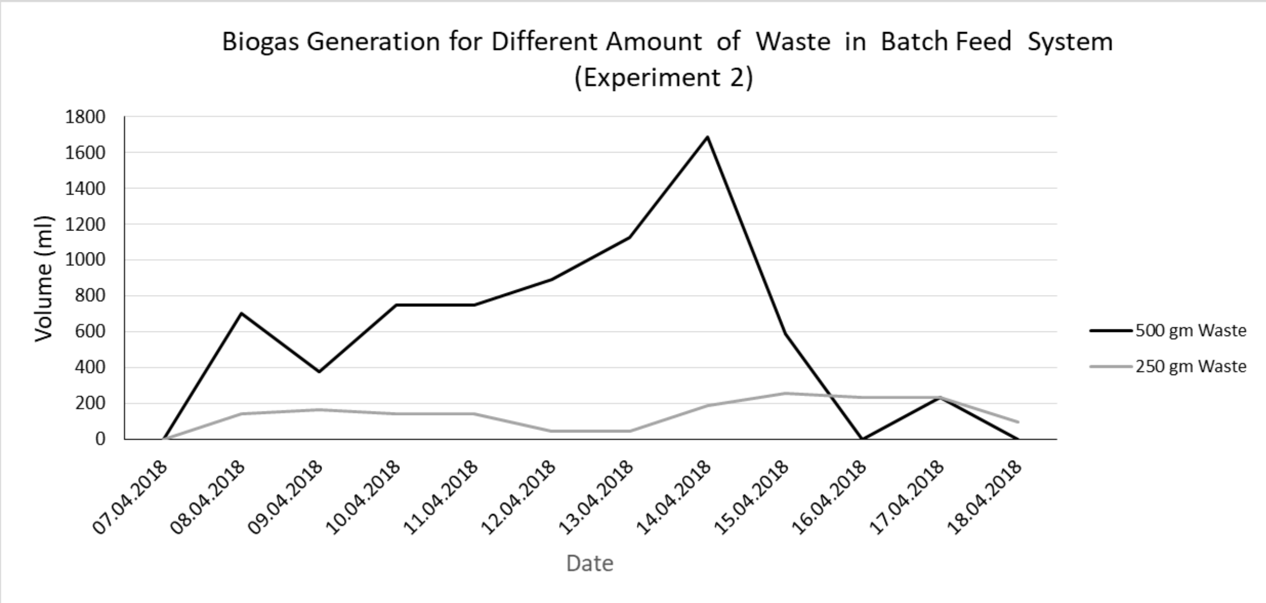

Figure 3.2: Bio-gas production from 2nd experiment

Gas production increased up to eight days for 500gm waste and then it started decreasing, and after twelve days gas production stopped. For 250gm waste, gas production gradually increased for seven days then after decreasing for two days it again started increasing up to eleven days and after that gas production finally stopped. Temperature of the experiment is maintained around (32°C-35°C) by a heater.

Biogas generation from the 3rd experiment, which is done by semi-continuous feeding system is shown below:

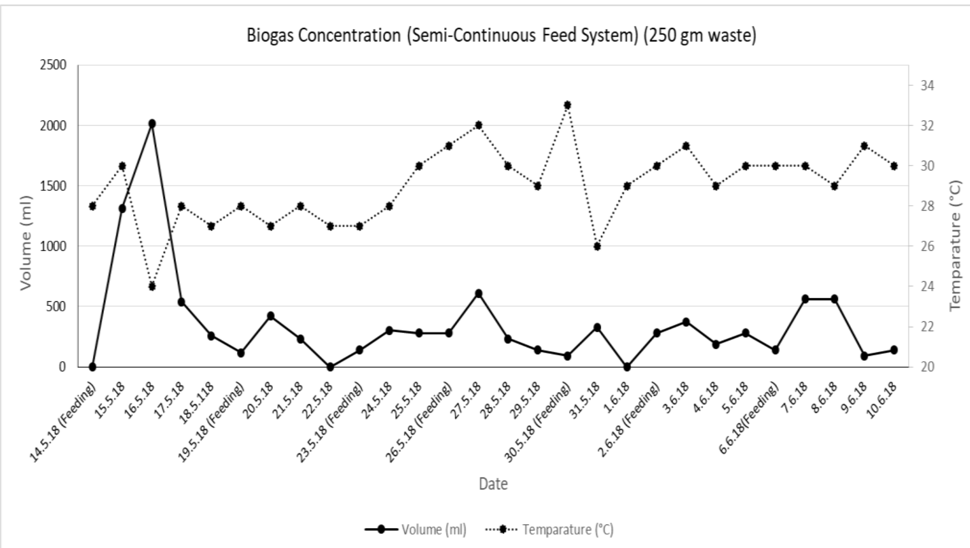

Figure 3.3:Bio-gas(black line) and temperature variation (ash line) for 250gm of waste

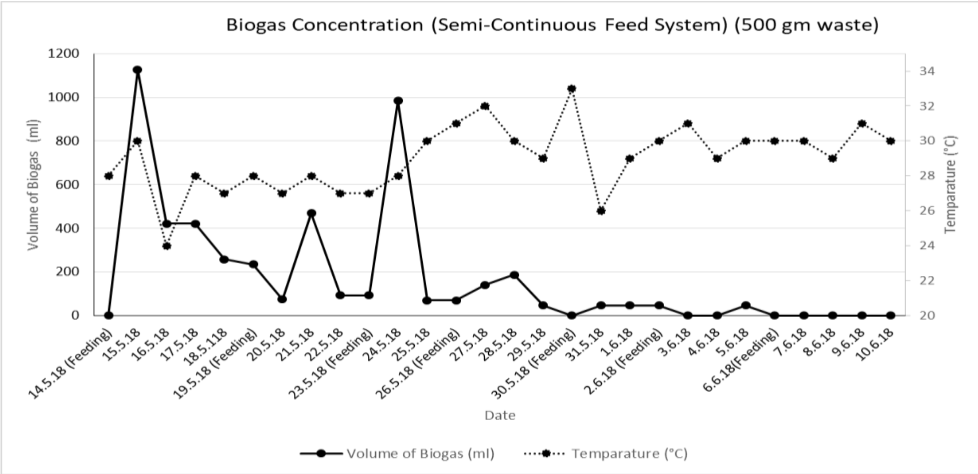

Figure3.4: Bio-gas(black line) and temperature variation (ash line) for 500gm of waste

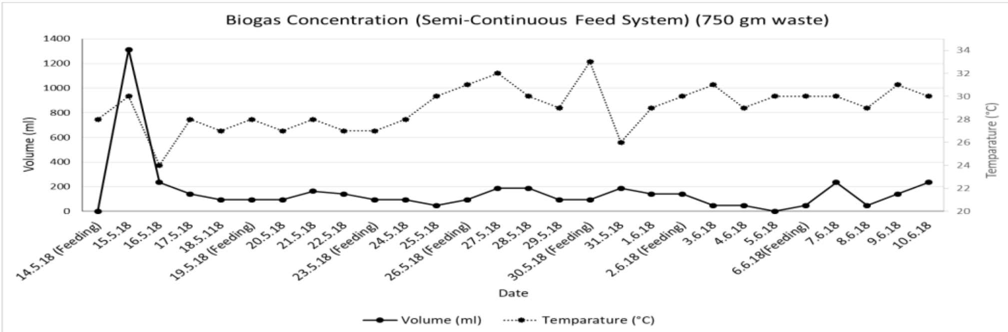

Figure 3.5:Bio-gas(black line) and temperature variation (ash line) for 750gm of waste

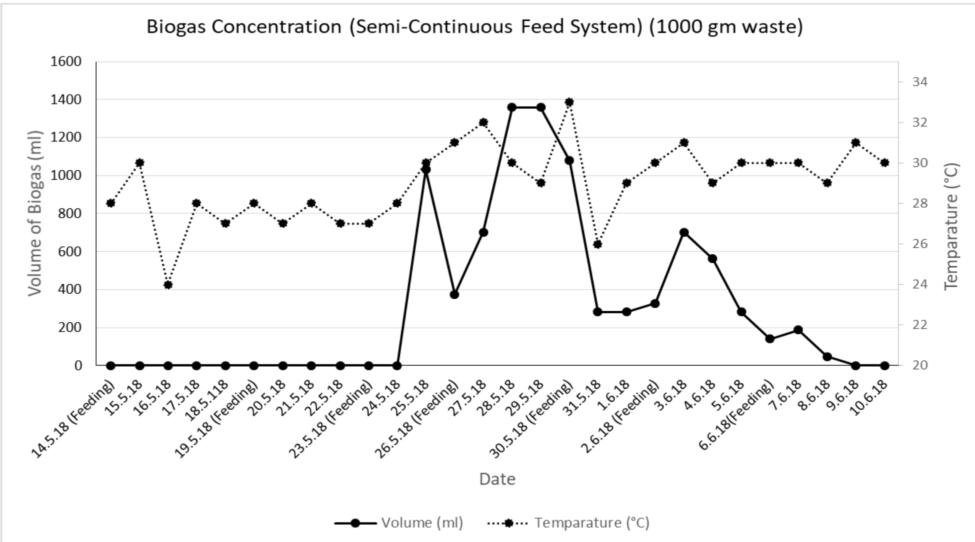

Figure 3.6:Bio-gas(black line) and temperature variation (ash line) for 1000gm of waste

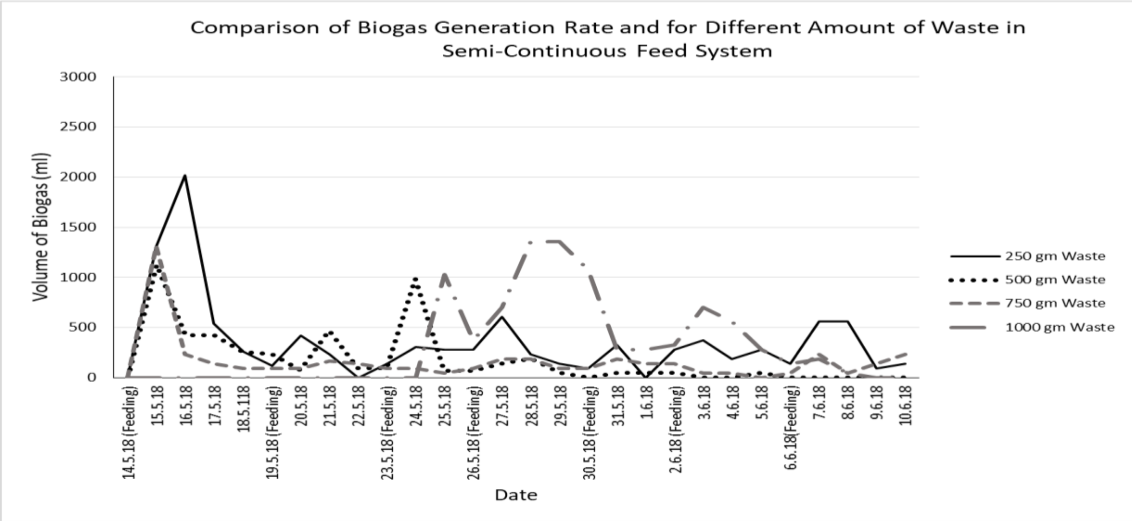

Figure 3.7: Bio-gas generation comparison from 3rd experiment

From figure 3.3 variation of temperature and biogas generation for 250gm, 500gm, 750gm and 1000gm waste is shown. From figure 3.4 it is seen that; the peak value of gas production is highest for 250gm waste among four and it also produce a good amount of gas than 500gm and 750gm waste throughout the time. On the other hand, after remaining stopped for ten days 1000gm waste then produced better amount of gas than 250gm waste and stopped gradually.

Bio-Gas generation for 4th experiment where nitrogen and phosphorus are added for showing a better result is shown:

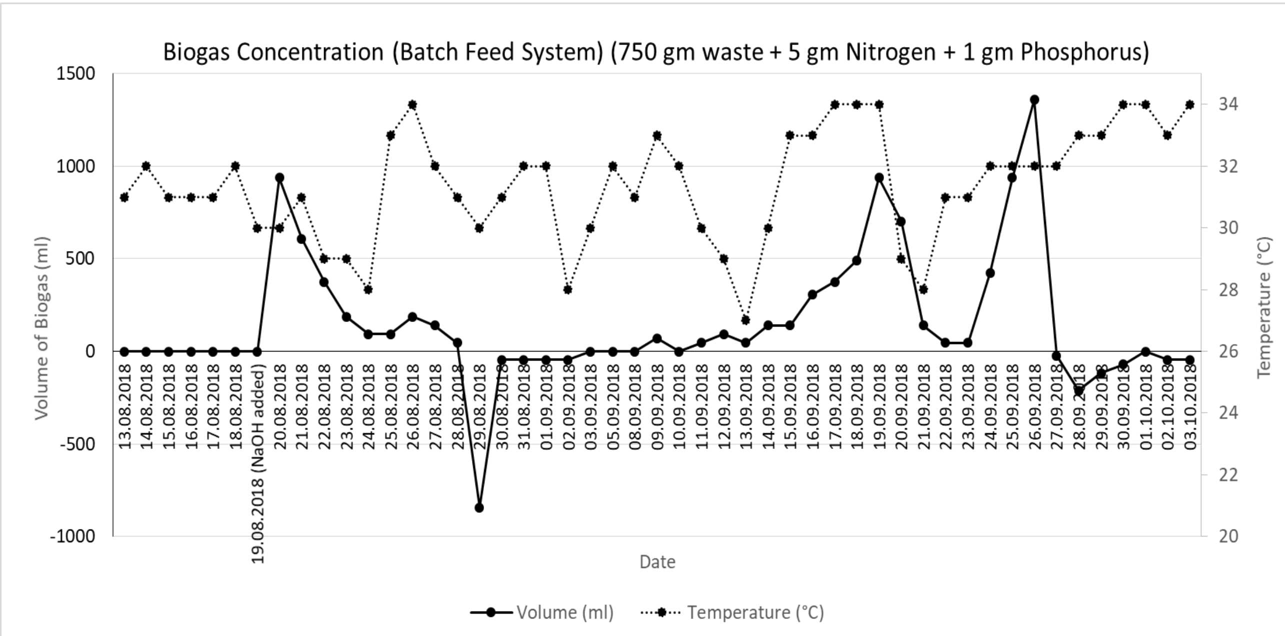

Figure 3.8: Bio-gas (black line) and temperature (ash line) variation for 750gm waste, 5gm Nitrogen, 1gm Phosphorus (Set 4)

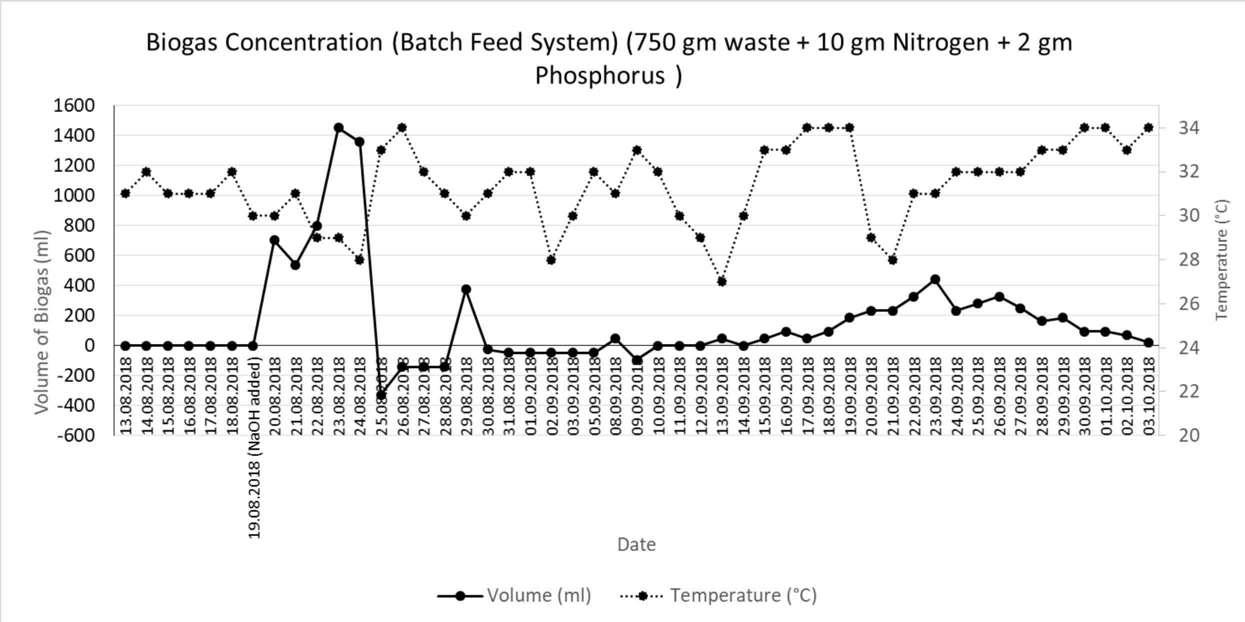

Figure 3.9: Bio-gas (black line) and temperature (ash line) variation for 750gm waste, 10gm Nitrogen, 2gm Phosphorus (Set 3)

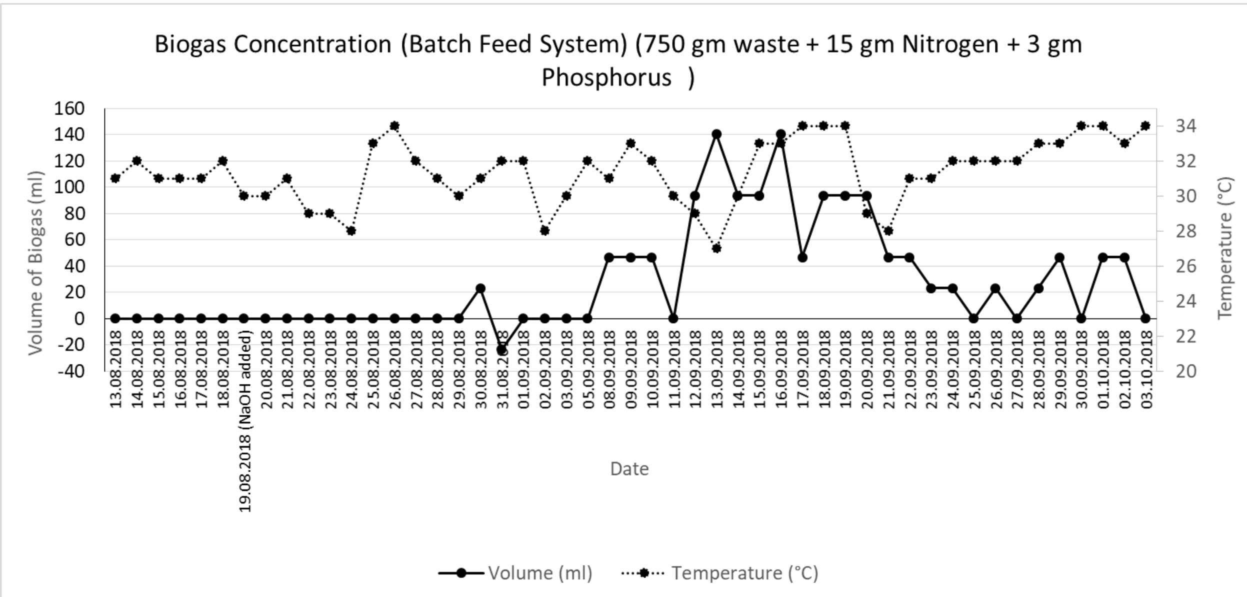

Figure 3.10: Bio-gas (black line) and temperature (ash line) variation for 750gm waste, 15gm Nitrogen, 3gm Phosphorus (Set 2)

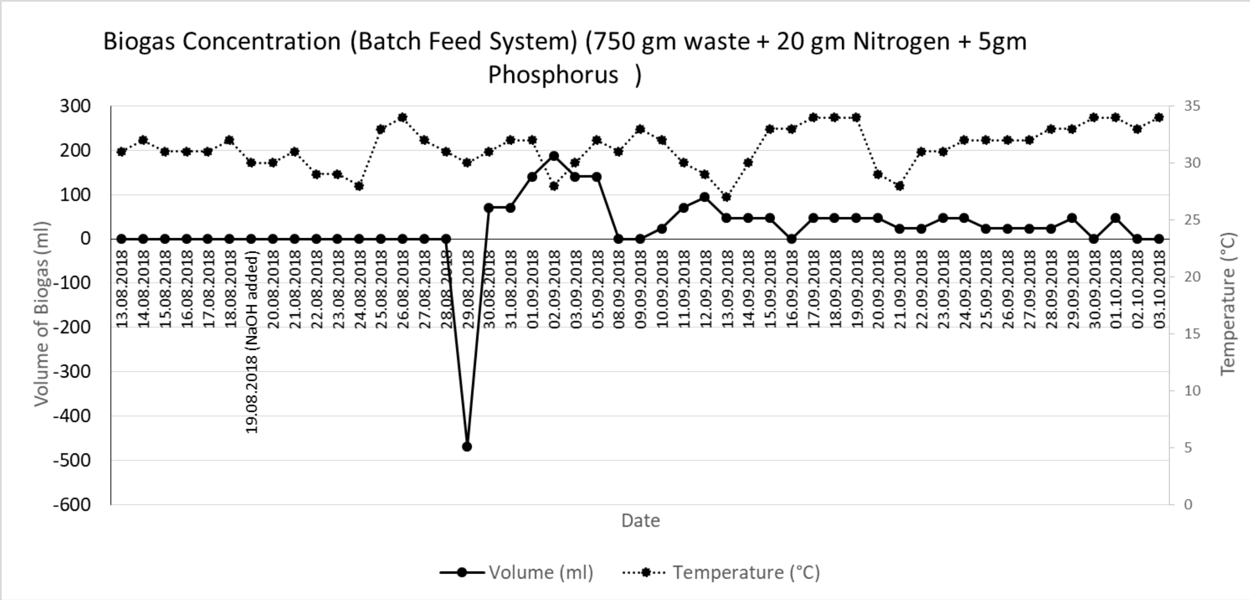

Figure 3.11: Bio-gas (black line) and temperature (ash line) variation for 750gm waste, 20gm Nitrogen, 5gm Phosphorus (Set 1).

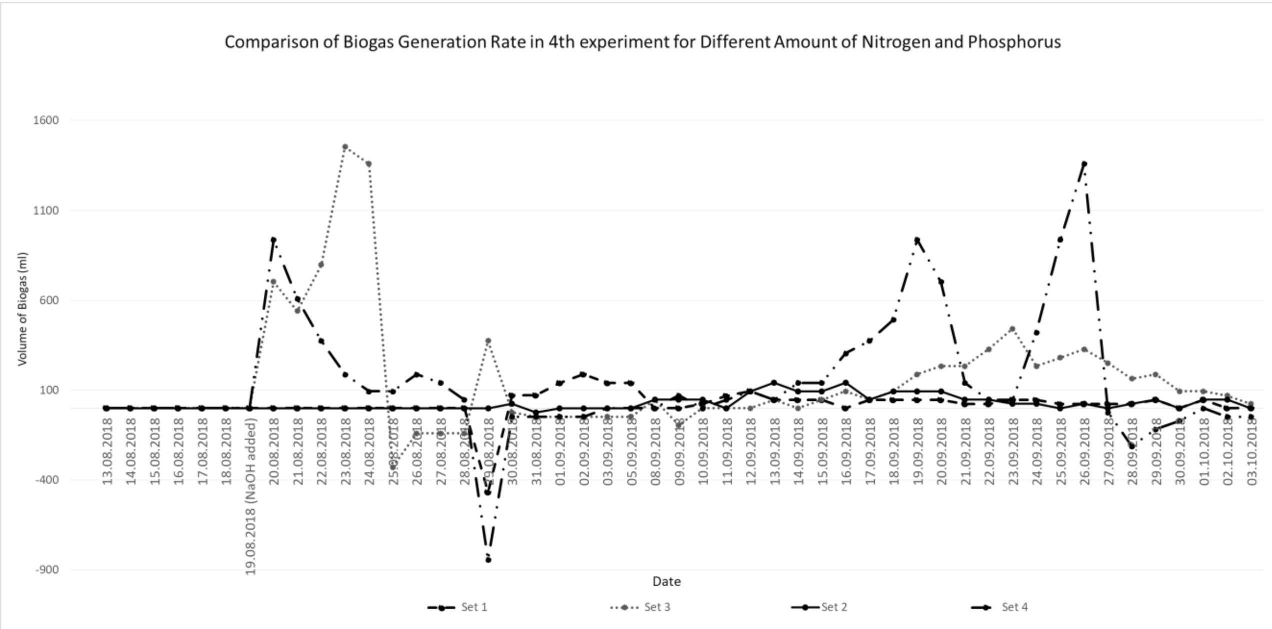

Figure 3.12: Bio-gas generation comparison from 4th experiment

From this comparison graph, it is seen that, set 3 and set 4 has shown comparatively better gas production than set 1 and set 2 even after consuming gas. For 6 days from starting, gas production was zero for all set so NaOH was added to increase pH value. For set 3 and 4 gas production varied according to variation of pH value proportionally. For set 2, it is seen that throughout the time it has higher value of pH but gas production was less than other sets. Biogas generation rates for all experiments are given below:

Experiment 1: 0.021 m3/kg of VS added (for 750gm waste).

Experiment 2: 0.033 m3/kg of VS added (for 250gm waste) and 0.069 m3/kg of VS added (for 500gm waste).

Experiment 3: 0.042 m3/kg of VS added (for 1000gm waste); 0.029 m3/kg of VS added (for 750gm waste); 0.047 m3/kg of VS added (for 500gm waste); 0.19 m3/kg of VS added (for 250gm waste).

Experiment 4: 0.0073 m3/kg of VS added (for set 1); 0.0088 m3/kg of VS added (for set 2); 0.049 m3/kg of VS added (for set 3); 0.048 m3/kg of VS added (for set 4).

In the experiments, we observed a low pH value ranging from 4 to 6 which represents acidic condition. It may be happened because of the production of various volatile fatty acids like Propionic acid, butyric acid, acetic acid, formic acid, lactic acid in the acetogenesis stage of anaerobic digestion.

4. CONCLUSIONS

In this research all observations, surveys, studies, experiments are done with great care but there may be some errors as practical works do not always follow theory properly. We tried our best to make an efficient and economical biogas production system to produce sufficient amount of gas from kitchen waste. From the whole research, we can establish some major findings, problems and difficulties, ways to overcome these.

- It is seen that 73% of the kitchen waste from hall is biodegradable. As the biodegradable portion is high, so it can be a good source of biogas generation.

- From solid waste sample, TS is found 33% and VS is found 20.7%. TS and VS indicate the biodegradability of solid waste.

- Biogas generation rate is found in the range of 0.021 m3/kg of VS added to 0.069 m3/kg for batch feed study, 0.0073 m3/kg of VS added to 0.049 m3/kg of VS added for batch study with nutrients, 0.029 m3/kg of VS added to 0.19 m3/kg of VS added for semi continuous feed study.

- In four experiments, different hydraulic retention times have been found. 51 days, 12 days, 28 days and 50 days are the retention time for four experiments respectively. From this, we can see that 1st and 4th experiment lasted for a long time.

- pH is one of the important parameters for biogas production. In experiment one, two and three pH varied from 4 to 6 which is acidic condition and is not desirable. So, in experiment four we tried to increase pH by adding NaOH and then pH varied from 4 to 9, and became almost stable in the range from 6.36 to 7.38 throughout the retention time.

- From this research, it is seen that gas has been produced successfully but after a certain time gas production has been stopped. In some cases, consumption of gas is also noticed.

ACKNOWLEDGEMENTS

The authors are rendering their profound thankfulness and regards to Mr. Akkas, Manager of Jahangirnagar University Biogas Plant, for helping the collection of microorganisms, which was a very important part of the research work and also to the kitchen workers of Chattri hall for helping while collecting and measuring the waste.

REFERENCES

Karve.A.D. (2007), Compact biogas plant, a low-cost digester for biogas from waste starch. http://www.arti-india.org.

WATER QUALITY INDEX (WQI) OF SHITALAKSHYA RIVER NEAR HARIPUR POWER STATION, NARAYANGANJ, BANGLADESH

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ABSTRACT

The present investigation is aimed at understanding the water quality parameters and the development of a water quality index (WQI) to assess the quality of the Shitalakshya River near Haripur power station, Narayanganj for five different years (2013-2018) considering monsoon, pre-monsoon, post monsoon seasonal variations. Water quality index (WQI) is a valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. In this study, three different methods were used to evaluate the WQI named as; Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. Essential parameters i.e. pH, total dissolved solids, dissolves oxygen, biochemical oxygen demand, electrical conductivity, chloride, turbidity, color, Silica, Iron, Phosphate were considered for calculating the WQI. According to Weighted Arithmetic Index Method the WQI value varied from 80 to 286 for the last five years. From the National Sanitation Foundation Method the WQI value was found within 36 to 56 for the study duration. The WQI value was varied from 3 to 16 according to Canadian Council of Ministers of the Environment Water Quality Index Method. Based on WQI values, the Shitalakhya river water was being classified as poor water for the above mentioned different years. Furthermore,the water quality were poor for different seasons as well.Among the different parameters, mostly turbidity, electrical conductivity, TSS, Iron were the parameters which caused the situation worst.Moreover, it was found there were no significant differences among the various methods for assessing WQI.

Keywords: *Water quality index, Pre-monsoon, Dissolved oxygen, Biochemical oxygen demand.*

1. INTRODUCTION

In the last few decades, there has been a tremendous increase in the demand for freshwater due to the rapid growth of population and the accelerated pace of industrialization. Most of the industries are growing beside the river because of the fastest accessibility. Furthermore, the expenses for the raw material transport is much cheaper through waterways. However, most of the industries do not maintain effluent treatment plant (ETP), eventually the effluents from those industries are being discharged directly to the rivers without any treatment. This has led to progressive and continual resource degradation and pollution, especially towards the surface water. Polluted water is an important vehicle for the spread of diseases. In developing countries, about 1.8 million people, mostly children, die every year because of water related diseases (WHO, 2004).

For healthy living, potable safe water is essential. It is a basic need of all human beings to get the adequate supply of safe and fresh drinking water. Moreover, Riverine water quality is an important issue for each stakeholder as it affects human uses as well as plant and animal life. A number of indices have been developed to summarize water quality data in an easily expressible and easily understood format. One of the most effective ways to communicate water quality is Water Quality Index (WQI), where the water quality is assessed because of calculated values. Quality of water is defined in terms of its physical, chemical, and biological parameters (Chowdhury & Hossain, 2012). WQI is defined as a rating that reflects the composite influence of different water quality parameters (Sahu & Sikdar 2008). Water Quality Index (WQI) is a very useful and efficient method for assessing the suitability of water quality. It is also a very useful tool for communicating the information on overall quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of water quality (both surface and groundwater). WQI reflects the composite influence of different water quality parameters and is calculated from the point of view of the suitability of (both surface and groundwater) for human consumption. Initially, WQI was developed by Horton in 1965, and improved version by Brown et al. in 1970.

The objective of this paper is to determine the WQI of water of the Shitalakshya River near Haripur power station, Narayanganj for five different years (2013-2018). The study area is shown on a satellite image with the power plant in Figure 1. Shitalakhya is the river which is regarded as one of the feeders of Brahmaputra,The stream of the river is the southwest direction at the initial stage. After that, it shifts its course to Narayanganj in the east and Dhaleswari near Kalagachhiya afterwards. The river is almost 110 kilometers or 68 miles long near Narayanganj in length and having 300-meter width. The Shitalakhya River consorted the Brahmaputra and then fell into Dhaleshwari (Islam & Jamal, 2012). Because of this significant location, at the bank of the Shitalakhya River, many factories and industries are established. However, these industries do not even follow or practice the treatment method of wastewater and toxic water. As a result, by the improper discharging process, a massive amount of toxic and wastewater mixed up in the Shitalakhya River. Besides, household and municipal sewage sludge from the Narayanganj urban areas are mixed up with this river without being treated. Hence, the dominance of pollution is rising at a higher rate day by day due to the heavy metals as well as various toxic substances are carried out by the industrial wastes and effluents (WARPO, 2000).

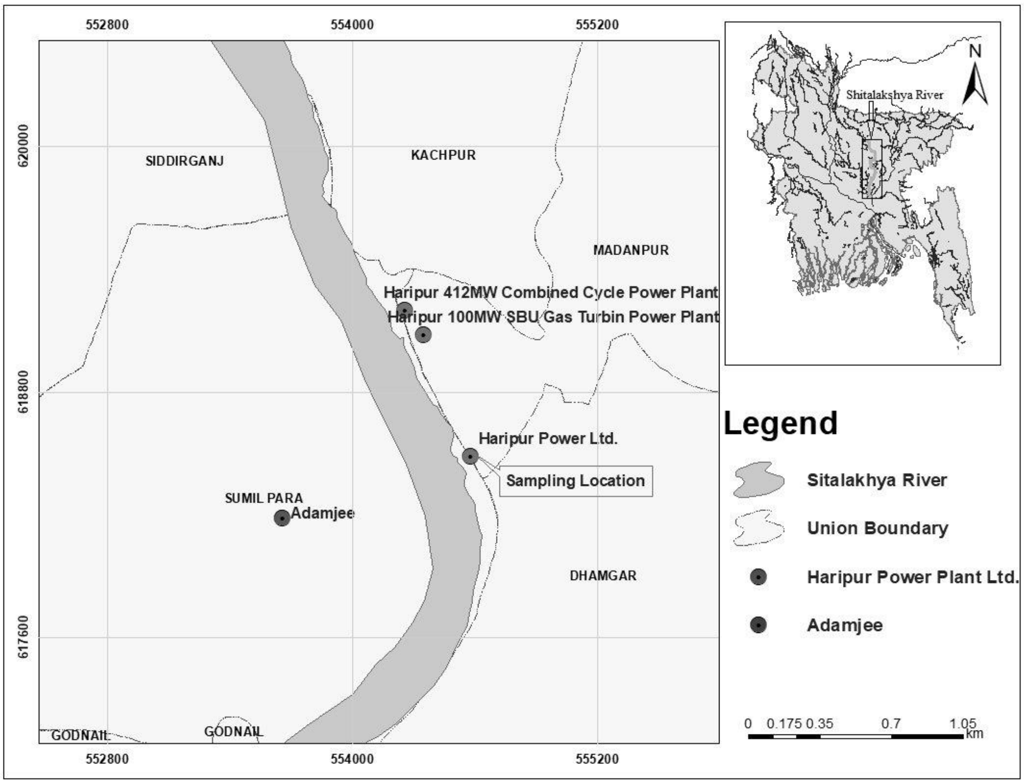

Figure 1: Location of main discharges on Sitalakhya River, Narayanganj.

Moreover, the government for establishing power plant for electricity generation has chosen this place. Power plants need huge amount of water for the cooling purposes and therefore power plants are built beside the river. Nevertheless, due to the pollution over the river, power plants required extensive level of treatment before using river water. Subsequently this increases the cost of treatment units so as the raise in overall cost of power production that affect the economy. Moreover, Local inhabitants of this area are dependent on the water of the Shitalakshya River for various purposes, which made the analysis inevitable. The single value of water quality index value will be useful for understanding the actual situation. Moreover, the trend in seasonal variation might help different stakeholders for stepping towards necessary actions. Foremost, the result might be beneficial for them to take decision for treating the worst parameters especially for the time of shortage in municipal supply water.

Over the years, several WQIs have been proposed and used appropriately by governmental agencies and researchers. These include: Index of River Water Quality, Overall Index of Pollution, Chemical Water Quality Index, Iowa Water Quality Index, Universal Water Quality Index-UWQI, Canadian Council of Ministers of Environment Water Quality Index-CCMEWQI, National Sanitation Foundation Water Quality Index – NSFWQI, Oregon Water Quality Index-OWQI, Weighted Arithmetic Water Quality Index Method WAWQIM. Out of these, the CCMEWQI, NSFWQI, OWQI, and WAWQIM are the commonly *us*ed (Oni & Fasakin,206). In this study, three different methods were used to evaluate the WQI named as; Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. The parameters assessed were water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), hardness (Ca & Mg), chloride, turbidity, alkalinity, iron and color for measuring the index values.

2. MATERIALS AND METHODOLOGY

2.1 Sample collection:

The samples are collected from the outlet of the power plant throughout the year and analysed immediately at the sampling site using standard equipment.
Water samples were collected once in week from Haripur (Figure 1) of the Narayanganj District of Bangladesh. The analysis was done for five years i.e., January 2013 to December 2018 except 2017.The samples were collected from the surface water of the Shitalakshya River.

2.2 Methodological Approach:

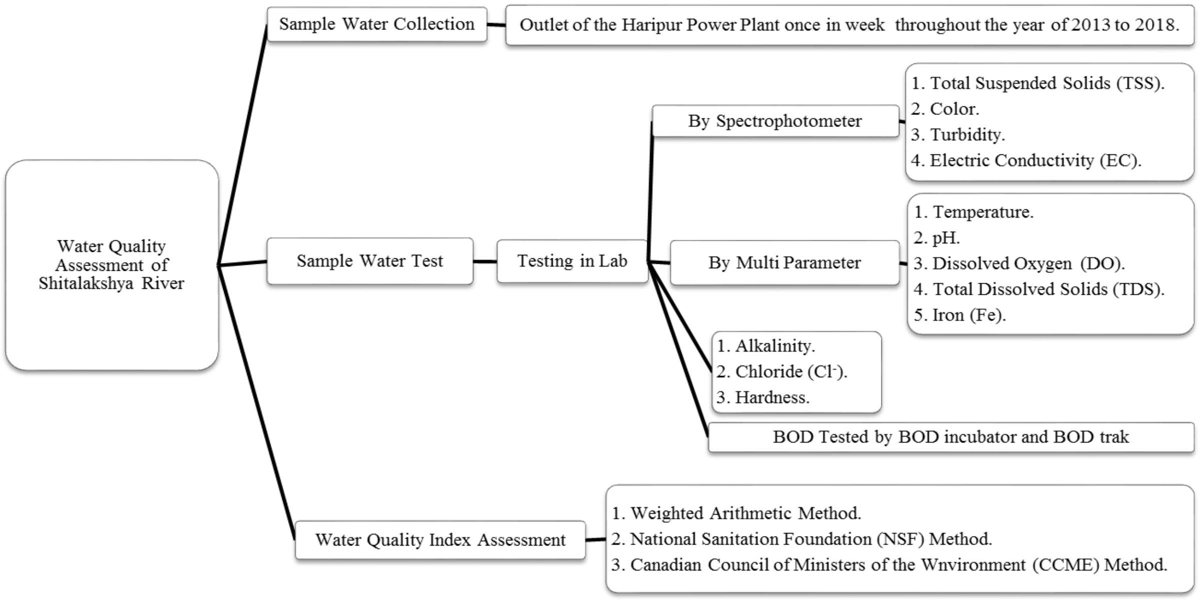

Figure 2: Methodological approach of the study.

2.3 Weighted Arithmetic Water Quality Index Method

The WQI, which is calculated using the weighted arithmetic index method (WAWQIM)is commonly used among researchers in developing countries where data collection infrastructure is not extensive for the database of the water quality parameters to be vast, and reliable rating curves are rare Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables.

The method has been widely used by the various scientists (Balan, Shivakumar & Kumar, 2012) and the calculation of WQI was made (Brown, McClelland, Deininger & O'Connor, 1972) by using the following equation:

$$WQI = \frac{\sum Qi\, Wi}{\sum Wi} \qquad (1)$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$Qi = 100[(Vi - Vo\, Si - Vo)] \qquad (2)$$

Where,
V_i is estimated concentration of i^{th} parameter in the analysed water.
V_o is the ideal value of this parameter in pure water.
V_o = 0 (except pH =7.0 and DO = 14.6 mg/l)
S_i is recommended standard value of this parameter
The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$Wi = K/Si \tag{3}$$

Where,
K = proportionality constant and can be calculated by using the following equation:

$$K = \frac{1}{\sum \frac{1}{Si}} \tag{4}$$

The rating of water quality according to this WQI is given in Table 1.

Table 1: Water quality rating as per weight arithmetic water quality index method.

WQI Value	**Rating of Water Quality**
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
Above 100	Unsuitable for drinking water for supply after conventional treatment

2.4 National Sanitation Foundation Water Quality Index (NSF WQI)

A usual water quality index method was developed by paying great rigor in selecting parameters, developing a common scale and assigning weights. The attempt was supported by the National Sanitation Foundation (NSF) and therefore as NSFWQI in order to calculate WQI of various water bodies which are critically polluted. The proposed method for comparing the water quality of various water sources is based upon nine water quality parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total solids (Brown, McClelland, Deininger & Tozer, 1970).

The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by

$$WQI = \sum_{i=1}^{n} QiWi \tag{5}$$

Where,
Q_i = sub-index for i^{th} water quality parameter.
W_i = weight associated with i^{th} water quality parameter.
n = number of water quality parameters.

For this NSFWQI method, the ratings of water quality have been defined by using following Table 3:

Table 2: Water Quality Rating as per National Sanitation Foundation Water Quality Index method.

National Sanitation Foundation Method (NSF WQI)	
WQI Value	**Rating of Water Quality**
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality

2.5 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

CCME WQI provides a consistent method, which was formulated by Canadian jurisdictions to convey the water quality information for both management and the public. Moreover, a committee established under the Canadian Council of Ministers of the Environment (CCME) has developed WQI, which can be applied by many water agencies in various countries with slight modification (Boyacioglu, 2010). This method has been developed to evaluate surface water for protection of aquatic life in accordance to specific guidelines. The parameters related to various measurements may vary from one station to the other and sampling protocol requires at least four parameters, sampled at least four times (Khan, Tobin, Paterson, Khan & Warren, 2005) The calculation of index scores in CCME WQI method can be obtained by using the following relation:

$$WQI = 100 - \frac{\sqrt{F_1{}^2 + xF_2{}^2 + F_3{}^2}}{1.732} \tag{6}$$

Where,
Scope (F_1) = Number of variables, whose objectives are not met.
F_1= [No. of failed variables /Total no. of variables] *100.
Frequency (F_2) = Number of times by which the objectives are not met.
F_2 = [No. of failed tests/Total no. of tests] *100.
Amplitude (F_3) = Amount by which the objectives are not met.

a) $Excursioni = [Failed\ test\ valuei\ /Objectivej] - 1.$

$$normalized\ sum\ of excursions, \qquad nse = \frac{\sum_{i=1}^{n} excursion}{No. of\ Tests}$$

b) $F_3 = [\mathrm{nse}/0.01\mathrm{nse} + 0.01]$

Five categories have been suggested to categorize the water qualities which are summarized in Table-3.

Table 3: Water quality rating as per Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) method.

Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)	
WQI Value	**Rating of Water Quality**
95-100	Excellent water quality
80-94	Good water quality
60-79	Fair water quality
45-59	Marginal water quality
0-44	Poor water quality

3. RESULTS & DISCUSSION

3.1 Assessment of Water Quality Using Different WQI Methods

In this study Water Quality Index of Shitalakshya River has been calculated by three different methods e.g. Weighted Arithmetic Index Method, Canadian Council of Ministers of the Environment Water Quality Index Method and National Sanitation Foundation Method. Maximum, Minimum, Mean, variance and standard deviation are given in Table 4. The standard deviation and variance indicate that there exists large fluctuation in the values of various parameters contributing the water quality of the river. Correlation matrix of water quality parameters has been shown in Table 5.

Table 4: Maximum, minimum and average values of different water quality parameters.

Parameter	Unit	Maximum Value	Minimum Value	Mean Value	Variance	Standard deviation
pH		7.87	7.13	7.47	0.14	0.37
DO	mg/l	5.87	0.23	2.88	0.48	0.69
Color	Pt-co	52.50	2.73	20.27	4.72	2.17
Conductivity	μ/c	1151.75	130.50	519.89	680.29	26.08
TDS	mg/l	637.25	64.40	277.45	1350.76	36.75
TSS	mg/l	136.25	20.20	63.69	30.55	5.53
Hardness	mg/l	196.50	38.50	107.21	27.32	5.23
Cl^-	mg/l	147.50	9.20	50.72	141.87	11.91
Turbidity	ftu	146.50	17.60	50.57	37.03	6.08
Alkalinity	mg/l	450.00	35.20	170.08	606.98	24.64
Fe	mg/l	10.25	0.02	0.52	0.12	0.34
Temperature	℃	32.08	21.20	28.20	1.26	1.12
BOD	mg/l	6.5	2.8	4.9	0.18	0.42

Table 5: Correlation matrix of water quality parameters of Shitalakshya River

	pH	DO	Color	Conductivity (C)	TDS	TSS	Hardness (H)	Cl^-	Turbidity (Tu)	Alkalinity (Alk)	Iron (Fe)	Temperature (T)	BOD
pH	1.00												
DO	0.84	1.00											
Color	0.13	-0.03	1.00										
C	0.32	-0.05	0.43	1.00									
TDS	0.26	0.15	0.12	0.84	1.00								
TSS	0.11	0.41	0.36	-0.60	-0.58	1.00							
H	0.35	0.17	0.92	0.60	0.38	0.25	1.00						
Cl^-	-0.24	-0.25	0.01	0.65	0.84	-0.67	0.09	1.00					
Tu	-0.05	0.12	0.76	0.04	0.05	0.65	0.76	-0.06	1.00				
Alk	-0.38	-0.73	0.06	0.65	0.48	-0.82	0.10	0.61	-0.23	1.00			
Fe	-0.08	-0.13	0.95	0.39	0.18	0.34	0.83	0.20	0.80	0.09	1.00		
T	0.47	0.47	-0.19	0.09	0.27	0.03	0.17	-0.19	0.11	-0.10	-0.34	1.00	
BOD	-0.60	-0.37	-0.78	-0.48	-0.24	-0.32	-0.92	0.20	-0.62	0.06	-0.59	-0.40	1.00

3.1.1 WQI by Weighted Arithmetic Method

To determine the WQI by Weighted Arithmetic Method (WAM), sub water quality index for various parameters were estimated. The bar chart (Figure 2) compares the seasonal water quality index values for different years. It was found most of the water quality parameters exceed permissible limit throughout the year.Worst scenario was visible in post monsoon season for most of the year. However, water quality parameters were slightly better in monsoon period which eventually made the index value barely within the limit to be considered as good water quality.According to the rating of arithmatic index value (Table 1) only monsoon season of 2018 showed good water quality.

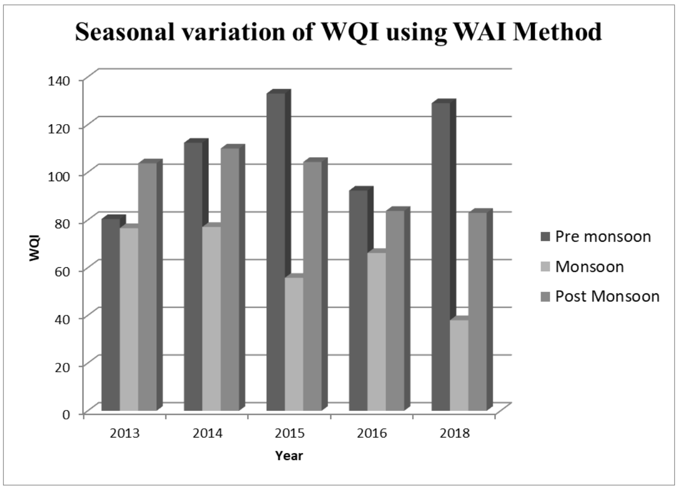

Figure 2: Seasonal variation in the WQI determined by weight arithemetic method.

3.1.2 WQI by NSF

Figure 3 shows the seasonal variation in water quality for the different years by NSF method. According to NSF method the water quality is degreding along with time.Among the 5 different years, the scenario was awful for the year 2018 almost throughout the year.

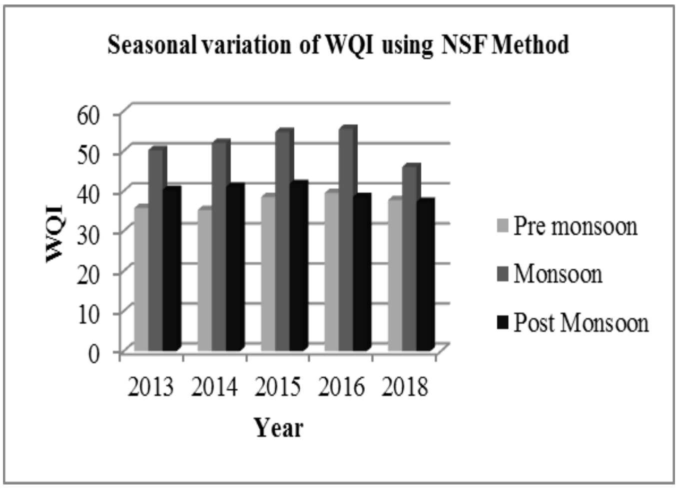

Figure 3: Seasonal variation in the WQI determined by National Sanitation Foundation Water Quality Index (NSF) method.

3.1.3 WQI by CCME

Following Table 6 shows the calculation of factors for the CCME method for the year 2018. It was found mostly there were three to seven parameters among the twelve parameters which were failed to be within permissible limit. For the particular year April was the month which falls within pre monsoon experienced poorest quality. According to the following method F_2 expresses the fact that mostly the parameters were far away from the standard values in post monsoon.

Table 6: Results of WQI founded by CCEM method.

Month	Failed Item	Total Item	F1	No. of Failed test	Total test	F2	Total Excursion	nse	F3	CCMEWQI
JAN	5	13	38.46	23	55	41.8	87.57	1.59	100.01	12.60
FEB	5	13	38.46	20	44	45.5	102.13	2.32	100.01	11.56
MAR	5	13	38.46	20	44	45.5	159.91	3.63	100.01	11.56
APR	7	13	53.85	21	44	47.7	135.10	3.07	100.01	6.38
MAY	3	13	23.08	12	44	27.3	21.23	0.48	100.01	19.30
JUN	3	13	23.08	9	33	27.3	14.58	0.44	100.01	19.30
JUL	6	13	46.15	19	47	40.4	42.95	0.91	100.01	10.85
AUG	4	13	30.77	16	44	36.4	54.45	1.24	100.01	15.83
SEP	5	13	38.46	17	47	36.2	59.14	1.26	100.01	14.07
OCT	5	13	38.46	18	47	38.3	27.67	0.59	100.01	13.54
NOV	6	13	46.15	20	45	44.4	61.81	1.37	100.01	9.75
DEC	6	13	46.15	22	46	47.8	85.11	1.85	100.01	8.76

In this table it has been noticed that in monsoon period number of failures is respectively low, on the other hand in pre monsoon and post monsoon the number of failures is high.

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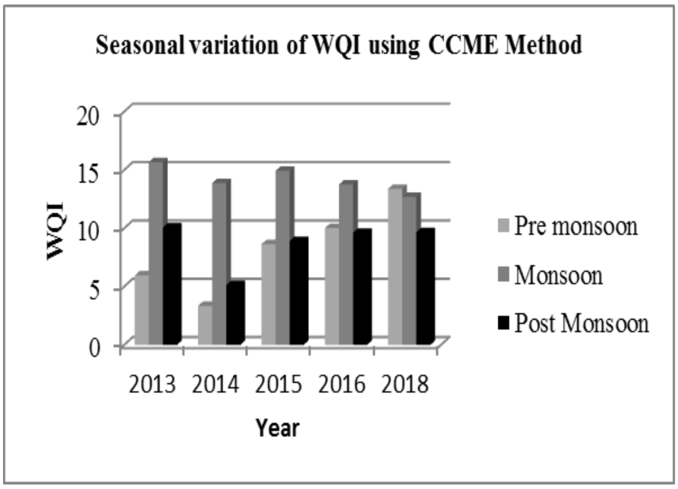

Figure 4: Seasonal variation in the WQI determined by Canadian Council of Ministers of the Environment Water Quality Index (CCME) method

Figure 4 compares the result for different seasons using CCME method. For the year 2014, pre monsoon season was awful according to Table 3.

3.2 Comparison of WQI between different methods

The Table-8 compares the seasonal water quality index method for different years for different methods. There was almost no variation among the three different methods for assessing water quality index values. Not only for almost every season but also for every method the water quality of the particular river water was proved to be unsuitable for domestic, drinking and aquatic species. However, rendering the method WAI, the quality showed good where as for the same season other two methods showed opposite result.

Tabel 7: WQI value for the period of 2013-2018 according to different methods considering corresponding rating.

WQI Method	Season	2013		2014		2015		2016		2018	
		WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating	WQI Value	WQI Rating
WAI	Pre monsoon	80	Very Poor water quality	112	Unsuitable for drinking water for supply after conventional treatment	133	Unsuitable for drinking water for supply after conventional treatment	92	Very Poor water quality	151	Unsuitable for drinking water for supply after conventional treatment
	Monsoon	77	Very Poor water quality	77	Very Poor water quality	56	Poor water quality	66	Poor water quality	87	Good water quality
	Post Monsoon	104	Unsuitable for drinking water for supply after conventional treatment	286	Unsuitable for drinking water for supply after conventional treatment	104	Unsuitable for drinking water for supply after conventional treatment	84	Very Poor water quality	108	Poor water quality
CCME	Pre monsoon	6	Poor water quality	3	Poor water quality	9	Poor water quality	10	Poor water quality	13	Poor water quality
	Monsoon	16	Poor water quality	14	Poor water quality	15	Poor water quality	14	Poor water quality	13	Poor water quality
	Post Monsoon	10	Poor water quality	5	Poor water quality	9	Poor water quality	10	Poor water quality	10	Poor water quality
NSF	Pre monsoon	36	Bad water quality	35	Bad water quality	39	Bad water quality	40	Bad water quality	38	Bad water quality
	Monsoon	50	Bad water quality	52	Medium water quality	55	Medium water quality	56	Medium water quality	46	Bad water quality
	Post Monsoon	40	Bad water quality	41	Bad water quality	42	Bad water quality	39	Bad water quality	37	Bad water quality

4. CONCLUSIONS

In this study, the samples were collected from the Shitalakshya River once in week at the outlet point of the Haripur power plant throughout the year. Assessment of Shitalkhya river water quality was done for past five years (January 2013 to December 2018). Comparison was shown considering different seasons; Pre monsoon, Monsoon, Post monsoon. Water quality parameter such as pH, DO, BOD, EC, colour, turbidity, hardness and some minerals were examined for the evaluation. The main purpose of the research work was to assess the water quality by means of different water quality index methods; Three widely used methods; (WAI method, NSF method, CCME method) were used to calculate the WQI. This kind of surface water rating might help people to have clear understanding of the water quality status for its further use. Besides, WQI integrates the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers. After assessing the results, the study clearly reveals that the quality of the Shitalakshya River possesses poor water quality. The results were similar for the three different methods which proved the validity of the result. Moreover, the water quality status was almost similar throughout the year regardless seasonal variation. Among the different parameters, mostly turbidity, electrical conductivity, TSS, Iron were the parameters which caused the situation worst. This will eventually affect the aquatic ecosystems, recreational and industrial use. Consequently, fish culture has been defused due to this condition. Furthermore, the cost of treatment of water to be used in industries is dramatically increasing. Indirectly, therefore, the worst quality of surface water helps to increase the cost of production and to affect the economy of the country.

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REFERENCES

Akoteyon, I. S., Omotayo, A. O., Soladoye, O., & Olaoye, H. O. (2011). Determination of water quality index and suitability of urban river for municipal water supply in Lagos-Nigeria. *European Journal of Scientific Research*, 54(2), 263-271.Retrieved from http://www.eurojournals.com/ejsr.htm

Balan, I. N., Shivakumar, M., & Kumar, P. M. (2012). An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India. *Chronicles of Young Scientists*, 3(2), 146. Retrieved from http://www.cysonline.org/text.asp?2012/3/2/146/98688

Boyacioglu, H. (2010). Utilization of the water quality index method as a classification tool. *Environmental monitoring and assessment*, 167(1-4), 115-124. doi: 10.1007/s10661-009-1035-1

Brown, R. M., McClelland, N. I., Deininger, R. A., & Tozer, R. G. (1970). *A water quality index- do we dare*.

Chowdhury, R. M., Muntasir, S. Y., & Hossain, M. M. (2012). Water quality index of water bodies along Faridpur-Barisal road in Bangladesh. *Glob Eng Tech Rev*, 2(3), 1-8. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.681.1779&rep=rep1&type=pdf

Goutam, A. (2018). *A survey to access household water quality at Narayanganj industrial zone*. Retrieved from http://dspace.bracu.ac.bd/xmlui/bitstream/handle/10361/10959/14146025_PHR.pdf?sequence=1&iisAllowe=y

Islam, S., Rasul, T., Alam, J. B., & Haque, M. A. (2011). Evaluation of water quality of the Titas River using NSF water quality index. *Journal of Scientific Research*, 3(1), 151-151. Retrieved from https://www.banglajol.info/index.php/jsr/article/download/6170/5153

Kankal, N. C., Indurkar, M. M., Gudadhe, S. K., & Wate, S. R. (2012). Water quality index of surface water bodies of Gujarat, India. *Asian J. Exp. Sci*, 26(1), 39-48. Retrieved from https://link.springer.com/content/pdf/10.1007/s10661-009-0848-2.pdf

Khan, A. A., Tobin, A., Paterson, R., Khan, H., & Warren, R. (2005). Application of CCME procedures for deriving site-specific water quality guidelines for the CCME Water Quality Index. *Water Quality Research Journal*, 40(4), 448-456. Retrieved from http://www.mae.gov.nl.ca/waterres/quality/background/Khan_2005_WQRJ_40_4.pdf

Kumar, D., & Alappat, B. J. (2009). NSF-water quality index: does it represent the experts' opinion?. *Practice Periodical of Hazardous, toxic, and radioactive waste Management*, 13(1), 75-79. Retrieved from https://ascelibrary.org/doi/pdf/10.1061

Kumar, A., & Dua, A. (2009). Water quality index for assessment of water quality of river Ravi at Madhopur (India). *Global journal of environmental sciences*, 8(1). Retrieved from https://www.ajol.info/index.php/gjes/article/viewFile/50824/39511

Lumb, A., Halliwell, D., & Sharma, T. (2006). Application of CCME Water Quality Index to monitor water quality: A case study of the Mackenzie River basin, Canada. *Environmental Monitoring and Assessment*, 113(1-3), 411-429. Retrieved from https://link.springer.com/content/pdf/10.1007/s10661-005-9092-6.pdf

Oni, O., & Fasakin, O. (2016). The Use of Water Quality Index Method to Determine the Potability of Surface Water and Groundwater in the Vicinity of a Municipal Solid Waste Dumpsite in Nigeria. *American Journal of Engineering Research (AJER)*, *5*(10), 96-101. Retrieved from https://www.researchgate.net/profile/Olayiwola_Oni/publication/329153085_The_Use_of_Water_Quality_Index_Method_to_Determine_the_Potability_of_Surface_Water_and_Groundwater_in_the_Vicinity_of_a_Municipal_Solid_Waste_Dumpsite_in_Nigeria/links/5bf81d9192851ced67d270b4/The-Use-of-Water-Quality-Index-Method-to-Determine-the-Potability-of-Surface-Water-and-Groundwater-in-the-Vicinity-of-a-Municipal-Solid-Waste-Dumpsite-in-Nigeria.pdf

Rabee, A. M., Hassoon, H. A., & Mohammed, A. J. (2014). Application of CCME Water Quality Index to Assess the Suitability of Water for Protection of Aquatic Life in Al-Radwaniyah-2 Drainage in Baghdad Region. *Al-Nahrain Journal of Science*, 17(2), 137-146. Retrieved from https://anjs.edu.iq/index.php/anjs/article/download/453/396

Sahu, P., & Sikdar, P. K. (2008). Hydrochemical framework of the aquifer in and around East Kolkata Wetlands, West Bengal, India. Environmental Geology, 55(4), 823-835. Retrieved from http://www.academia.edu/download/40326122/Env_Geol_Published_paper_P_Sahu.pdf

Semiromi, F. B., Hassani, A. H., Torabian, A., Karbassi, A. R., & Lotfi, F. H. (2011). Water quality index development using fuzzy logic: A case study of the Karoon River of Iran. *African Journal of Biotechnology*, 10(50), 10125-10133. Retrieved from https://www.ajol.info/index.php/ajb/article/viewFile/95887/85228

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of water quality index. *American Journal of Water Resources*, 1(3), 34-38. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1011.2307&rep=rep1&type=pdf

Verma, N., Tripathi, S. K., Sahu, D., Das, H. R., & Das, R. H. (2010). Evaluation of inhibitory activities of plant extracts on production of LPS-stimulated pro-inflammatory mediators in J774 murine macrophages. *Molecular and cellular biochemistry*, 336(1-2), 127-135. Retrieved from https://idp.springer.com/authorize/casa?redirect_uri=https://link.springer.com/article/10.1007/s11010-009-0263-6&casa_token=_-mgyDhvG9MAAAAA:hJa3IyG8PFw03pixcTTNHzM-P9AFO0IlDW3zqPZwwfgOpq843uiY4n5R1n_ECirqLfpTbT8VLaCgM7nAGg

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FEASIBILITY STUDY OF WASTE TO ENERGY CONVERSION FROM MUNICIPAL SOLID WASTE IN CHARLOTTE-MECKLENBURG COUNTY, NORTH CAROLINA

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ABSTRACT

In this paper Charlotte-Mecklenburg County waste generation data has been used to study the feasibility of recovering energy from municipal solid waste (MSW) generation. To do so, the study evaluated greenhouse gas emissions of the waste material based on a life cycle assessment approach developed by the United States Environmental Protection Agency. The study focuses on energy recovery potential and economic analysis of Charlotte-Mecklenburg county MSW. The waste-to-energy assessment considered the short-term and long-term plans of the County's MSW practices in determining the cost of incineration. Assumptions are adopted from World Bank guideline for an incineration plant. The literature review has been done on European best practices with MSW to determine a more management oriented strategy to handle waste. Methodology included waste component analysis, heating value measurement, greenhouse gas emission estimate, waste management plan as well as environemental impact. An average lower calorific value (LCV) of 20.34 MJ/kg was estimated from the MSW after implementing the solid waste management plan of the County, an indication of energy recovery potential. For a long-term plan with an LCV of 20.34 MJ/kg, approximately 1.8 million houses can be supplied electricity for an hour. Value of energy sale 20.34 MJ/kg of waste is $91/ton and for 16.62 MJ/kg of waste is $75/ton. If NRP is used as combustion fuel along with other fuels, we could approximately save $10,000,000 of fuel.

However, implementation of a waste incineration plant to recover energy from the commercial sector waste generated would require a per capita fee increment to $41 annually. Also waste incineration cost per kg MSW is almost $3. Finally energy potential from the current trend of waste generated has been discussed in the result section.

Keywords: *Waste generation, Energy recovery, Municipal solid waste, Greenhouse gas emission.*

1. INTRODUCTION

The Charlotte-Mecklenburg County is one of the rapidly growing urban cities in the United States since the economic downturn in 2008. The growth in population and economic activities affects systems such as transportation, solid waste management, water and wastewater, and energy which characterize urban ecosystems. Hence, there is the need to ensure these systems are economically and environmentally sustained in providing the necessary support to the urban ecosystem. Solid waste management, being intrinsic to urbanization, forms part of various systems the Charlotte-Mecklenburg County is addressing to ensure its sustainability whiles reducing its impacts on the environment and climate change.

Adopting the United States Environmental Protection Agency (EPA) waste management hierarchy, the Charlotte-Mecklenburg County, through its ten-year solid waste management plan (SWMP) developed in 1997, has embarked on sustainable solid waste management system (HDR, 2012). The plan emphasizes on, in the order of, source reduction and reuse, recycling and composting, energy recovery and disposal. The County's SWMP has since seen updates over the years with the recent one being for the period 2012-2022. Through outreach campaigns to residential and commercial sectors, significant achievement has been attained in source reduction, recycling, composting with national recognition (HDR, 2012). Nonetheless, a large amount of solid waste is disposed of in landfills. The County currently has two main landfill sites serving its waste management system. The Foxhole landfill located within the county serves construction and demolition (C&D) waste and the Speedway landfill located in the Cabarrus County. Although the Foxhole landfill has the capacity for residential and commercial waste, the contract with Cabarrus County maintains Foxhole landfill for C&D waste.

Waste incineration programs initiated by the County were abandoned simply due to the increasing cost of compliance with environmental regulations as well as Federal laws that restricted diversion of waste to the energy recovery facilities (Gledhill, 2007). However, through the advancement of technology, recovering energy from the incineration of MSW makes it a cost effective method and more sustainable method of waste management. Regarding emissions, several studies in Europe evaluating greenhouse gas (GHG) emissions from MSW incineration indicate that incineration has sinks in GHG emissions (Yang *et al.*, 2012). However, in McPhail *et al.* (2014) study on the impact of MSW composition and moisture content on the environment, cost and energy generation from co-combustion, it was concluded that further analysis is carried out on the reaction kinematics and plant operation conditions to evaluate GHG emission sinks related combustion. With best available technologies (BAT) to control emissions, MSW can provide a sustainable source of energy to compliment other sources of renewable energy in the County. Waste-to-Energy (WtE) systems derive energy in the form of heat, electricity or transport fuels from waste materials. These systems can be classified into three namely: thermo-chemical, bio-chemical and chemical conversions (World Energy Council, 2013). Smith *et al.* (2015) discusses WtE technologies as an industrial ecological approach to municipal solid waste management. Bajpai (2015) also discusses operating conditions for new technologies for extracting energy from waste such as pyrolysis, direct liquefaction among others.

Thermo-chemical conversion utilizes thermal treatment at high temperatures to extract the energy content of waste. Based on the fuel choice processes such as incineration, co-combustion, residual fuel (RDF) plant and thermal gasification can be selected (World Energy Council, 2013). Bio-chemical conversion utilizes bio-chemical processes such as fermentation, anaerobic digestion and microbial fuel cell to extract the energy content of the primary source primarily through bio-decomposition of the waste (World Energy Council, 2013). Chemical conversion – esterification is the notable chemical process that can produce varying types of biofuel from waste (World Energy Council, 2013). McPhail et al. (2014) evaluated the environmental, economic and energy impact of MSW composition and moisture content in a co-combustion system.

With the rapid increase in raw materials and energy prices in the early seventies, Majority of European countries went through a thorough review of methods for better conservation of resources and potentials of recovery and reuse of materials that have been refused as waste. To obtain a much cleaner society there was constant increase of pressure on the orthodox disposal route, landfilling etc. Those were also transforming to be more expensive due both to the reduction in available land area locatable to the centers of population. Also, the environmental issues associated with landfill e.g. leachate, methane, odor etc. (Barton, 1985). BMW is a biodegradable municipal waste. Separate BMW collection system provided by the local authorities leading to separate, mandatory BMW treatment systems in Austria and Netherlands. Some EU members use economic instrumentation like Pay-As-You-Throw (PAYT), Organic waste Tax. Example: Belgium, Norway, Ireland, Luxembourg etc. Pires et al., 2011).

In UK BMW system and Landfill Allowance Trading System (LATS) were launched to provide local authorities more flexibility to manage waste stream. LATS allows waste diversion to the cheapest and most practicable area using transferable allowances. Pires et al., 2011).

Packaging waste system promoted analogous incentives to ensure maximum reuse and recycling. The utmost popular system is Green Dot System firstly applied in Germany in 1990s and later all over Europe. The elementary idea is to establish a privately organized channel which will assure all primary packaging can be collected from the consumers goes to a material specific recycling process. The so called green dot is used to classify the product belonging to the dual system during consumption phase. (Pires et al., 2011).

Pretreatment such as sorting and homogenizing is required in implementing the incineration plan. The key waste product stream from incineration is the slag or bottom ash. Typically it amounts to 20 to 25 % by weight of the waste combusted but only to 5 to 10 percent by volume. After being removed by gravitational pull the main disposal method for slag is the landfilling. (Rand et al., 2000).

2. METHODOLOGY

2.1 Waste Composition Analysis

Data for the waste composition analysis was extracted from the waste composition study conducted by SCS Engineers for the Charlotte-Mecklenburg County in 2011. SCS ENGINEERS (2011) reported the study area for three institutions namely: Charlotte – Mecklenburg Schools (CMS), County government buildings such as the Department of Social Services and Medical Facilities (County Facilities) and the Central Piedmont Community College (CPCC) with a sample size of 50. Based on the limitation data on the County's waste composition, this study assumes that the composition analysis result generated by (SCS ENGINEERS, 2011) is a representation of the waste generated by the commercial sector for the fiscal year 2010/2011. Hence, a simple arithmetic mean of the waste composition for the three institutions mentioned above should represent the commercial sector waste generated for the fiscal year 2010/2011.

2.2 Greenhouse Gas Emission Analysis

MSW is associated with GHG emissions throughout the lifecycle of the materials which impact the environment and climate change. In assessing the GHG emissions from the solid waste management practices, the waste reduction model (WARM) developed by the United States EPA which is a life cycle assessment tool that assist solid waste mangers to report on GHG emissions reductions based on implemented waste management practices (USEPA, 2016a). For baseline and alternative waste management practices – source reduction, recycling, composting, combustion and landfilling, WARM estimates the associated GHG emissions based on emission factors developed from the life cycle of the materials. The alternative waste management practices were based on the SWMP 2012-2011 of the Charlotte-Mecklenburg County.

Although WARM accounts for emissions from incineration, this study takes into account climate-relevant emissions namely carbon dioxide (CO_2), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_x), ammonia NH_3), non-methane volatile organic compounds (NMVOCs) based on the proposed methodology by Lee *et al.* (2001) as follows:

2.3 Waste Management Plan

2.3.1 Charlotte-Mecklenburg County SWMP (Livingstone)

The County's SWMP plan had the fiscal year 1998/1999 as its baseline but for the purpose of this study and the data available, the fiscal year 2010/2011 was selected as the baseline. The revised SWMP goals for the commercial sector is shown in
Table *1* below.

Table 1. Revised commercial sector goals for Charlotte-Mecklenburg County for 2012-2022.

	Baseline FY10/11	**Short-Term Plan FY16/17**	**Long-Term Plan FY21/22**
Population	923,944	1,027,829	1,114,398
Disposal tons if NO new programs	513,081	637,665	691,373
Disposal tons with PROPOSED short-term programs	N/A	575,376	623,837
Disposal tons with PROPOSED short-term and long-term programs	N/A	N/A	512,888
Proposed rate tons/person/year	0.56	0.56	0.46
Rate reduction % of baseline year	N/A	0%	18%
Proposed tons diverted from disposal	N/A	62,289	178,485

2.4 Heating Value Analysis

The capability of municipal solid waste to sustain a combustion process without auxiliary fuel depends on a few physio-chemical parameters, of which the lower calorific value (LCV) is the most vital. Besides it also depends on the water content of the municipal solid waste. The higher the moisture content the more fuel is required to burn the waste. A wet waste with a moisture content greater than 95% percent or a sludge waste with less than 15% percent solids content would be considered poor for incineration (Brunner, 1991). Water vapors from the combustion process and the moisture content of the fuel disperse with the flue gasses during ignition. The energy content of the water vapors is actually the difference between a fuel's higher calorific value (HCV) and lower calorific value (LCV). If the LCV is not noteworthy, incineration would not be a feasible disposal method. Usually a waste with a heating value less than 1000 BTU/lb is not relevant for ignition.(Brunner, 1991) MSW with a soul purpose of combustion should have a LCV of minimum level. The requirement of minimum LCV for a controlled ignition also depends on the incinerator design. If MSW is burnt with assistance of low-grade fuels, it must need a heat loss minimization strategy with a drying of waste before ignition. (Rand *et al.*, 2000).

2.5 Heating Value Measurement:

The most reliable method of determining heating value quantities is by experiment. The most widely used equipment for testing for heating value is the oxygen bomb calorimeter. In this apparatus a measured sample typically 1 g, is ignited in an atmosphere of pure oxygen by an electric wire. When the sample heat of combustion heats a water bath surrounding the bomb the water bath temperature rises and the heat of combustion is calculated from this temperature increase (Brunner, 1991).

2.5.1 *Assessment of Heating Values of Mecklenburg MSW:*

After carefully performing literature review, we have chosen the Modified Dulong model for estimating the heating value of MSW. There are also other models like Modified shafizadeh model. The LCV differs from the HCV by the heat of condensation of the combined water vapors, which comes from the fuel's moisture content and the hydrogen released through combustion (Rand *et al.*, 2000).

Modified Dulong model:

$$HCV\ \left(kJ/kg\right)\ =\ 337C+1428\left(H-O/8\right)+95S \tag{1}$$

$$LCV\left(kJ/kg\right)=HCV-0.212H-0.0245W-0.008O \tag{2}$$

Where, C: Carbon%; H: Hydrogen %; O: Oxygen %; S: Sulfur %; and W: water content % (Menikpura *et al.*, 2007).

2.6 Chemical Composition of MSW

There are two types of chemical composition analysis namely:
Proximate analysis - It is a comparatively swift and economical laboratory test to determine the percentages of moisture, volatile matter, fixed carbon and ash.
Ultimate analysis - It is a standard approach to determine the quantities of fundamental components present in a sample. It is an obligatory process to determine the products of combustion of a material, its combustion air requisite and the nature of the combustion products. Carbon, Hydrogen, Sulfur, Oxygen, Nitrogen, Halogens, Heavy Metals can be determined from this analysis. (Brunner, 1991). As we did not have any scope to do laboratory test in this class project, we have used literature review to best fit the chemical composition of Mecklenburg county waste.

In performing the chemical composition analysis the study relied on literature review (Shi *et al.*, 2016) in the absence of laboratory test, we used the effort exerted by (Shi *et al.*, 2016) in tabulating different chemical composition of MSW around the world. In the attached excel sheet the County's waste was compared to 153 type of waste category to determine the chemical composition. And further validated using the F test, a statistical analysis tool. For example we had to make assumptions like similarity in types and characteristics of plastics or paper wastes from the literature review. We have also made assumptions from the book 'Integrated Solid Waste Management' (Tchobanoglous *et al.*, 1993) on water content of different waste component.

2.7 Cost Estimation of Mecklenburg MSW

Assumptions are as follows:

- The average LCV of the waste must be at least 6 MJ/kg throughout all seasons. The yearly average lower calorific value must not be less than 7 MJ/kg.
- Plant life span assumed to be 15 years.
- According to the World Bank guideline, the annual amount of waste for incineration should not be less than 50,000 metric tons and the weekly variations in the waste supply to the plant should not exceed 20 percent (Rand *et al.*, 2000).
- A LCV of the waste of 20.34 MJ/kg and 16.62 MJ/kg (Please refer to Results section) is assumed as the design basis. A higher calorific value will increase the actual investment costs and vice versa.
- For compliance with basic level emission control the total investment cost can be reduced 10%. But for an advanced level control it will go high 15% of total investment cost.

- The operating and maintenance costs comprise of fixed (i.e. administrative cost or salary) and variable operating costs (gas cleaning system, electricity bill, water bill, waste water handling cost, residual disposal etc.)
- Maintenance costs comprises of machine maintenance, building maintenance etc.
- Capital cost has a 6% interest rate.
- The income from sale of energy is based on the lower calorific value (LCV) of the waste of 20.34 MJ/kg.

2.8 Flue Gas Volume Calculation

$$\mathit{Flue\ gas\ volume} = 2 \times LCV \times (273 + t) / (21 - y)(100 - z) \qquad (3)$$

Where LCV = low heating value;
t = temperature of combustion;
y = oxygen content; and
z = water vapor content of MSW
For MSW incineration, the standard condition is most often 0 °C (= 273 K), 101.3 kPa (= ~ 1 Atm.), 0 % H2O, 11% O_2. This is the standard condition. Volumes corrected to 0 °C and 101.3 kPa are named Standard or Normal cubic meters = Nm^3. (Rand *et al.*, 2000)

2.9 Environmental Impacts

3. RESULT & DISCUSSIONS

Based on the assumptions made in this study and for the baseline 2010/2011, the commercial waste composition is summarized as shown in

Figure *1* below. Review of the detailed waste composition result by SCS ENGINEERS (2011) indicated some marginal errors as some exhibitions did not add up to 100 % whiles others exceeded 100 % marginally. However, the study adjusted values less than 0.01% where necessary to zero resulting in an increase in commercial waste generated for FY 2010/2011 from 513,081 tons to 526,421 tons.

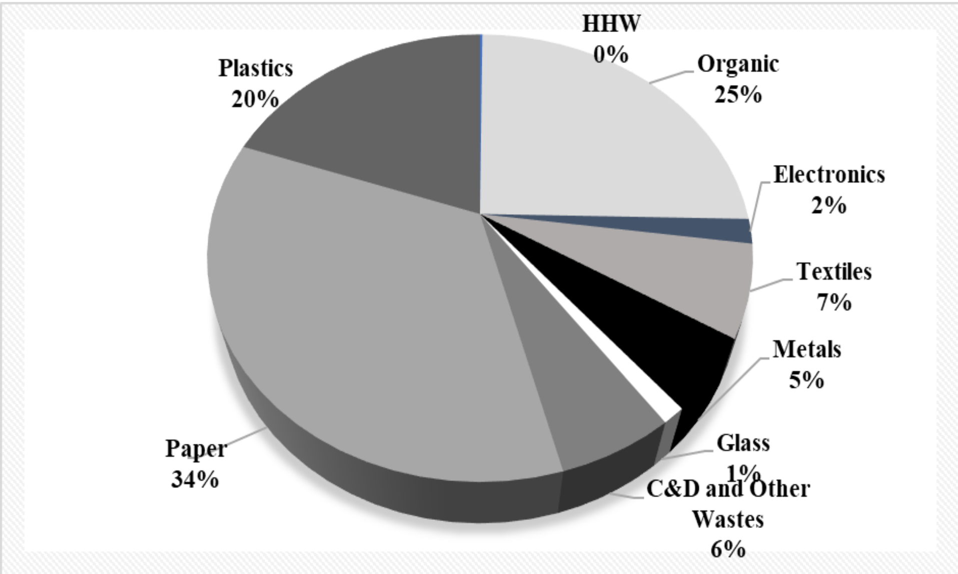

Figure 1: Assumed commercial waste composition.

Two scenarios were assessed using WARM to evaluate the GHG emissions based on the life cycle of the waste material. The first scenario considers the County's SWMP of source reduction and recycling whereas the second scenario included incineration (combustion) in addition to the above mentioned plans. Results are shown in
Figure *2* below.

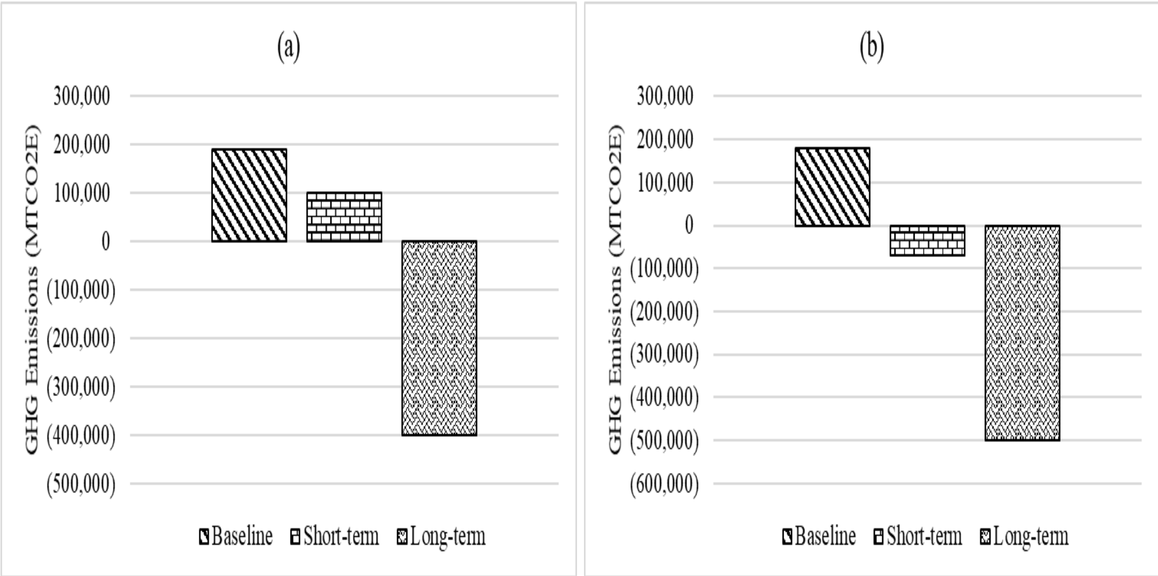

Figure 2: GHG emission results (a) without combustion (b) with combustion

For
Figure *2* (a), the short-term goal which excludes source reduction, diverted approximately 10% of waste generated to recycling and composting facilities resulting in a 45% reduction in GHG emissions compared to the baseline. Significant savings in GHG emissions of about 300% was made in the long term goal which seeks to achieve 18% source reduction, and 26 % recycling and composting. Recycling displaces 100 % virgin inputs whereas source reduction displaces some recycled and some virgin inputs. These account for the significant saving made in the GHG emissions considering the County's SWMP. The incorporation of combustion resulted in significant savings as shown in
Figure *2* (b). GHG emissions from biogenic materials are considered savings, hence, the presence of more biogenic material than non-biogenic material in combusted wasted results in some amount of savings which was the case in the results in
Figure *2* (b).

From equation (1) and (2) the average LCV was estimated to be 20.36 MJ/Kg considering the County's SWMP. Assuming a 100% recycling, the LCV = 16.62 MJ/kg. LCV value of 34.18 MJ/Kg was estimated for only non-recyclable plastic in the waste generated to compare the MSW as a partial replacement of fuel to burn MSW. From cost estimation the total costing of MSW incineration per kg for both long and short term is almost the same:

Table 2. Incineration cost per kg.

LCV(BTU/kg)	**LCV (MJ/kg)**	**Total Cost (USD/kg)**
19,279	20.34	$ 2.10
15,753	16.62	$ 1.05

But as the reduction scheme is not possible to implement in short term strategy taken by Mecklenburg County the per capita cost for incineration goes higher in case of short term. As incineration is not implementable within this short period, the only representable per capita cost for incineration is:

Table 3. Annual per capita cost for incineration

LCV(BTU/kg)	LCV (MJ/kg)	$/per capita/annually
19,279	20.34	$ 491.93
15,753	16.62	$ 240.46

Energy potential of 20.34 MJ/kg waste is equivalent to 4.56 MWh/m ton and 16.62 MJ/kg is equivalent to 3.74 MWh/m ton. For a long-term plan with an LCV of 20.34 MJ/kg, approximately 1.8 million houses can be supplied electricity for an hour. Value of energy sale 20.34 MJ/kg of waste is $91/ton and for 16.62 MJ/kg of waste is $75/ton. If NRP is used as combustion fuel along with other fuels, we could approximately save $10,000,000 of fuel.

4. CONCLUSIONS

- MSW should be considered as a supplemental source of energy for some facilities e.g. cement factories and brick production plants as these plants rely heavily on fossil fuel to generate heat for their production.
- Incineration of msw to recover energy under bat can be considered in the north carolina state's renewable energy sources whiles saving on the capacity of available landfills.
- Co-combustion (natural gas) should be considered to increase the heating value of the MSW as well as improve the emission quality.
- Using nrps as fuel can save fuel cost up to $10,000,000 annually.
- Biodegradable waste separation can be considered as an option for bio-chemical conversion e.g. austria and netherlands.
- PAY-AS-YOU-THROW (PAYT) OR BMW taxation should be implemented as a scheme to reduce waste generation. if waste is significantly reduced tax rebate can be declared to honor each household.
- Further studies should be performed to determine the optimum amount of waste to be reduced, recycled, composted and incinerated in order to make the swmp a cost effective one. As these alternatives have some benefits to offer the system in making it sustainable.

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REFERENCES

Bajpai, P. (2015). New Technologies for Energy Recovery from Waste *Management of Pulp and Paper Mill Waste* (pp. 45-78): Springer.

Brunner, C. R. (1991). *Handbook of incineration systems*: McGraw-Hill.

Gledhill, B. (2007). *2008 State of the Environment Report*. Retrieved from http://charmeck.org/: http://charmeck.org/mecklenburg/county/luesa/documents/enviroreport08solidwste.pdf

HDR, E. I. o. t. C. (2012). *Mecklenburg County Solid Waste Management Plan 2012-2022* Retrieved from http://charmeck.org/: http://charmeck.org/mecklenburg/county/luesa/solidwaste/managementplan/documents/meckcosolidwastemgmtplanjune2012.pdf

Lee, E., Irving, B., Martinsen, T., & Mareckova, K. (2001). *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Retrieved from http://www.ipcc-nggip.iges.or.jp/: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_3_Waste_Incineration.pdf

McPhail, A., Griffin, R., El-Halwagi, M., Medlock, K., & Alvarez, P. J. J. (2014). Environmental, Economic, and Energy Assessment of the Ultimate Analysis and Moisture Content of Municipal Solid Waste in a Parallel Co-combustion Process. *Energy & Fuels*, *28*(2), 1453-1462.

Menikpura, S., Basnayake, B., Boyagoda, P., & Kularatne, J. (2007). Estimations and mathematical model predictions of energy contents of municipal solid waste (MSW) in Kandy.

Pires, A., Martinho, G., & Chang, N.-B. (2011). Solid waste management in European countries: A review of systems analysis techniques. *Journal of Environmental Management*, *92*(4), 1033-1050.

Rand, T., Haukohl, J., & Marxen, U. (2000). *Municipal solid waste incineration: Requirements for a successful project* (Vol. 462): World Bank Publications.

SCS ENGINEERS. (2011). *Waste Composition Study Summary of Results*. Retrieved from http://charmeck.org/: http://charmeck.org/mecklenburg/county/luesa/solidwaste/managementplan/documents/mecklenburg%20co%20report%20final.pdf

Shi, H., Mahinpey, N., Aqsha, A., & Silbermann, R. (2016). Characterization, thermochemical conversion studies, and heating value modeling of municipal solid waste. *Waste Manag, 48,* 34-47.

Smith, R. L., Sengupta, D., Takkellapati, S., & Lee, C. C. (2015). An industrial ecology approach to municipal solid waste management: II. Case studies for recovering energy from the organic fraction of MSW. *Resources, Conservation and Recycling, 104, Part A,* 317-326.

Tchobanoglous, G., Theisen, H., & Vigil, S. (1993). *Integrated solid waste management: engineering principles and management issues*: McGraw-Hill, Inc.

USEPA. (2016a, February 23, 2016). Solid Waste Management and Greenhouse Gases. Retrieved from https://www3.epa.gov/warm/SWMGHGreport.html

USEPA. (2016b, April 11, 2016). Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. Retrieved from https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy

World Energy Council. (2013). *Waste to Energy*. Retrieved from www.worldenergy.org: https://www.worldenergy.org/wp-content/uploads/2013/10/WER_2013_7b_Waste_to_Energy.pdf

Yang, N., Zhang, H., Chen, M., Shao, L.-M., & He, P.-J. (2012). Greenhouse gas emissions from MSW incineration in China: Impacts of waste characteristics and energy recovery. *Waste Management*, *32*(12), 2552-2560.

STUDY ON THE SOLIDS AND COD REMOVAL OF SHRIMP PROCESSING WASTEWATER THROUGH A SLOW SAND FILTER IN KHULNA

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ABSTRACT

The shrimp production and processing is an important sector in context of Bangladesh and most of the industries are situated in the Khulna region. There are 145 numbers of fish processing plants in Bangladesh among which 48 are located in Khulna. Among, Shrimp processing industries are major. A survey has been shown 47500L/day/plant effluents are released in the environment which contains much organic loading. These shrimp process indusries are not interested to install wastewater treatment plant in their factory. They seem it requires excess cost for chemicals, land, and personnel etc. In this circumstance, it was the main objective to found out such a treatment method which requires less cost, less chemical or chemical free, and a little amount of land required. The effluent of shrimp process industries are contain BOD_5 of 200-400 mg/L, COD of 400-800 mg/L, DO of 2-4 mg/L, TDS of 1200-2000 mg/L and pH of 7-9 mg/L. To filter the raw wastewater from shrimp processing industry, a slow sand filter was installed in the civil engineering building of KUET. There were five filter beds consist the filter. The filter media were used fine sand & sylhet sand as a fine media and gravel or stone chips as a coarse media. A steady flow was maintained throughout the study. The treated water was collected from the last stage of the filter. The treated water was tested in a laboratory and found remarkable organic solids reduction rate by the filter. From the study it can be said that the slow sand filter can be used for reduction of organic load in the shrimp process industris.

Keywords: *Fish process, Organic waste, Sand filter.*

1. INTRODUCTION

Shrimp process industries play a vital role in Bangladesh in the GDP sector, employment, nutrition, and socio-economic condition. Production and processing of shrimp industries are an important sector in the context of Bangladesh. Most of the shrimp processed industries are situated in the southern region, especially Khulna, Bagerhat, Satkhira district in Bangladesh. The shrimp culture was started in the coastal district of Satkhira in the 1960s. Gradually, shrimp culture expanded to the coastal belts of Khulna, Bagerhat, cox's bazar and Chittagong (Naureen et al., 2006). Its contribution to the national GDP its contribution to the national GDP is mentionable. In 2004-05 this sector was gained us$ 420 million and us$ 526.45 million in 2016-17 fiscal year (BFFEA, 2006).

Most of the shrimp industries in Bangladesh do not follow the environmental compliance for effluent treatment plant (ETP) in their factories and discharge effluent direct to the environment (Debnath & Bari, 2018). Effluent is discharged by these process industries 47500l/day/plant directly in the environment (Billah, 2016). High amount of biodegradable organic loading is carried out by this wastewater. (Debnath & Bari, 2018). One analysis is showing that the wastewater generated from shrimp processed factory varies BOD from 560 mg/l to 1226.6 mg/l, COD ranges from 1666 mg/l to 3666 mg/l (Thomas et al., 2015). Another research has been conducted in Khulna region by Billah (2016), and found COD is approximately 790 ppm, BOD_5 - 490 ppm, Dissolved Oxygen 0.15 – 1.82 ppm, ss-780 ppm, Total Dissolved Solids-1320-2350 ppm, Total Organic Carbon-220 ppm, Oil & Grease 65 ppm, and Salt-11mg/l.

There is conventional treatment method is available nowadays. In Bangladesh, the different types of effluent treatment plants (ETP) are seen such as Physico-chemical, Biological, MBBR, Physico-chemical cum biological, etc. The chemical treatment of wastewater is highly cost in general. On the other hand, biological treatment is difficult to its maintaining. The well-known and trained personnel are required to operate a biological ETP. The shrimp processing factories are not big industries and they do not want to treated wastewater because of its cost, technical reasons and being morally dishonesty. In this circumstance, cost-effective and easy to operate based design is needed. Only physical treatment maybe meets the national standard for solid contents of wastewater discharge**.** The main goal of this study was to determine whether only physical treatments such as slow sand filters, were able to reduce total solids (TSS and TDS) and chemical oxygen demand (COD) in shrimp processing wastewater.

Sand filtration can be the easiest way to reduce solids from wastewater of shrimp industry. There are very common two types of sand filter are used widely in the world. One is Slow Sand Filter (SSF) and another is Rapid Sand Filter (RSF). In the sand filter, water passes through a layer or a combination of layers of sand& gravel. The sand filter removes particles such as organic debris, bacteria, and viruses via mechanical and biological processes (Arndt & Wagner, 2004).

Sand filters have been shown highly effective to reduction of pathogens from wastewater. Schuler et al. (1991) removed from contaminated water 99.9% of experimentally added cysts of Giardia and Cryptosporidium, ranging from 1 to 25 mm, as well as coliform bacteria by using of SSF. Bellamy et al. (1985) accomplished 100% removal of Giardia cysts using sands with effective sizes of 130, 280, and 620 mm. Effective size is defined as the size range at which only 10% of smaller particles remain in a quantity of sand (Wheaton, 1985). Slow sand filter is further effective in removing viruses from water supplies (Hendricks & Bellamy, 1991).

The wastewater used for this study has been collected from a selected shrimp process industry. Typically range of waste loading was measured of COD 383-645 mg/L, TDS 2519-3980 mg/L, pH 7-9 mg/L, SS 60-212 mg/L, TS 3846-4521.

To filter the raw wastewater from the fish processing industry, a gravity-flow slow sand filter has been installed. There were five filter beds consist of the filter. The filter media has been used fine sand & Sylhet sand as a fine media and gravel or stone chips as a coarse media. A steady flow has been maintained throughout the study. The sample collected from the filter was measured in the laboratory. The next section is about the discussion of the methodology and result of the study.

2. METHODOLOGY

To fulfill the purpose, a plan for the entire job was set out. This was an experimental study where studies were done from books and the internet, laboratory tests and software were used to sort the result. First, a shrimp processing industry was selected to collect wastewater samples, after which it was determined a method and arrangement for making a sand filter. Next, some parameters are set for measurement in the laboratory. Only PH, TDS, TSS, and COD were selected for the experiment. Theese four parameters have been choosed cause the purpose was to determine whether the slow sand filter, were able to reduce total solids (TSS and TDS) and chemical oxygen demand (COD) in shrimp processing wastewater. Wastewater was collected from selected industry and it was measured in a laboratory of Khulna University of Engineering and Technology (KUET). The result was recorded and finally presented graphically. The total chart of the study is given in the following chart.

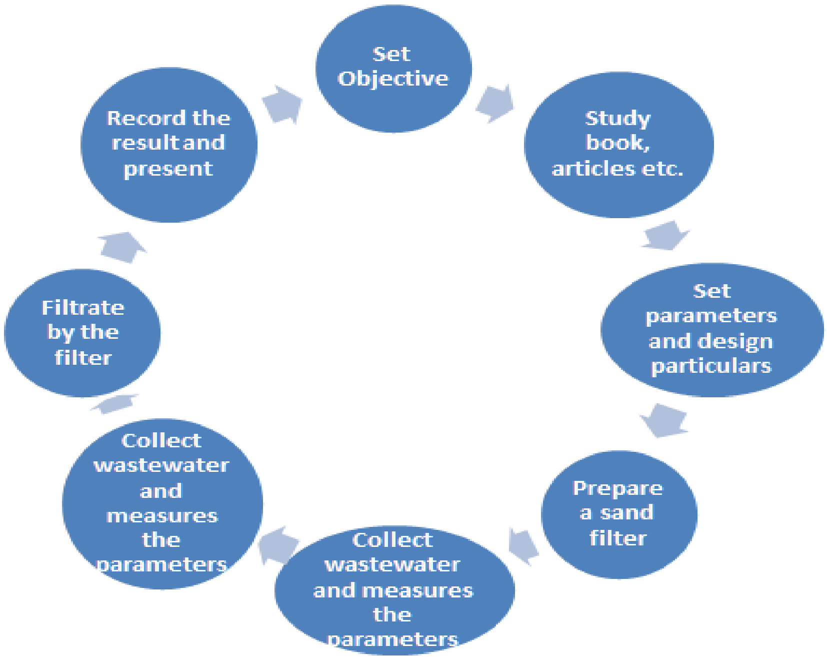


Figure 1: Schematic Diagram of the Methodology

2.1 Experimental Set up

A plastic container (cylinder type) was used with capacity of 30 litres and having diameter of 10 inch and height 12 inch. A water dispenser faucet tap was set 1 inch above from the bottom of the container. A sponge mesh was set due to avoid clogging the water in the top layer of the filter. Also the fine mesh sponge was used on every layer of filter media. The mechanically backwash system was managed like the following Figure 3 (b,c,d). Water was passed through the tap by pressure. Water was up flowed inside the filter media. Backwash water down flowed through the pipe that set in the mid of the cylinder (see the following Figure 3).

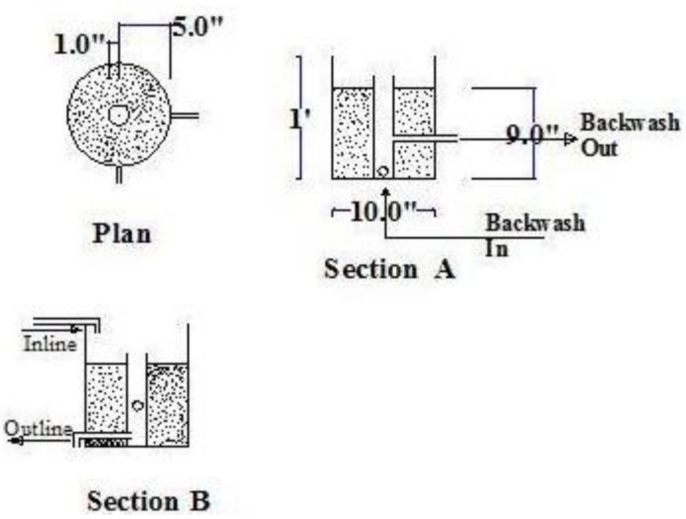


Figure 2: Plan and section of the slow sand filter

2.2 Filter media

Coarse and fine aggregates were used as filter media. Stone chips were used as coarse media whereas coarse and fine sand was used as fine media. Sieve analysis has been performed to maintain uniformity of filter media. Fineness Modulus ratio was not calculated in this study. The # 4, 8, 16, 50 and 100 no sieve was used in this analysis. There are five steps of layers were set in. The layers were decorated in finer to course accordingly. The size, sieve number and layer wise material list is given in the following Table.

Table 1: Size and sieve detail of the media used

Layer	Material	Size	Sieve No
1st	Coarse aggregate (crash stone)	12.5 (mm)	3/4
2nd	Coarse aggregate (stone chips)	256 (mm)	08
3rd	Coarse sand	600 (µm)	30
4th	Fine sand	106 (µm)	50
5th	Fine sand	121 (µm)	100

(a)

(b)

(c) (d)

Figure 3: (a) Filter Media used in experiment
(b) Set of the filtration system before filling the filter media
(c) Top view of the filtration system
(d) Set of the filtration system after filling the filter media

2.3 Sample collection

A shrimp processing industry was selected to collect wastewater sample. Next, some parameters are set for testing in the laboratory. Only pH, TDS, TSS, and COD were selected for the experiment. Samples were collected by plastic jar which capacity was 10 liter.

(a) (b)

Figure 4: (a) Sample collection jar (b) Sample collection from shrimp industries drain Outlet

3. RESULTS AND DISCUSSION

The filter was operated two months. In these two months total eight samples were measured. One sample was measured each week in laboratory. The result was shown the shrimp process wastewater contain mass number of organic solids. From laboratory test the influent wastewater or raw wastewater characteristics were found is given in bellow.

Table 2: Characteristics of Shrimp Process Wastewater

Parameter	Unit	Concentration Range
COD	mg/l	383-645
TSS	mg/l	60-212
TS	mg/l	3846-4521
TDS	mg/l	2519-3980

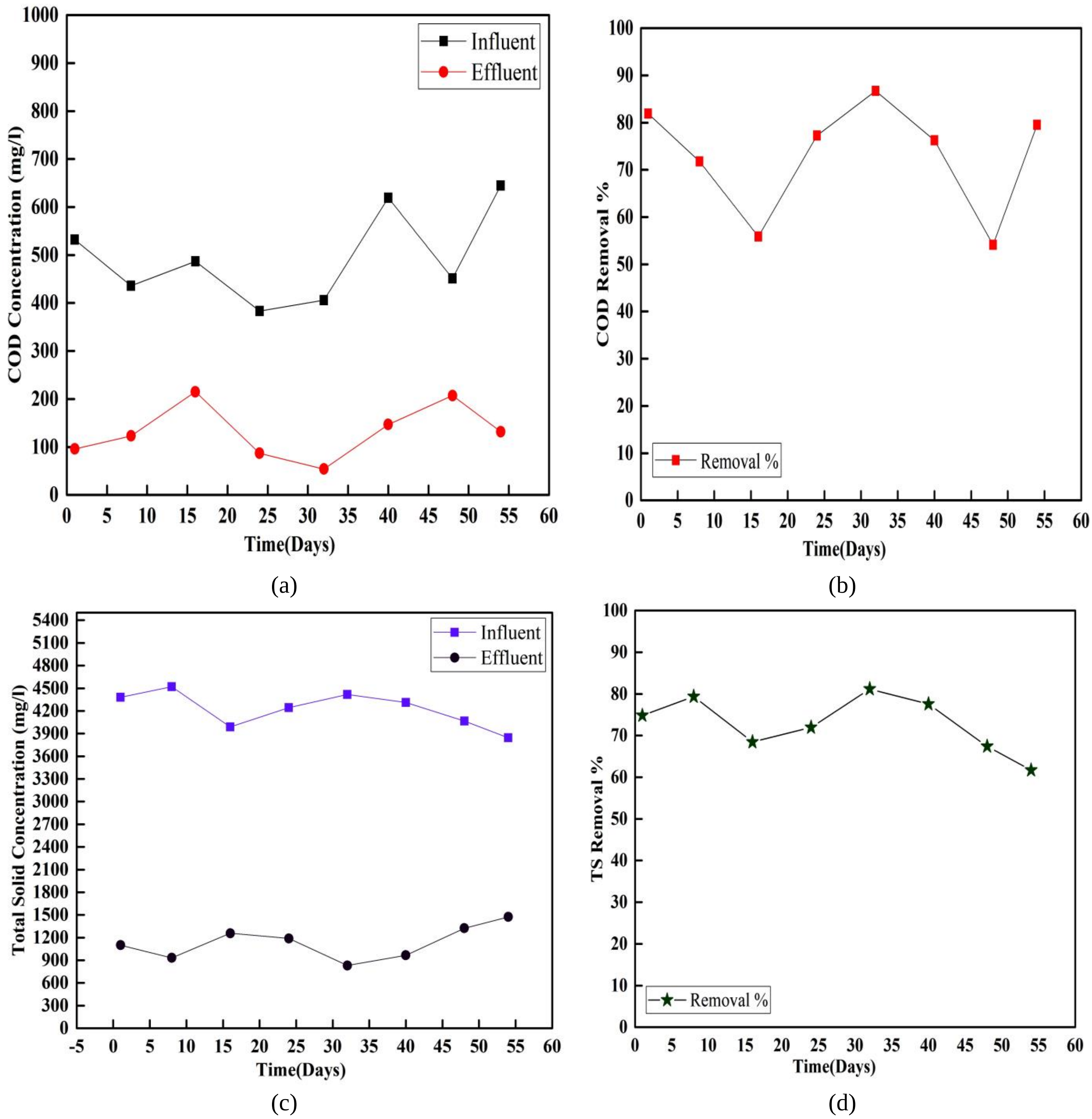


Figure 5: (a) COD Concentration in entire experiment; (b) COD removal percentage in experiment; (c) TS Concentration in entire experiment; (d) TS removal percentage in experiment.

Only the above-mentioned parameters were measure. The Chemical Oxygen Demand was reduced above 70% in the study. In conventional treatment practice, there are many unit processes are combined to treatment wastewater and remove COD. However, based on this study, it is clear that the sand filter can remove COD like those processes. The highest amount of COD of effluent was found near of 200 ppm and lowest one found below of 50 ppm. The national recommendation for discharging effluent should contain equal or less than 200 ppm of COD. The Removal rate and result of COD removal of this study has been given in the Figure 5 (a) and (b) in the above.

Total solid was measured average 4221 mg/L. The removal rate was calculated 86%. The Total Solids of influent was observed almost linear. It was always near to 4000 mg/L (ppm). In this filtration system, influent has been passed through the five filter beds and reduce mass number of solids. The treated wastewater of the filter used in the study contained Total Solids in between 900 to 1200 mg/L. The figure 5 (c) and (d) has been shown the concentration of TS of influent and effluent of the study along with the removal percentage of solids.

The dissolved solids cannot filtrate easily because it is found as the more diluted form in the water. The average amount of dissolved solids was found 3482 mg/L in wastewater of shrimp process industry. After treatment or passing through the filter media, it was found 2145 mg/L in average. The lowest number of dissolved solids of treated wastewater was measured 2450 mg/L whereas highest one was found more than 3900 mg/L. The rate of removal of dissolves solids was 38%. The following figure 6 (a) and (b) is shown more pictorial view of waste concentration of influent and effluent after treatment along with removal rate.

The total solids are divided into major two types of solids like Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). In this study, TSS was found below 50 mg/L. of filtrated wastewater. The solids which is suspended, was settled on the surface of media. The overall removal rate was measured 72. In the figure 6 (c) and (d) is shown the details in graph. The list of parameters considered in the study, concentration in influent and effluent and removal percentage is given in the following table.

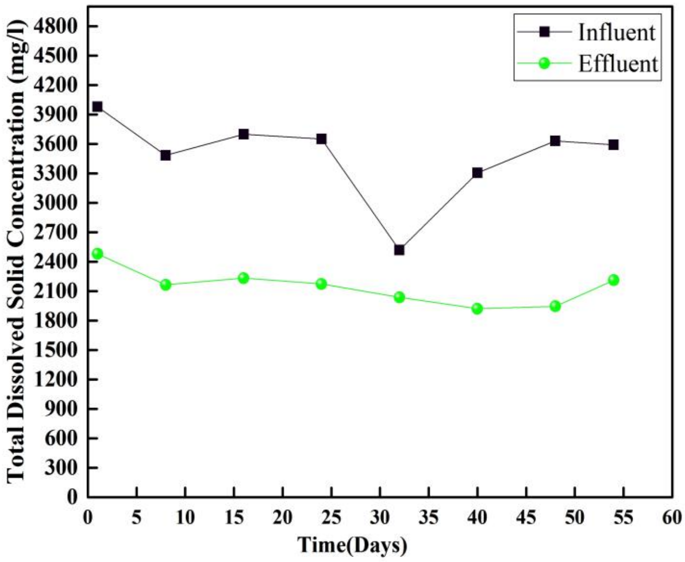
Table 3: Efficiency of the slow sand filter system

Parameter	Unit	Influent	Effluent	Removal %
COD	mg/l	494.87	132.62	73
TSS	mg/l	153.25	42.37	72
TS	mg/l	4221.62	1134.50	86
TDS	mg/l	3482.87	2145.62	38

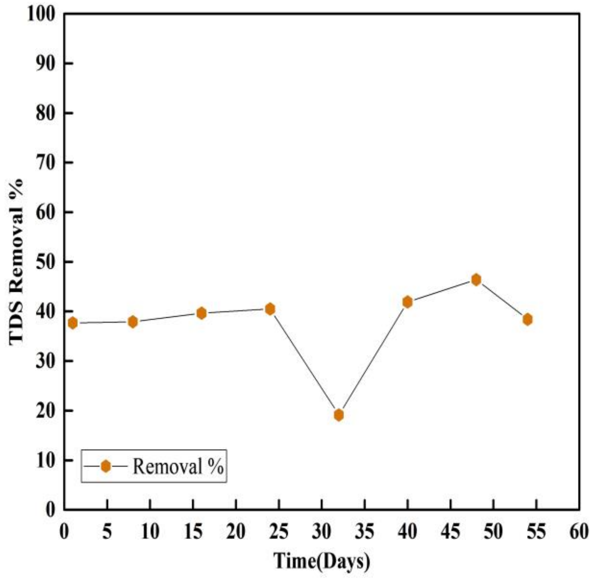
(a)

(b)

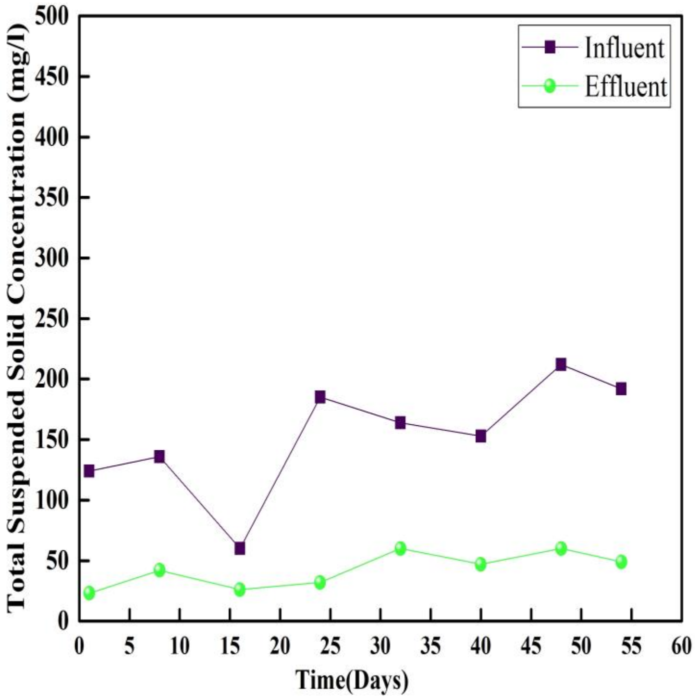
Figure 7: (a) Influent of the filtration system; (b) Effluent of the filtration system



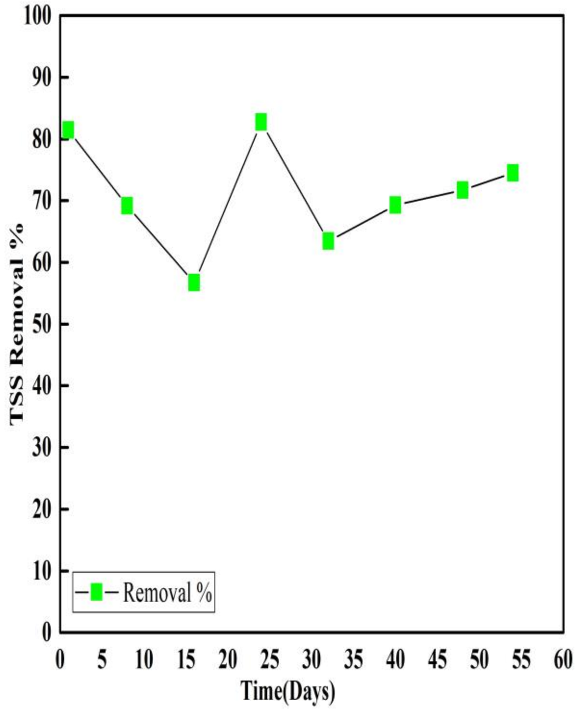
(a)



(b)



(c)



(d)

Figure 6: (a) TDS Concentration in entire experiment (b) TDS removal percentage in experiment (c) TSS Concentration in entire experiment (d) TSS removal percentage in experiment

4. CONCLUSION

The slow sand filter has been removed of solids successively 73%, 72%, 86%, & 38% of COD, TS, TSS, & TDS of shrimp process wastewater. The influent was contained 380 to 650 mg/L of COD and 3500 to 4500 mg/L Total solids which removes considerably. Sand filter may be the good alternatives for such a developing country like Bangladesh. SSF can operate followed by screening, grit removal, aeration process etc. In the industries level, where a good amount of wastewater discharge in an hour, the pressure sand filter there may be good options. Where there is slid concentration is medium level in such case only physical treatment may be good alternatives to remove solids from wastewater.

REFERENCES

Arndt, R. E., & Wagner, E. J. (2004).Rapid and slow sand filtration techniques and their efficacy at filtering triactinomyxons of Myxoboluscerebralis from contaminated water. *North American Journal of Aquaculture*, *66*(4), 261-270.

BFFEA: Bangladesh Frozen Food Exporters Association, retrieved from *www.bffea.org.bd*.

Bellamy, W. D., G. P. Silverman, and D. W. Hendricks. 1985. Filtration of Giardia cysts and other substances, volume 2. Slow sand filtration. U.S. Environmental Protection Agency, Report 600/S2-85/ 026, Washington, D.C.

Billah, S M., 2016. Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city, *PhD Thesis*, Department of Soil, Water and Environment, University of Dhaka.

Debnath P.K & Bari Q. H., 2018. Design and Operation of a Bench Scale Wastewater Treatment Plant For Shrimp Processing Industries, 4th International Conference on Advance in Civil Engineering 2018 (ICACE 2018), Chattagram, Bangladesh.

Hendricks, D. W., and W. D. Bellamy. 1991. Microorganism removal by slow sand filtration. Pages 101– 121 in G. S. Logsdon, editor. Slow sand filtration. American Society of Civil Engineers, New York

Naureen, M; Kabir, DS; Ali, MS and Kamal M. 2006. Status of the shrimp sector in Bangladesh in the context of HACCP and trade issues - A Review, *Bangladesh.f. Fish. Res.*, 10(2), 2006: 185-202.

Schuler, P. F., M. M. Ghosh, and P. Gopalan. 1991. Slow sand and diatomaceous earth filtration of cysts and other particulates. Water Research 25:995–1005.

Thomas S, Harindranathan N. M.V. and Bright S.I.S., 2015, Physicochemical Analysis of Seafood Processing Effluents in Aroor Gramapanchayath, Kerala, *Volume 9, PP 38-44, ISSN: 2319-2399*

Wheaton, F. W. 1985.Aquacultural engineering.Robert F. Krieger Publishing Company, Malabar, Florida.

PERFORMANCE STUDY OF PILOT-SCALE ANAEROBIC-AEROBIC FILTER SYSTEM FOR FAECAL SLUDGE TREATMENT

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ABSTRACT

In Bangladesh, the wastewater is being dumped without any plan. The outlet of most of the septic tank is connected with public sewer and maximum drain outlet is connected with river and this is very harmful for our ecosystem. The disposal of human excreta required treatment before its discharge into the environment. The objectives of the study were to design and fabricate an anaerobic-aerobic filter system (AAFS) system and monitoring the performance of developed purification tank. This system was implemented and tested as part of a research project focused on innovative decentralized wastewater treatment solutions. This system consist of four chambers in series with different filter media. First two chambers were anaerobic and third was aerobic and last chamber was sedimentation tank. Moving bed biofilm media and plastic bio cube ball were used as filter media. The reactor was made with 5mm acrylic sheet. The catalyst behind the system was the bacteria that helps to digest all the inputs. The output is reusable and can be released to a common water body. The structure of this system was designed fully demonstrate the purification function of microorganism attached growth system. High removal of organic load was achieved under all loading criteria in this system. The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH_3-N, 72% for NO_3-N, 92% for PO_4 and outstanding removal was 92% for FC. This anaerobic-aerobic system is a feasible option of onsite domestic wastewater treatment for the people of the developing country like Bangladesh. Treated wastewater of the system has been meet national standards for wastewater discharging.

Keywords: *On site wastewater treatment, Anaerobic, Aerobic, Attached growth system.*

1. INTRODUCTION

Faecal Sludge Management (FSM) is one of the complex and difficult job in the world. FSM is important as over a billion people in urban and peri-urban areas of Africa, Asia, and Latin-America are served by on-site sanitation technologies, Faecal Sludge (FS) is not well managed in many cities (Murungi & Peter 2014) of the above continents. This trend particularly intense in developing country, where an additional 2.1 billion people are expected to be living in cities by 2030. These cities produce billions of tons of waste every year, including faecal sludge. The disposal of sludge become a problem with the application of the more intensive methods of treatment, which resulted in the production of large volumes of sludge (Metcalf & Edddy 1995). FS may be treated in separate treatment works or co-treated with sludge produced in wastewater treatment plants. (Strauss et al 2002). Waste generation of the world is increasing along with the population and development of the region. Management of this produced waste is one of the prime concerns of the countries. Sludge Management is a major Challenge in Bangladesh. Bangladesh has shown remarkable progress in liminating open defecation, but there is urgent need for Faecal Sludge Management (FSM) in Bangladesh mainly in urban areas (Islam, 2016), where most human waste is dumped untreated into waterways or onto marginal land, harming the environment and health, especially of the country's poorest (Opel 2011). Only 20% of the population of Dhaka is served by a highly expensive sewerage network; the rest use septic tanks, pit latrines, unhygienic latrines (Hasan et al 2014) and other major cities of Bangladesh do not use sewer network. Only a small percentage of faecal sludge is managed and treated appropriately (Hasin & Abdullah 2015). The outlet of most of the septic tank is connected with rain water sewer. Consequently, untreated wastewater is directly discharged into the rain water sewer. The proper emptying mechanism for pits or septic tanks are almost absent. Most of the containment emptied manually where the percentage of mechanical emptying is very low and private sweepers are dominantly doing the emptying job. (M. Sabok et al 2018). Khulna is the third largest city of Bangladesh situated in the south-western part of the county and lies in the delta of the river Ganges (Hasan et al 2004), The city has an estimated population of 1.6 million and total number of households is 66257 Toilet with septic tank is rising in Khulna city. There are 94% septic tank is connected with surface or gray water drain and maximum drain outlet is connected with river and this is very harmful for our environment ecosystem. Maximum septic tank has not been emptied for a long time. More than 85% of households practice unsafe faecal sludge (FS) emptying and conveyance. Collected sludge from septic tank is directly or indirectly disposed into waterbodies. Septic sewage is also considerably more offensive to the olfactory nerves (Davis & Conwell., 2006). So, the disposal of human excreta required treatment before its discharge into the natural environment. If the wastewater does not treat well enough this will pollute recipient with phosphorus and nitrogen, organic matter and bacteria that can lead to eutrophication and potential health problems. The Mayur is the example of that is almost dead due to siltation and waste disposal. Application of a proper on-site decentralized technology needed for faecal sludge treatment.

Presence of organic micropollutants in municipal wastewater is well documented (Reemtsma et al., 2006; Lishman et al., 2006; Vieno et al., 2007) and a potential threat to the receiving water (Parrott and Blunt, 2005; Zeilinger et al., 2009). Removal efficiency of these compounds at wastewater treat-ment plants, WWTPs, is often highly dependent on the bio-logical treatment (Carballa et al., 2004; Zorita et al., 2009); moreover, it has been shown that the biological treatment design can influence the overall micropollutant removal (Stumpf et al., 1999). Biological wastewater treatment techniques can normally be classified as either suspended or attached growth pro-cesses. The suspended activated sludge process is the most frequently used biological treatment at municipal WWTPs, thus, technical and operational solutions that can improve micropollutant removal in this process are highly desirable. Previously, it has been reported that upgrading of high loaded activated sludge processes to nitrogen removal through enlargement of the treatment basin enhances removal of some micropollutants (Andersen et al., 2003; Schaar et al., 2010). Despite this improvement, numerous micropollutants are rather stable in activated sludge treatment (Mie`ge et al., 2009). However, for some of these compounds considerably higher removal rates have been observed for biofilm carriers than activated sludge (Fala˚s et al., 2012; Zupanc et al., 2013), which suggests that further optimization of the biological micropollutant removal is possible.

In Recent years, Moving bed biofilm reactor(MBBR) is a novel technology for wastewater treatment. This type of biological treatment begins in the 1970s. The moving bed biofilm reactor (MBBR) was first developed for treatment of municipal wastewater in terms of nitrogen removal (Odegaard et. al., 1994). Afterwards, other applications of the MBBR process were developed such as treatment of industrial wastewaters, nitrification in water treatment for land based fish farming and removal of soluble organic matter in secondary treatments of municipal wastewater (Helness et. al., 2005). In moving bed biofilm process suspended porous polymeric is used as a carrier which moves continuously in the aeration tank and the active biomass grows as a biofilm on the surface of carriers (Loukidou & Zouboulis, 2001). In this context, more than 90% of biomass is attached to the media rather than suspended in the liquid (Schmidt & schaechter, 2011). The advantage of this system in comparison to a suspended growth one is the higher biomass concentration, less sensitivity to toxic compounds, lack of long sludge settling period (Loukidou & Zouboulis, 2001), less prone to the process upsets from poorly settling biomass (Schmidt & schaechter, 2011), cost effectiveness (Fang, 2011) and the achievement of both organic and ammonia removals efficiently in single stage (Horan et al., 1997). Moving bed biofilm filter within its small footprint has a positive property of the area requirement which is one fifth to one third of that needed for activated sludge treatment as well as a lower effect of temperature on the rate of biological nitrification (Salvetti et al., 2006). However, the operational costs are higher in MBBR than that of activated sludge treatment. These systems could be efficient for BOD removal and tertiary nitrification and denitrification following suspended or attached growth nitrification (Metcalf & Eddy, 2004). As the MBBR system has the important advantage of flexibility of carrier’s fill fraction, these systems have become very popular for use in industrial applications and applications with high variation in the expected load in time (Haandel & Lubbe, 2012). Some factors have been reported to affect the performance of MBBR. The high specific area of the carrier media controls the system performance which is as a result of very high biofilm concentrations presence in a small reactor volume. It was reported that typical biofilm concentrations range from 3000 to 4000 g TSS /m3, which is similar to values obtained in activated sludge processes with high sludge ages. The percentage of reactor volume comprised of media is limited to 70%, with 67% being typical (Odegaard et al.,2000). However, wastewater characteristics and specific treatment goals are the main factors determining the percentage of media required in the reactor.

This article aims to design and fabricate a modified aerobic-anaerobic tank system with the concept of MBBR process and Anaerobic filter process and monitoring the performance of developed aerobic-anaerobic filter system. This project demonstrates a modern low-cost onsite wastewater treatment technology tasted with varying hydraulic loading rates with attched growth biological traetment.

2. METHODOLOGY

2.1 The structure and working principle of Anaerobic-Aerobic Filter System

To design a special aerobic and anaerobic tank system including combination of anaerobic and aerobic chamber and filter media. The medium-scale anaerobic-aerobic tank made with 5mm plastic acrylic sheet. There are four chambers in this tank system.

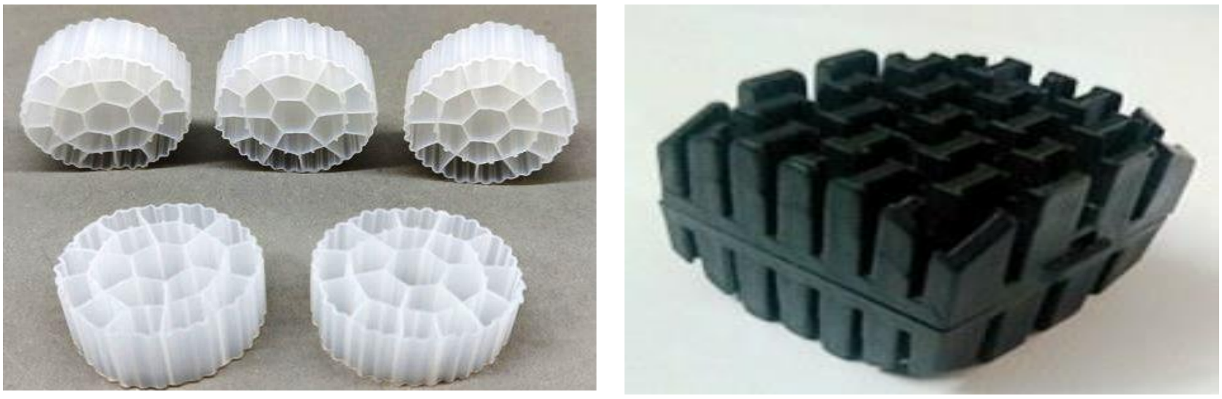
Figure 1: Process flow of anaerobic-aerobic filter system

First two chamber are anaerobic filter tank where plastic biocube balls are used as filter media. Biocube ball is made with polypropylene and combined with rectangular sponge in the ball where maximum solids retain in the filter media and anaerobic bacteria attached growth in the filter media. In the anaerobic tank, denitrification process is taking place. Second chamber is aerobic chamber where Anoxkaldles K3 media was is used as plastic media. Aeration was taking place by an aerator and nitrification process was occurred in this chamber and last one is sedimentation chamber. A 30watt capacity blower was used to continue the aeration process. Plastic carrier was moved with moving part of the water.

2.2 Characteristic of different carrier media:

Table 1: Characteristic of different carrier media used in experiment

Chamber	Commercial Name	Material	Shape	Specific surface area	Dimension	Filling Factor
Anaerobic Filter	Biocube Ball	polypropylene	Rectangular parallelepiped	378 m^2/m^3	30mm; 30mm	40%
Aerobic Filter	Anoxkaldes K3	polypropylene	Cylindrical	500 m^2/m^3	12mm; 25 mm	70%



(a) (b)

Figure 2: (a) Kaldes Media used in aerobic chamber
(b) Biocube ball media used in anaerobic filter

The carrier elements can be installed in anaerobic, anoxic reactor or aeration basin. In the MBBR process, small high-density polyethylene (HDPE), polypropylene, plastic, ceramic, porous carrier elements with a large surface area are used for the growth of microorganisms within the reactor. In the reactor, agitation pattern is designed in such a manner that the upward movement of the carrier takes place across the surface of the screen. It protects from clogging so that the entire reactor will be in active biologically causing higher biomass activity.

2.3 Operational condition:

The anaerobic-aerobic filter tank volume is 0.052 m^3 and 52 litre capacity. This tank system was operated different operational condition, these conditions is given below in the table-

Table 2: Different operational condition in experiment

Phase no	Flow	Hydraulic Retention Time
1	9 ml/minute	104 hours
2	12 mL/min	72 hours
3	19 mL/min	48 hours
4	36 mL/min	24 hours

2.4 Sample collection:

After installing the anaerobic-aerobic tank, faecal sludge collected from selected septic tank according to standard sampling method and insert into anaerobic-aerobic tank. Sample was collected from conventional septic tank effluent. Sample was collated by plastic container. Each container capacity was 30 liters.

(a) (b)

Figure 3: (a) Samples were collected from a conventional septic tank
(b) Sample collection plastic container

This sample will be tested in laboratory. Regular monitoring will be done and parameter will be measured in laboratory. Selected parameters namely Dissolved Oxygen, Biochemical Oxygen Demand(BOD_5), Chemical Oxygen Demand(COD), Total Dissolved Solids(TDS), Total Suspended Solids(TSS), Volatile Suspended Solid(VSS), Ammonia Nitrogen(NH_3-N), Phosphate(PO_4-P), Nitrate Nitrogen(NO_3-N), Faecal coliform(FC), pH etc will be measured. At least 3-5 samples will be tested routinely. Characteristic of Septic tank effluent is given bellow in the Table 3-

Table 3: Characteristic of septic tank effluent

Parameter	Unit	Concentration Range
BOD_5	mg/l	284-715
COD	mg/l	397-1236
TSS	mg/l	324-793
TS	mg/l	1736-2589
TDS	mg/l	981-1796
VSS	mg/l	97-212
NH_3-N	mg/l	58.40-93.47
PO_4-P	mg/l	24.21-62.47
NO_3-N	mg/l	18.38-56.27
FC	Nos/100ml	1743-3974
pH	-	6.32-8.20

Based on initial tested parameter the treatment method and unit processes will be selected and volume of reactors will be calculated. Regular monitoring will be done and parameter will be measured in laboratory. Investigating and maintenance the septic tank routinely.

3. RESULTS AND DISCUSSION

The height percent of BOD removal occurred in phase three. The organic load of the reactor was increased gradually. The mean values of BOD removal % was get 79 percent removal of the purification tank. The values of BOD effluent concentration are gradually decreasing till phase 3 but at phase 4 the values of effluent slightly increase because of high organic load but there was not so significant change in last phases of the investigation. The value of effluent in phase three is 49 mg/l and this is meet the maximum permissible value of ECR 1997 of Bangladesh government. The permissible value of BOD is 50 mg/L by law of the Bangladesh government.

The maximum 89 % of COD removal was found in phase 3 (HRT=48 h). This result is better than the results obtained by Coelho et al. who obtained removal efficiencies from 70–75%, treating domestic wastewater using conventional septic tank at 48 h HRT. The COD value in influent range was 397 to 1142 mg/l. The minimum and maximum value of 1st chamber was 148 and 730 mg/l respectively, 2nd chamber was 84 and 634 mg/l respectively and the rest chamber was 29 and 550 mg/l respectively. The average value of COD in effluent was 227.9 mg/l where the standard COD value for discharging is 400 mg/l. AAFS effluent COD value is agree with the standard discharging value of Bangladesh.
The TS values in influent range was 1736 to 2589 mg/l. The minimum and maximum value of 1st chamber was 316 and 1641 mg/l respectively, 2nd chamber was 319 and 969 mg/l respectively and the rest chamber was 119 and 561 mg/l respectively. The highest reduction of TS was occurred in 1st chamber due to maximum solid and garbage was retained in the anaerobic filter media. The maximum reduction value of TS reduction with maximum removal percentage found in phase 3 (HRT=48 h). The average values of influent and effluent were 771 and 228 mg/l respectively. AAFS effluent TS value is agree with the standard discharging value of Bangladesh.

For SS, the values of influent and effluent vary from 324 to 620 mg/l and 52 to 185 mg/l respectively. The removal percentage of SS about all HRT was 78%. The average values of influent and effluent were 662 and 99 mg/l respectively in entire experiment. The efficiency of TSS removal was slightly decreased in last 30 days of experiment due to height organic load.

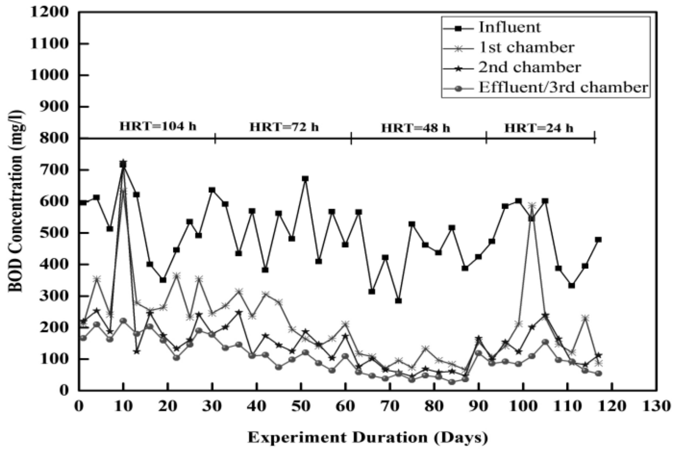
The maximum and minimum values TDS concentration in influent was 1474 and 981 mg/l and effluent were 345 and 67 mg/l which was significantly reduced by AAFS. The average value of TDS removal efficiency was achieved 84% by the system. The average value of effluent was 195 mg/l is agreeing with the effluent discharging standard value which is 2100 mg\l.

The highest and lowest values for VSS was 185 to 97 mg/l for influent and 119 to 32 mg/l for effluent. The values of VSS was suddenly increased in 1st chamber due to detachment of biomass. The biomass in the bio cube at anaerobic chamber was growing rapidly due to high level of organic firstly retained in the bio cube. The highest removal percentage was achieved in HRT 48h which was 65% and it was indicated that the AAFS was applicable to biodegradation of a wide range of VSS concentration. The reduction of VSS is reduced shown in phase 4 during experiment and when the velocity of material is increased so that the mixing is poor and oxygen transfer is inhibited.

In the AAFS, the nitrification process is mainly occurred in the 2nd chamber and full of this process happened in the surface of moving biofilm carrier and why high NH_3-N removal efficiency was achieved in the second chamber of the reactor. The lower and higher value was 58.4 to 93.47 mg/l for influent and 5.21 to 30.62 mg/l for effluent. The highest ammonia removal percentage was achieved in HRT 48h which was 86%. The average values of NH_3-N removal percentage in the study was 15 mg/l and that was quite good to discharge.

Under a different hydraulic loading time, the 77 % maximum average Nitrate removal was found in the AAFS effluent. The highest and lowest value was 58.4 to 93.47 mg/l for influent and 5.21 to 30.62 mg/l for effluent. The lowest and highest value was 18.38 to 56.27 mg/l for influent and 6.14 to 18.36 mg/l for effluent. The average value of effluent was 10.77 mg/l. The average value of removal was 72 percentage in the study. under different operational condition.

For phosphate, the highest and lowest values for influent and effluent was 62.47 and 24.21 mg/l respectively. The mean value of influent and effluent was 40.38 and 3.64 mg/l respectively. Under a different hydraulic loading time, the 96% maximum average Phosphate removal was found in the AAFS effluent which was occurred in HRT=104 h. The average values of removal percentage in entire experiment was 92%. It was noticed that the highest reduction of phosphate occurred in the 2nd chamber of modified purification tank system due to nitrification process.



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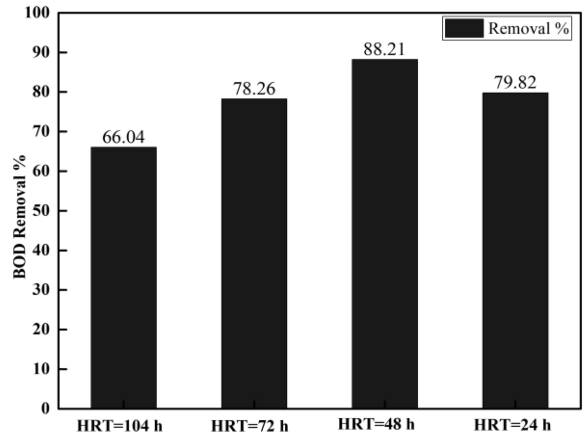

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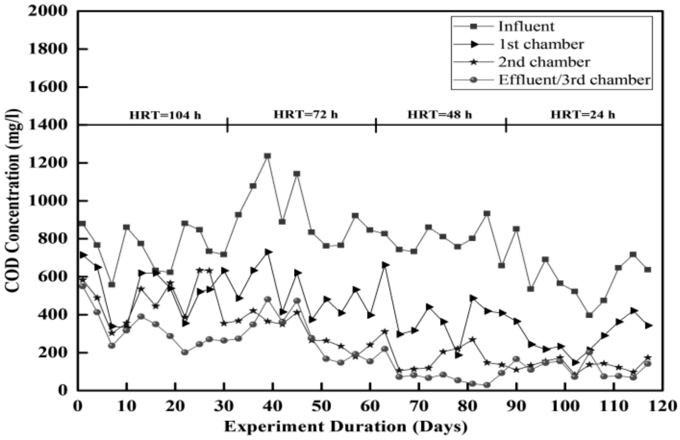

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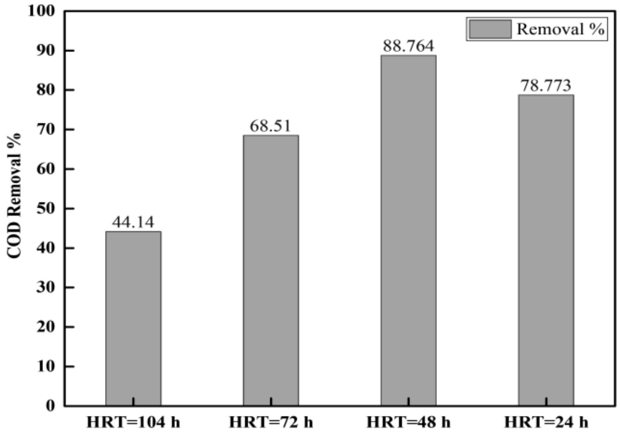

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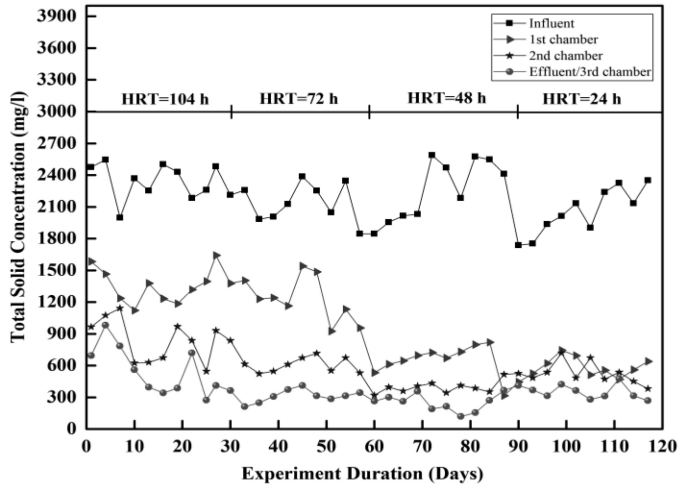

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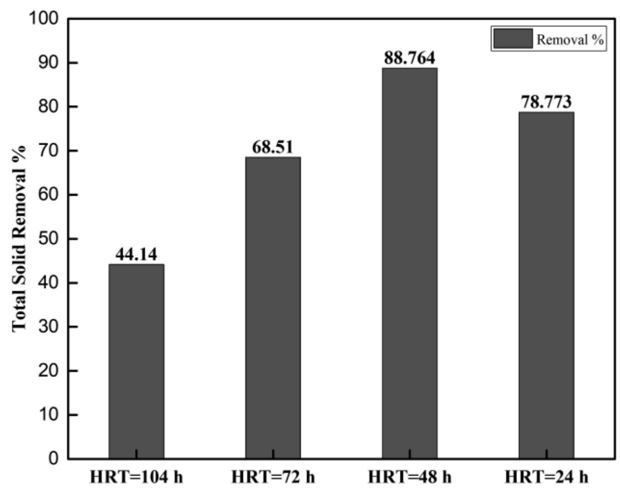

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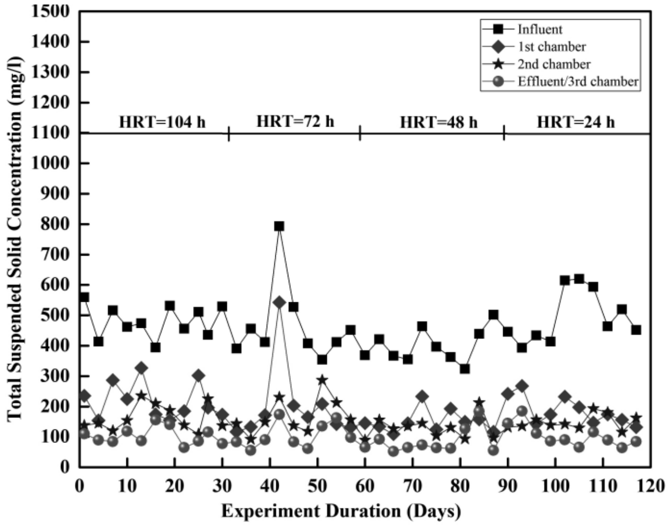
Figure 5: (a) BOD concentration in entire experiment (b) BOD removal percentage in experiment (c) COD concentration in entire experiment (d) BOD removal percentage in experiment (e) TS concentration in entire experiment (e) TS removal percentage in experiment



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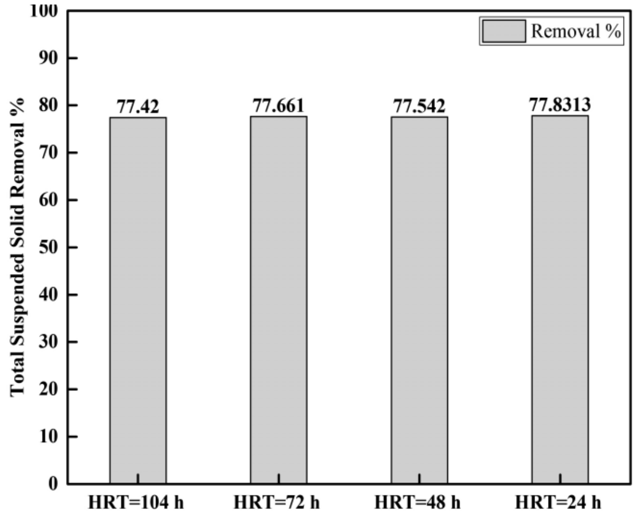

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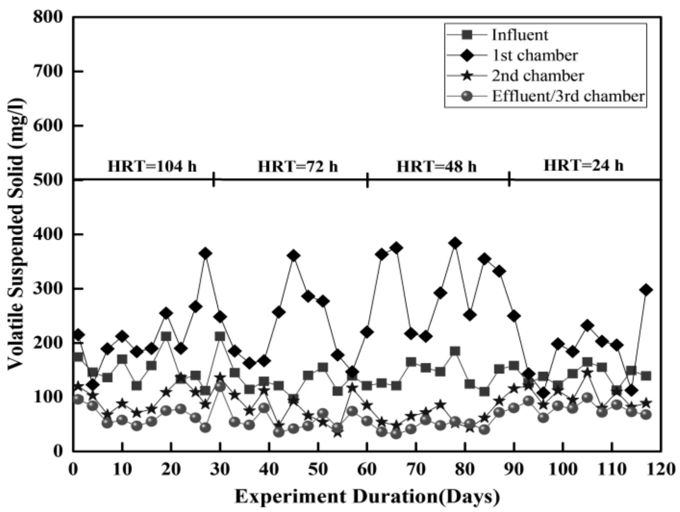

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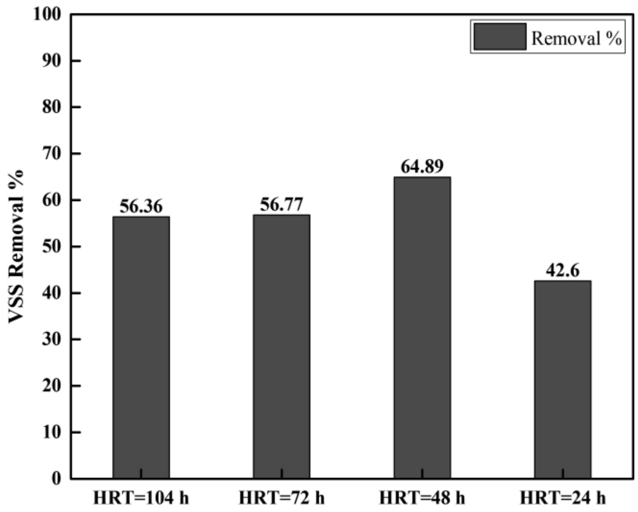

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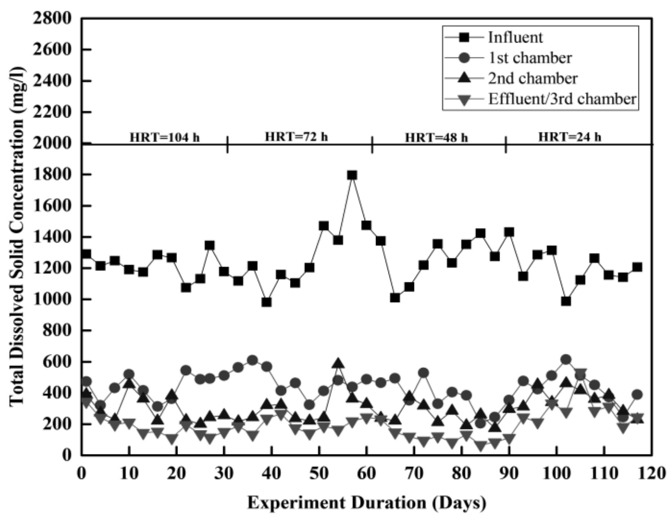

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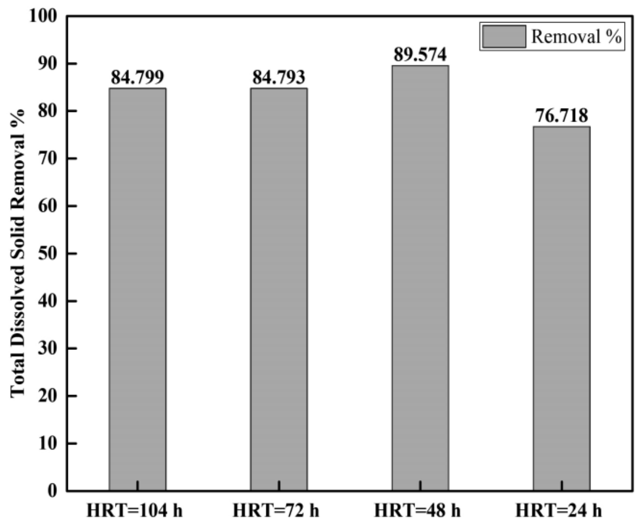

(f)

Figure 6: (a) TSS concentration in entire experiment (b) TSS removal percentage in experiment
(c) VSS concentration in entire experiment (d) VSS removal percentage in experiment
(e) TDS concentration in entire experiment (e) TDS removal percentage in experiment

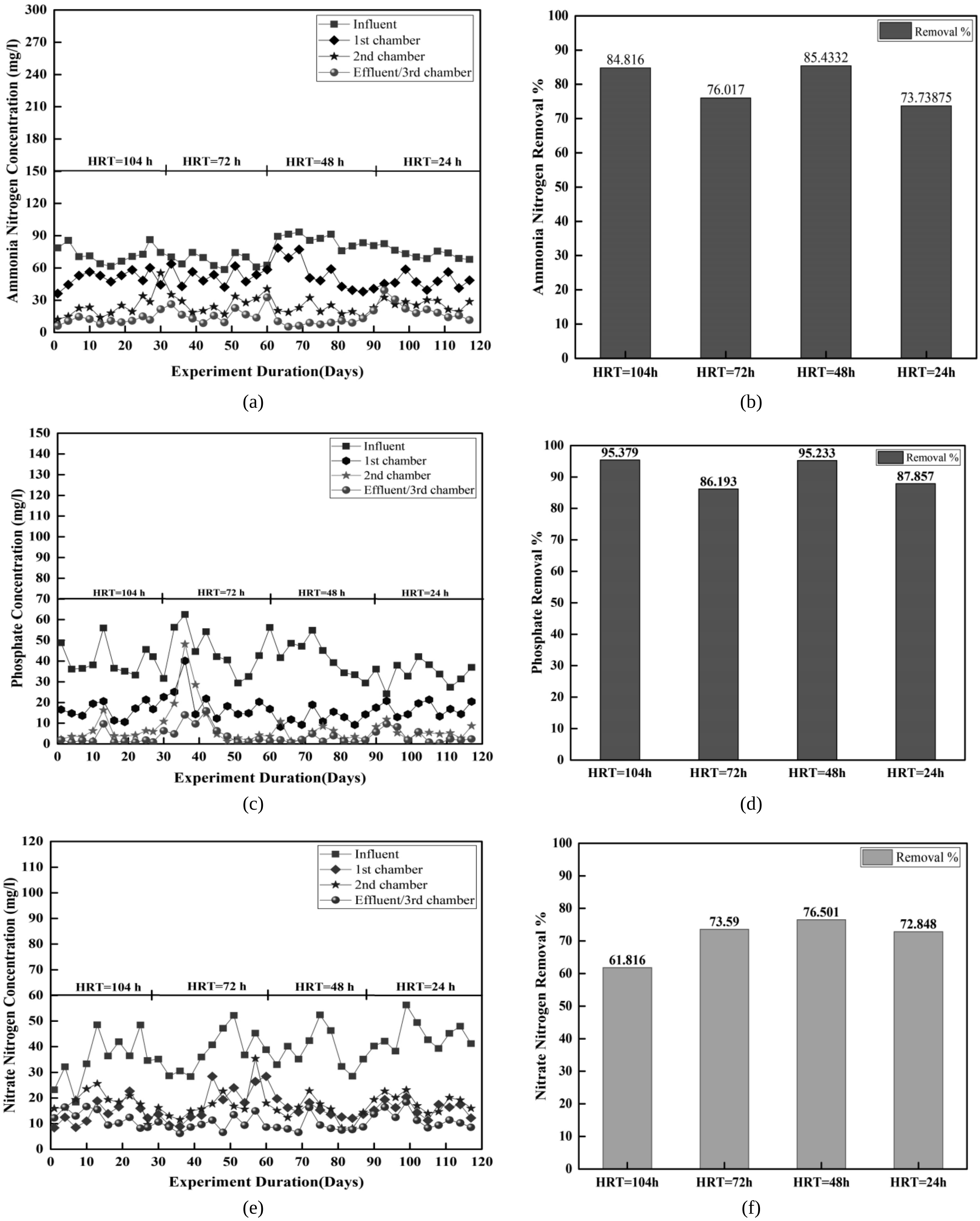

Figure 7: (a) NH_3-N concentration in entire experiment (b) NH_3-N removal percentage in experiment (c) PO_4-P concentration in entire experiment (d) PO_4-P removal percentage in experiment (e) NO_3-N concentration in entire experiment (e) NO_3-N removal percentage in experiment

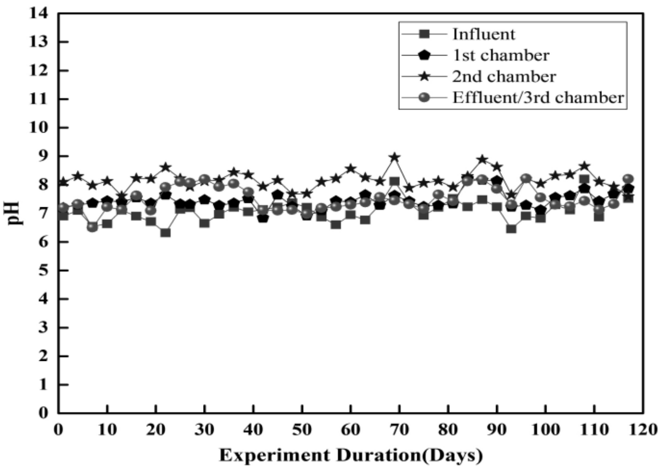

Figure 8: pH variation in entire experiment

Table 4: Result of physical wastewater parameters mean values in entire experiment

Parameter	Unit	Phase 1		Phase 2		Phase 3		Phase 4	
		Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
BOD_5	mg/l	527.70	174.10	530.30	112.50	437.60	49.30	481.90	95
COD	mg/l	755.60	403.30	927.20	298.50	797.10	88.80	603.60	121
TS	mg/l	2349.20	76.15	2179.88	85.22	2262.20	86.55	2052	82.55
TSS	mg/l	475.50	105.50	473.40	102.60	400.10	84.30	495.20	104
VSS	mg/l	150.20	65.10	136	60	140.50	48.90	140.80	79.60
TDS	mg/l	1221.70	185	1260.30	186	1279.20	133.20	1205.70	274.10
NH_3-N	mg/l	72.71	10.92	67.82	16.37	84.07	11.26	71.82	18.95
PO_4-P	mg/l	40.80	2.10	43.64	6.50	42.98	2.03	34.08	3.91
NO3-N	mg/l	35.31	12.23	38.04	9.93	38.38	8.91	44.25	11.99
pH	-	6.85	7.42	7.02	7.46	7.29	7.55	7.15	7.56
FC	Nos/100ml	3030.20	215.80	2533.4	190.50	1918	145.60	2018.7	205.90

Table 4 represented the Result of physical wastewater parameters mean values in entire experiment For Faecal Coliform, the highest and lowest values for influent and effluent was 3469 and 1743 nos/100ml respectively. The mean values of influent and effluent was 2375 and 189 nos/100ml respectively. Under a different hydraulic loading time, the 93% maximum average Phosphate removal was found in the AAFS effluent which was occurred in HRT=104 h. The average values of removal percentage in entire experiment was 92%.


(a)


(b)

Figure 9: (a) kaldnes K3 media before using in experiment
(b) kaldnes K3 media after ending the experiment with biomass

The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH_3-N, 72% for NO_3-N, 92% for PO_4 and outstanding removal was 92% for FC.

It was noticed that the amount of biomass attached to the biocarriers (see in the Figure 9) increased slightly after the start-up of the reactor until it reached a steady state on day 40. However, there was no significant change in the biomass during the 120 days of operation. It was concluded that the biofilms in all the reactors are nonuniform in thickness, but covers most of the inner part of the bio carriers, as the external part of biocarriers showed no signs of biofilm.

4. Conclusion:

Anaerobic-aerobic filter system is a very cost effective and eco-friendly option for the removal of organic matters (OM) from wastewater. This particular research work analysed the removal of OM from the domestic wastewater using combination of MBBR and anaerobic filter. This purification tank was operated for 120 days. In this study, the effects of vital factors such as carrier organic loading rate (OLR) and hydraulic retention time (HRT) affecting the system were investigated. In general, this research ascertained that MBBR with polyethylene media (PE) as biofilm support carrier could be efficient for OM removal from wastewater. Some specific findings of this study can be drawn as follows:

- Moving Bed Biofilm Career (MBBC) was capable of retaining a considerable quantity of attached biomass which would provide successful performance and achieve appreciable organic removal. Thus, the higher the OLR led to the greater the amount of attached biomass on support material that resulted in consumption of a greater part of the substrate by this biofilm.
- Higher organic removal rates were achieved at 48-hour hydraulic retention time.
- High accumulations of biomass in the biofilm process when coupled with good oxygen transfer capability of the system ensure the high treatment capacity and operational stability. This can make the MBBR process attractive and promising to apply for organic matter removal from wastewater.
- Biofilm layer was formed on biofilm carriers' surface in different HRT except HRT 24 hour because biomass layer was washed out at HRT 24 hour.
- The system was observed to remarkably efficient in removing pollutants with the average removal efficiency of 79% for BOD, 70% for COD, 82% for TS, 84% for TDS, 78% for TSS, 56% for VSS, 80% for NH_3-N, 72% for NO_3-N, 92% for PO_4 and outstanding removal was 92% for FC.
- This anaerobic-aerobic system is a feasible option of onsite domestic wastewater treatment for the people of the developing country like Bangladesh.

REFERENCES

Hasan, A., Uddin, M.N. and Parkinson, J. (2004). The role of non-governmental Hasan, A., Uddin, M.N. and Parkinson, J. (2004). The role of non-governmental organizations in decentralised wastewater management in Bangladesh. 30th WEDC Intemational Conference, Vientiane, Lao PDR.

Murungi, C. and Pieter M. D., 2014. Emptying, Transportation, and Disposal of faecal sludge in informal settlements of Kampala Uganda: The economics of sanitation. UNESCO-IHE, Institute for Water Education, Netherlands.

Opel, A., Bashar, M. K., and Ahmed M. F., 2011. Landscape Analysis and Business Model Assessment in Faecal Sludge Management: Extraction and Transportation Models in Bangladesh, Water Aid Bangladesh.

Strauss, M., Drescher, S., Zurbruegg, C., Montangero, A., Cofie, O., Drechsel, P. (2003). Co composting of Faecal Sludge and Municipal Organic Waste - a Literature and State-of- Knowledge Review.

Islam, S., 2016. Study on Faecal Sludge Management in Three Municipalities of Bangladesh.M. Sc. Thesis, Department of Civil Engineering. Khulna University of Engineering and Technology (KUET), Bangladesh.

Metcalf and Eddy, Wastewater Engineering treatment disposal reuse, 3rd edition. pp: 08-09

Davis & Cornwell, Introduction to environmental engineering, 4th edition, pp: 351

M. Sabok et al., 2018. Study on emptying of faecal sludge at selected areas in Khulna city, M. Sc. Thesis, Department of Civil Engineering. Khulna University of Engineering and Technology (KUET), Bangladesh.

Andersen, H.,Siegrist, H., Halling-Sørense, B., Ternes, T.A., 2003. Fate of estrogens in a municipal sewage tretment plant. Environmental Science and Technology 37 (18), 4021e4026.

Carballa, M., Omil, F., Lema, J.M., Llompart, M., Garcı´a-Jares, C., Rodtiguez, I., Go´mez, M., Ternes, T., 2004. Behavior of pharmaceuticals, cosmetics and hormones in a sewage tretment Plant. Water Research 38 (12), 2918e2926.

Reemtsma, T., Weiss, S., Mueller, J., Petrovic, M., Gonza´lez, S., Barcelo, D., Ventura, F., Knepper.,T.P., 2006. Pollar pollutant entry into the water cycle by municipal wastewater: a Eropean Perspective. Environment Science & Technology.(4), 1167e1175.

Lishman, L., Smyth, S.A., Sarafin, K., Kleywegt, S., Toito, J., Peart, T., Lee, B., Servos, M., Beland, M., Seto, P., 2006. Occurrence and reductions of pharmaceuticals and personal care products and estrogens by municipal wastewater treatment plants in Ontario, Canada. Science of the Total Environment 367 (2e3), 544e558.

Mie`ge, C., Choubert, J.M., Ribeiro, L., Euse`be, M., Coquery, M., 2009. Fate of pharmaceuticals and personal care products in wastewater treatment plants e conception of a database and first results.Environmental Pollution 157 (5), 1721e1726.

Schaar, H., Clara, M., Gans, O., Kreuzinger, N., 2010. Micropollutant removal during biological wastewater treatment and a subsequent ozonation step. Environmental Pollution 158 (5), 1399e1404. Stumpf, M., Ternes, T.A., Wilken, R.-D., Rodrigues, S.V., Baumann, W., 1999. Polar drug residues in sewage and natural waters in the state of Rio de Janeiro, Brazil. Science of the Total Environment 225 (1e2), 135e141.

Vieno, N., Tuhkanen, T., Kronberg, L., 2007. Elimination of pharmaceuticals in sewage treatment plants in Finland. Water Research 41 (5), 1001e1012.

Zorita, S., Ma˚rtensson, L., Mathiasson, L., 2009. Occurrence and removal of pharmaceuticals in a municipal sewage treatment system in the south of Sweden. Science of the Total Environment 407 (8), 2760e2770.

Zupanc, M., Kosjek, T., Petkovsek, M., Dular, M., Kompare, B., Sirok, B., Blazeka, Z., Health E., 2013. Removal of pharmaceuticals from wastewater by biological processes, hydrodynamic cavitation and UV treatment. Ultrasonics Sonochemistry 20 (4), 1104e1112.

A STUDY ON MEDICAL WASTE MANAGEMENT SCENARIO OF BADDA THANA

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ABSTRACT

In Badda thana, Dhaka city, a medical waste management investigation was conducted. Medical waste is the result of the continued operation of health centers such as hospitals, medical colleges, private practices, clinical laboratories and dental practices. This form of waste is extremely hazardous and contagious. Every mishandling or mismanagement causes human health and a country's climate to be very catastrophic. Medical waste causes various health hazards such as bad smell, animal infestation, vomiting, skin diseases, and so on. This project highlights that medical waste management has now become a major concern for the environment due to the rising number of health care facilities in both the public and private sectors of Bangladesh and the simultaneous production of enormous amounts of medical waste. This research focuses on the current waste management system of the five major hospitals. Data was gathered from project authority, superintendents, nurses, evaluation, and secondary sources through direct fieldwork. Dhaka North and South City Corporation has assumed full responsibility with the aid of a non-governmental organization' PRISM' to collect the waste as well as dumping. This work is also primarily focused on the proper management of medical waste materials from multiple sources. This research also shows that in order to achieve the spontaneous and productive participation of the group of people in proper medical waste management, the level of awareness and understanding among the people who are involved in the medical industry about the risks of medical waste management needs to be increased to the acceptable level.

Through this inquiry, it was quite clear that Badda's hospitals lack a proper framework for the management of hospital waste. The lack of proper record keeping of hospital waste and the hospital authority's mysterious indifference in cooperating with me have been major challenges in gathering data for this study. Dhaka was the country's only city with a long-standing hospital waste management system (HWMP). Generally, PRISM collects, transports and dumps waste in the open space as there was no waste treatment plant in it. But they do not treat waste before dumping. Although there are small numbers of hospitals in my area of study, there were no satisfactory hospital waste management facilities. In the last couple of years, PRISM has initiated programs to collect hospital waste from various hospitals and transport it to the Matuail area's open dumping site away from town. The organization still has no plan for any treatment of hazardous hospital wastes before its final dumping and it does not have any waste treatment plant.

Lastly, it can be concluded that it was quite evident that Badda's health care facilities completely lack a satisfactory medical waste management system and awareness level that needs sustainable improvement and further study at every stage of waste management.

Keywords: *Medical waste, Comparison, Amount of waste, Classification of waste, Decomposition technique.*

1. INTRODUCTION

Medical waste is extremely contagious and generates a significant environmental threat. The proper management system is necessary to ensure protection for the climate and wellbeing. According to the World Health Organization (WHO), approximately 85% of hospital waste is not dangerous or non-hazardous, 10% is contagious, and around 5% is non-infectious yet hazardous. Around 15 percent of hospital waste, for instance, is controlled as infectious waste in the US. In India, this could vary between 15 and 35% depending on the total quantity of waste generated (Chartier, 2014). In Pakistan, substantially 20% of medical discharge is considered to be potentially infectious or harmful (Agarwal, 1998). The total waste production in Dhaka is 3,500 metric tonnes per day, of which only 5.7% originates from a health care center (Nasima, 2000). Nearly 200 metric tonnes of hospital waste is created daily in the city of Dhaka, Bangladesh. Approximately 20% of this quantity is contagious. The study shows that hospital waste is not correctly and consistently handled except in a few private hospitals that isolate their contagious or infectious waste. It was found that many cleaners used needles, sterile bags, blood bags and test tubes for retail value and reuse. Decent hospital waste disposal is a recent phenomenon in Bangladesh, and the government of Bangladesh is working on developing a new and fresh solution to proper medical waste treatment. Farming, rural agriculture, scientific and medical Project (PRISM BANGLADESH FOUNDATION Bangladesh), a nationally recognized NGO in Bangladesh, has started to develop a low-cost hospital waste management facility in Dhaka City with monetary support from the Canadian International Development Agency (CIDA) (Hossain, Santhanam, Nik Norulaini, & Omar, 2011)

In the late 1990s and early 2000s, with the cooperation of City Corporation, some relevant authorities such as DGHS (Directorate General of Health Services) and in some major cities in Bangladesh such as Dhaka & Narayanganj, NGOs started working on hospital waste management (PRISM Bangladesh, 2018). A reliable local NGO in Bangladesh, PRISM is now collaborating to control hospital waste (Thesis & Rumi, 2014).

Hospital waste management systems in Bangladesh concentrated only on Dhaka and Narayanganj, the major city corporation. For the rest of Bangladesh's cities and towns, no significant attention was given to hospital waste treatment, and medical waste is processed and disposed of as solid household waste.

For recycling, industrial dumps and dumping grounds have often been used. They were found to be less concerned with proper medical waste disposal. According to the United States Health and Preventive Medicine Center of the Army (1995), medical waste must be segregated from a regular waste starting point of generation and continuing during storage, transportation and through to treatment point and ultimately waste disposal (Zhu, Asnani, Zurbrügg, Anapolsky, & Mani, 2008). Sadly, there is no formal form of treatment for medical waste in Bangladesh, and for natural degradation, most waste is dumped in open areas. In dealing with waste disposal and laboratory testing of infectious or dangerous materials, no safety measures are found (Bleckman & McLarney, 1985).

Hospital waste is created by hospitals, private practices, laboratories for pathology, clinics, testing centers, and other health centers and research facilities. These wastes include infectious, hazardous, radioactive and other general wastes. Hospital wastes are categorized according to their weight, density, and constituents. Here is a brief list of health care centers around Dhaka city in table 1.

Table 1: Number of HCEs in the city of Dhaka (PRISM, 2013)

Types of HCE	DCC North	DCC south	Total (%)
Hospitals	85	89	174 (17)
Clinics	118	46	164 (16)
Pathology	143	66	209 (21)

Types of HCE	DCC North	DCC south	Total (%)
Dental Clinic	289	176	465 (46)
Total	635	377	1012

1.1 Types of waste

Infectious waste: Waste infected with blood and several other bodily fluids (e.g. discarded test samples), crops and supplies of laboratory-based pathogens (e.g. autopsy waste and laboratory-based infected species) or contamination from patients in insulation unit sand instruments (e.g. swabs, bandages, and disposable medical devices).
Sharp waste: syringes, needles, scalpels and blades that can be disposed of.

Recycled waste: waste not posing a specific biological, chemical, nuclear or physical risk and can be further used after proper disinfection.

2. METHODOLOGY

After a review of the literature, the major difficulties regarding medical waste management that took place in Badda thana were gone through. Subsequent to that, six major hospitals in this region identified that were found to lead to medical waste. Their position, storage type, and building form are also listed for convenience as shown in Table 2. Data were collected over a total of 11 months via fieldwork for the study. Furthermore, the types of waste produced in different medicines and potential risks may emerge from them were found out. Next, a description of the existing management, color schemes and necessary materials used to manage the waste were done. Subsequently, the data were analyzed to resolve major concerns of waste treatment in healthcare centers. Finally, the fieldwork observations were compared with the PRISM foundation for the validity of the result. The hospital authority was not so friendly on some of the hospitals to work separately. For this reason, the survey team had to collaborate with the NGO to follow the same procedure of sorting wastes. We couldn't distinguish some other wastes because of our limitations.

Table 2: Details of major six hospitals at Badda thana

SL. No	Name	Location	Story	Single	Multi/Joint Building
1	Ibn Sina Hospital	Uttar Badda	7	✓	
2	Prescription point	Uttar Badda	3	✓	
3	Sun Health Care	Uttar Badda	5	✓	
4	Surjer Hashi Clinic	Middle Badda	4	✓	
5	Labaid Diagnostics	Merul Badda	8	✓	
6	Asian Hospital	Merul Badda	6	✓	

3. ILLUSTRATIONS

3.1 Waste generation rate in different hospitals

This segment addresses the total medical waste created by Badda thana's selected medicines and hospitals. PRISM Bangladesh Foundation involves the collection and dumping of all waste from the medicines and hospitals selected. Data provided by PRISM was cross-checked and validated during fieldwork analysis where a similar procedure of collection of wastes has been followed. From Table 3, it is shown that as per PRISM the highest overall amount of waste produced in IbnSina Hospitals. The average daily production of this medication is 6.752 kg/day. But, as described in table 3 below from weekday production and Friday waste production which is 7.4 kg/day and 7.07 kg/day respectively, the values were a little larger from our fieldwork.

Table 3: Estimated medical waste production by the selected hospitals in Badda thana

Hospitals & Medicals	No. of beds	Daily Production (PRISM) (kg/day)	Weekday Production (kg/day)	Friday Production (kg/day)	Average Production (kg/day)
Asian Hospital	20	0.993	1.5	1.7	1.397
IbnSina Hospital	NA	6.752	7.4	7.07	7.074
Labaid Hospital	NA	1.883	2.3	2.605	2.26
PrescriptionPoint Hospital	NA	0.922	1.60	1.825	1.449
Sunhealth Hospital	NA	0.888	1.5	1.70	1.363
Surjerhashi Hospital	20	0.990	1.85	1.99	1.61

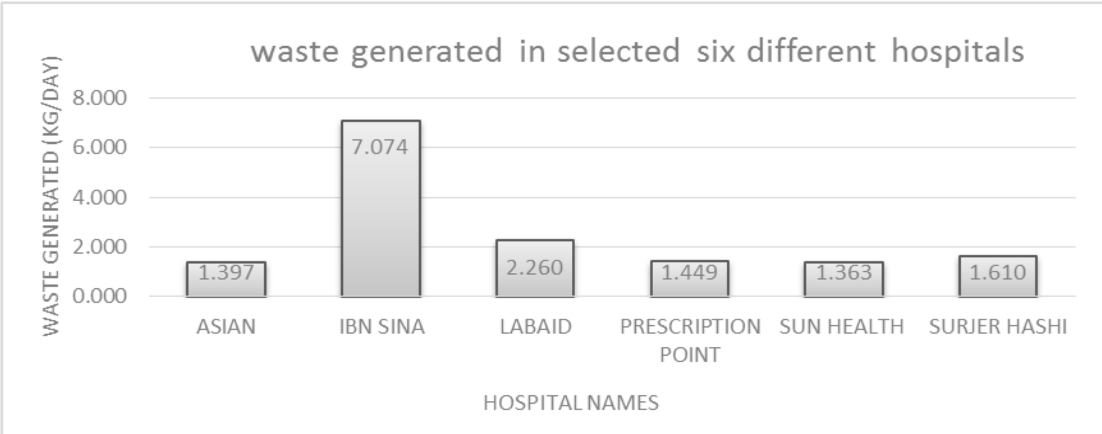

Figure 1: Average everyday waste generation per bed in different hospitals and medicals

The total average waste resulting from different medicines per bed in a day was estimated according to the bar diagram above. Waste amounts in Asian Hospital, Ibnsina Hospital, Labaid Hospital, Prescription Point Hospital, Sun Health Hospital, and Surjerhashi Hospitals were 1.397 kg, 7.074 kg, 2.260 kg, 1.449kg, 1.363 kg, 1.610 kg per bed per day.

Separate containers were used to store medical waste, and varying types of wastes are handled by the medical authority using color code. Under the medical authority, there were some workers works to collect the waste from the wards to the primary processing center.

3.2 Quantity of different categories of waste generated

Asian Hospital is one of Badda’s oldest private medical. This number of beds is 20. The patient is more crowded than the hospital's capacity. The authority is using separate plastic containers to store waste in addition to any wards. Some workers are working here to move the waste from this container to the temporary storage building behind the site.

The temporary storage building is a space designed specifically for storing waste. It can not render an odor to its surroundings by storing medical waste in this space. In this medication, according to PRISM, the average total waste generated was 0.993 kg/day. We then separately did the sorting and compared with the result PRISM for the validity of their program. In most cases, they were right, with a slight decrease in value. This may happen because they got a very short period of time for sorting and human errors can easily occur while counting.

Table 4: Generation of medical waste in Asian Hospital

Types of waste	Waste generated(kg/day)			
	PRISM Bangladesh foundation	Field Work Observation 1	Field Work Observation 2	Comparison[(Ob1+Ob2)/2]-PRISM Bangladesh foundation)
Infectious	0.78	0.92	0.95	0.155
Sharps	0.10	0.40	0.45	0.325
Recycled	0.053	0.19	0.13	0.107
Total	0.993	1.51	1.53	0.527

Likewise, in Table 4, all the data were compared for all the six hospitals with the PRISM foundation. The waste collected by the waste collection vehicles of Dhaka City Corporation from this temporary location. DCC collects and disposes of waste in the Matuail region. Before dumping, they do not treat the waste.

3.3 Contributions of six hospitals in a different category of waste

This section discusses the current situation where various kinds of medical discharge are produced from different sources. One of the objectives of this study is to examine the types of waste generated from different hospitals. Different waste materials are produced and waste is typed as the following class for better management options. From Figure 2, the percentage of different waste from the six hospitals can be seen. Out of the three wastes categories infectious waste holds a major chunk of 81%. Whereas, the sharp waste contains 16% and recycled wastes only 3%.

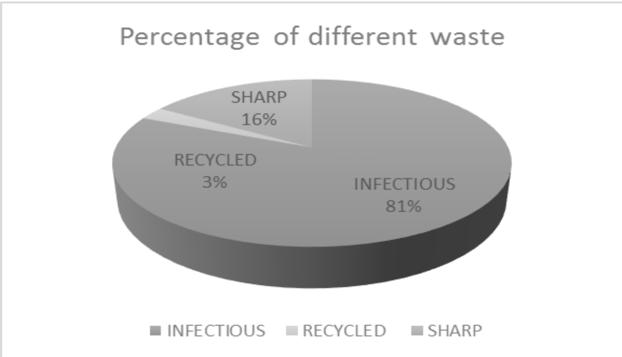

Figure 2: Percentage of different waste accumulated after separation

Figure 3, 4, 5 expresses the same thing but for different category of waste. It may be seen as in Figure 3, the maximum percentage of sharp waste that is generated in Badda thana comes from IBN SINA hospitals which are about 49%. The next big contributor in this category is LAB AID hospitals with a percentage of 39%.

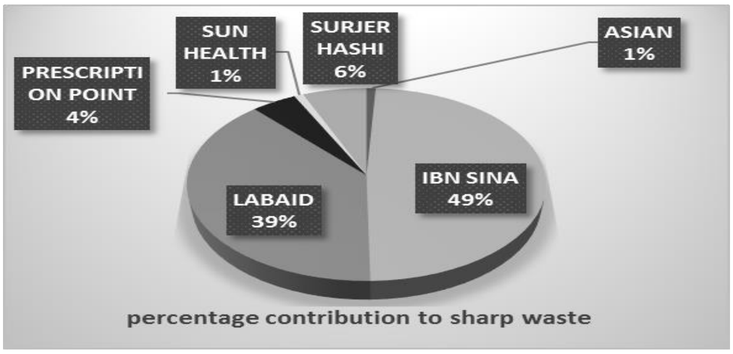

Figure 3: Percentage contribution of six hospitals to sharp waste

The similar process was followed for Figure 4 and Figure 5 to find out the most contributing hospital in infectious waste and recycled waste. In both cases, IBN SINA was the major contributor. But in case of recycled waste ASIAN hospital holds the major position surpassing LAB AID hospital right after IBNSINA hospital.

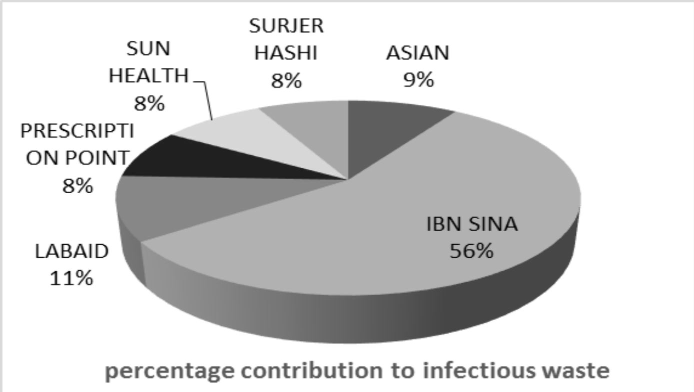

Figure 4: Percentage contribution of six hospitals to infectious waste

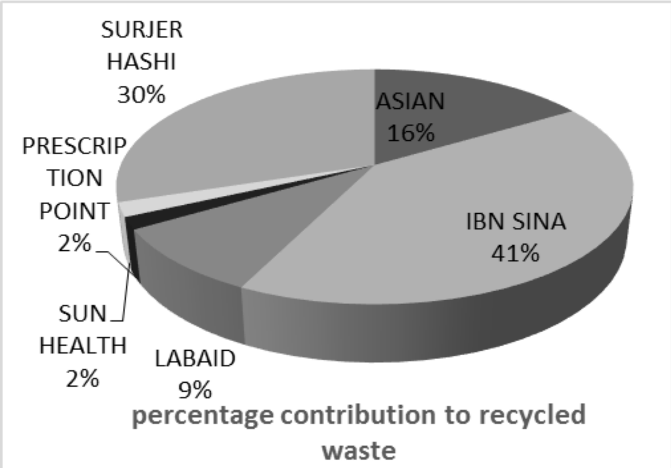

Figure 5: Percentage contribution of six hospitals to recycled waste

3.4 Disposal method and dumping site

Safe disposal is the most important thing in hospital waste management. Matuail, approximately eight kilometers south of Dhaka from Gulisthan / zero points, is used for solid waste dumping. The DCC authority uses various open locations to dump landfill waste, which increases the local community's risk of health hazards.

Figure 6: Matuail area; the waste dumping site

4. CONCLUSIONS

This study can be concluded as the followings:

1. Overall, the experience gained from the study presented in the current paper is that IBN SINA is the largest producer of all categories of medical wastes at every level in Badda thana.
2. Total medical waste production is 15.153 kg/day in targeted hospitals and medicines. Most of the waste is divided into certain categories, such as contagious waste, recycled waste, sharp waste.
3. Difficulties are identified primarily due to the lack of sufficient staff training on hospital waste treatment problems and the dangers that may emerge from their improper treatment. Inadequate steps have been applied to the safety and health of waste handlers. In view of the identified issues, the suggestions discussed in this study should be implemented so that proper waste management, as well as a treatment method, can be implemented by the hospital management.

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REFERENCES

Agarwal, R. (1998). Medical Waste Issues , Practices and Policy. *Seminar on Health and the Environment Centre for Science and Environment*, 1–52.

Bleckman, J. R., & McLarney, V. J. (1985). Waste management practices. *Hosp. Eng.*, Vol. 39, pp. 4–6. https://doi.org/10.1201/b16576

Hossain, M. S., Santhanam, A., Nik Norulaini, N. A., & Omar, A. K. M. (2011). Clinical solid waste management practices and its impact on human health and environment - A review. *Waste Management*, *31*(4), 754–766. https://doi.org/10.1016/j.wasman.2010.11.008

Nasima, A. (2000). Medical Waste Management : A Review Nasima Akter Environmental Engineering Program School of Environment , Resources and Development Medical Waste Management : A Review. *Asian Institute of Technology*, 1–25.

PRISM. (2013). *Survey on Quantitative and qualitative assessment of medical waste generation and management in Dhaka North City Corporation*.

Thesis, A., & Rumi, A. A. (2014). *Medical Waste Management System in Dhaka City Corporation : South , Bangladesh*. 2008–2009.

Zhu, D., Asnani, P. U., Zurbrügg, C., Anapolsky, S., & Mani, S. (2008). *Improving Municipal Solid Waste Management in India : A Sourcebook for Policy Makers*. https://doi.org/10.1596 978-0-8213-7361-3

OXIDIZERS EFFECT OF SULPHIDE REMOVAL FROM HAIR DISSOLVING LIMING WASTEWATER IN TANNERY

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ABSTRACT

Hair dissolving is the conventional operation in the tannery where raw animal skins are treated with sodium sulphide and calcium hydroxide to remove keratin proteins e.g., hair and wool epidermis and to dissolve non-structural proteins. The hair dissolving liming process discharges wastewater containing soluble sulphide. In acidification, wastewater contains soluble sulphide creates toxic hydrogen sulphide, which is a great concern. In this present study, the efficiency of hydrogen peroxide (H_2O_2) and sodium chlorite ($NaClO_2$) oxidizers are compared to remove sulphide from the hair dissolving liming wastewater. The physicochemical parameters of the liming wastewater were: pH 12.3 and sulphide 3666.01 mg/L. The physicochemical parameters: sulphide and pH at optimum conditions of the treated liming wastewater for hydrogen peroxide (H_2O_2) and sodium chlorite were 109.2 mg/L, 6.1 and 98.3 mg/L, 7.0, respectively. The sulphide removal efficiency for H_2O_2 and $NaClO_2$ were 97.0% and 98.5%, respectively. The simple and easy method would be effective for treating hair dissolving liming in reducing soluble sulphide discharge from the tanneries.

Keywords: *Tannery, Hair dissolving liming, Wastewater, Environment, Oxidizers.*

1. INTRODUCTION

The leather industry is one of the indispensable sectors for economic development contributing to high earning. In the world, 15 million tons of hides and skins are processing per year in this industry; the discharged wastewater is more than 1500 million litres/day in the average calculation (Rajamani, Chen, Zhang & Su, 2009). The amount and kind of waste created during leather production is variable and depends on numerous factors like breed, slaughter procedure, conservation of hides and the technology of used for hair removal (Souza & Gutterres, 2012). In Bangladesh, during liming operation in hair burning process, 208-623 metric ton sulphide is released (Hashem, Nur-A-Tomal, Ahsan & Bushra, 2018). It has been estimated that over 55,000 ha of land have been contaminated with tannery wastes and around 5 million people are affected by the low quality of the social environment and drinking water (CSIRO, 2001; Sahasraman & Jackson, 2005).

Now those days, in hair removal technology makes up 60-70% of the total pollution discharge from the leather industries (Xu, Zhang & Hao, 2009). Having of sulphydryl (SH^-) group in hair/wool, it leads to accumulation of heavy metals (Mondal, Hashem, Nur-A-Tomal & Aminur, 2016). The beam house operation naming liming and unhairing is functioned to remove hair, fatty substance, interfibrillary components, epidermis and to rupture the fibre structure (Covington, 2011). This technology depends upon the phenomenon of destroying or loosening and removal of hair by chemical and mechanical action; the keratinous materials (hair, hair root, epidermis, etc.) are removed from the pelts conventionally with the mixture of sulphides (Na_2S, NaSH) and lime (CaO) (Quadery, Uddin, Azad & Chowdhury, 2014).

The sulphur present into effluent comes from organic matter (especially hair) and from compounds used in the processing of hides of unhairing agents. Sulphur is found in the effluent in the form of sulphates (SO_4^{2-}) and sulphides (S^{2-}) (Souza & Gutterres, 2012). If the hair dissolving wastewater pH 8, soluble sulphide emits poisonous hydrogen sulphide (H_2S) gas (Dixit, Yadav, Dwivedi & Das, 2015) as the following equation (i):

$$S^{2-} + H^+ \rightarrow H_2S.....(i)$$

The risk of H_2S formation during effluent treatment poses a serious environmental problem (Souza & Gutterres, 2012). Increasing salinization of rivers and groundwater has led to the loss of agricultural production and reduce the quality of drinking water (Money, 2008). The high pH concerned the liming water produce H_2S by mix up with low pH carried chrome tanning wastewater after discharge it from the industry (Hashem, Nur-A-Tomal, Ahsan & Bushra, 2018).

So far, many researchers worked on treating liming wastewater in various ways. For example, electrocoagulation (Sengil, Kulac & Ozacar, 2009); coagulation-electrocoagulation process (Hashem, Nur-A-Tomal, Ahsan, Momen, Hasan, Hasan & Sheikh, 2017); oxidation-coagulation-filtration method in sulphide removal (Hashem, Nur-A-Tomal & Bushra, 2016); simple coagulation filtration process (Barman, Juel & Hashem, 2016). Also, applying the techniques of flotation, electrochemical treatment, sedimentation, coagulation, ultra-filtration and reverse osmosis (Ates, Orhon, & Tunay, 1997; Song, Williams, & Edyvean, 2004). In those techniques, most often coagulants are used for the treatment of the hair dissolving liming wastewater are commercial aluminium sulfate ($Al_2(SO_4)_3$. $18H_2O$), iron sulfate ($FeSO_4.7H_2O$), ferric chloride ($FeCl_3.6H_2O$) and lime (CaO) (Genovese, & Gonzalez, 1998). Likewise, in electrocoagulation (Hashem, Nur-A-Tomal, Ahsan, Momen, Hasan, & Hasan, 2017) electricity is used which is a costly and time-consuming process. The development of wastewater treatment techniques depends on several factors e.g., efficiency, cost-effective and environmental capability (Costa & Olivi, 2009).

In this study, an attempt was made to remove sulphide from the hair dissolving liming wastewater with low-cost oxidizers. The oxidizers hydrogen peroxide (H_2O_2) and sodium chlorite ($NaClO_2$) are used to compare their sulphide removal efficiency in simple and cost-effective.

2. METHODOLOGY

2.1 Sampling

The hair dissolving liming wastewater was collected into the high-density polyethylene (HDPE) bottle from the Superex Leather Ltd. Khulna, Bangladesh. The samples were taken immediately to the laboratory for the experiment.

2.2 Chemicals and Reagents

The reagents H_2O_2 (50%, TPL, Thailand), sodium chlorite (Hoechst, Switzerland) hydrochloric acid (Sigma Aldrich, Germany), potassium ferricyanide and barium chloride (UNI-CHEM, China); ammonium chloride (Loba Chemie, India), dimethyl glyoxime (Loba Chemie, India); iron(II) sulphate heptahydrate (Loba Chemie, India), ammonia (Loba Chemie, India), sulphuric acid (Merck Specialities Pvt. Ltd. India), ethanol (Merck KGaA, Germany) were purchased from a local scientific store. The buffer solution was prepared using 200 g ammonia chloride and 200 g ammonia per litre in deionized water. The indicator was prepared by mixing 10 mL 0.6% ferrous sulphate, 50 mL 1% dimethylglyoxime in ethanol which acidified with 0.5 mL concentrated sulphuric acid. The barium chloride solution was prepared by dissolving 12.5 g barium chloride in 1000 mL deionized water. The titrant 0.1 N potassium ferricyanide was prepared by dissolving 32.925 g potassium ferricyanide in 1000 mL deionized water.

2.3 Treatment of Hair Dissolving Liming Wastewater

Hair dissolving liming wastewater was treated with H_2O_2 and $NaClO_2$ oxidizers through the oxidation process. Scheme for the hair dissolving liming wastewater operation process by H_2O shown in Figure 1. Firstly, the process parameters of the untreated wastewater were analysed. Secondly, untreated wastewater was poured into a beaker, to which H_2O_2 was added and the mixture was stirred for 5 min to eliminate the evolved H_2S gas. Thirdly, the final pH of the mixture was assimilated with the help of dilute HCl and the final mixing was done by keeping on a stirrer for an additional 5 min. Finally, the mixture was allowed to settle. After settling, process parameters of the treated wastewater were analysed.

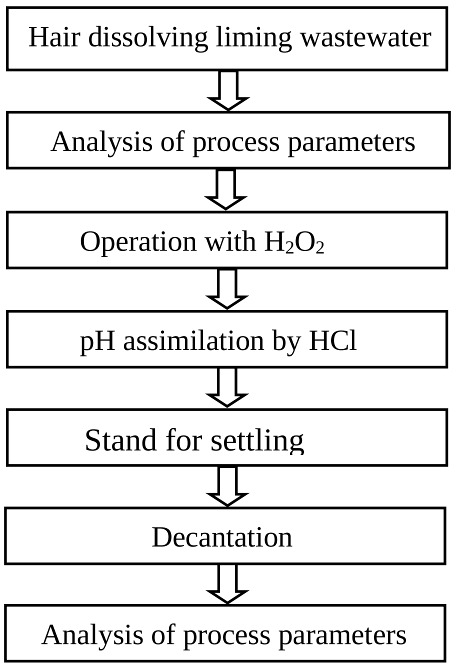


Figure 1: Scheme for the hair dissolving liming wastewater operation process by H_2O_2.

At the same time, the untreated liming wastewater was treated with $NaClO_2$. Scheme for the hair dissolving liming wastewater operation with the $NaClO_2$ is shown in Figure 2. At first, the process parameters of the untreated liming wastewater were analysed. Then, the untreated lime was poured into a beaker, to which $NaClO_2$ was added in the liquid phase. Then, the mixture was stirred for 5 minutes and the final pH was assimilated by using diluted hydrochloric acid. After final mixing, keeping on a stirrer for an additional 5 min to oxidize perfectly and settling was done. Finally, again the process parameters were analysed.

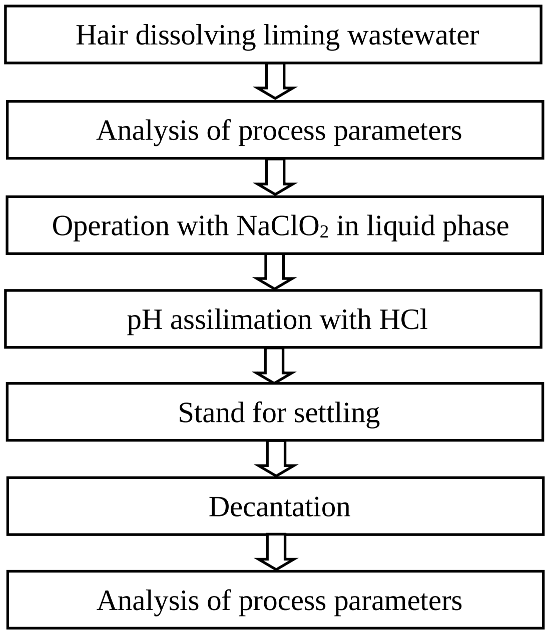


Figure 2: Scheme for hair dissolving liming wastewater operation process by $NaClO_2$

2.4 Analysis of Process Parameters

The electrical conductivity (EC), total dissolved solids (TDS), and salinity were measured by using an electrical conductivity meter (CT-676, BOECO, Germany). pH meter (UPH-314, USA) was used to measure the pH of the hair dissolving liming wastewater. Before measuring all the parameters, the meter was calibrated using the standard solution. EC, TDS, salinity was estimated gravimetrically following the standard methods of APHA (APHA, 2012). Sulphide level was measured by following the official method (SLC 202) of analysis (Society of Leather Technologist and Chemists, 1996).

2.5 Measurement of Sulphide

The soluble sulphide was determined by the titrimetric method following Society of Leather Technology and Chemist (1996) official method (SLC 202). A 25 mL treated hair dissolving liming wastewater without using filter paper and coagulant was pipetted into 200 mL conical flask. Then, 10 mL buffer, 1 mL indicator, and 2.0 mL barium sulphite were added and stopped the flask. The flask was left for 1 minute to precipitate the sulphite as barium sulphite to mask the interference. Then, the solution was titrated with the 0.1 N potassium ferricyanide until the pink colour was disappeared.

2.6 Process Escalation

Appraisals were carried out to optimize the treatment parameters: pH and oxidizers dose. The process parameters were engrafted by investigating the various physicochemical parameters e.g., sulphide, EC, TDS, and salinity of the treated wastewater. To optimize H_2O_2 dose, varying doses were used for each batch 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 where other parameters were left unchanged, such as pH (6.1). For the optimization of pH, mildly acidic to mild alkali pH (5.0 to 8.0) was preselected. And to optimize the $NaClO_2$ dose, varying doses were used for each batch 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 mL, where the other parameters were left unchanged (pH 7.0). Here, for the optimization of pH, mild acidic and mild alkali pH (6.0, 6.5, 7.0, 7.5 & 8.0) were preselected.

3. RESULTS AND DISCUSSION

3.1 Optimization of Oxidants Dose

From the assessment to determine the effect of oxidizers obtained result is represented in Figure 1 and Figure 2. Figure 1 shows the sulphide removal efficiency of H_2O_2 dose and in Figure 2 shows the sulphide removal efficiency of $NaClO_2$ dose. It was discerned that the sulphide removal percentage was gradually increased with the increasing dose of H_2O_2 and $NaClO_2$. Both oxidizers were applied at pH 7 and in both purpose removal percentage was increased to the 1.0 g of dose per 50 mL wastewater and after that the near about constant with the increasing dose of oxidizers. Here, it was realized that in same dose $NaClO_2$ gives a better result. At 7 pH, 1.0 g of oxidizers dose, 97.03% of maximum removal with $NaClO_2$ and 97.02 % of maximum removal with H_2O_2.

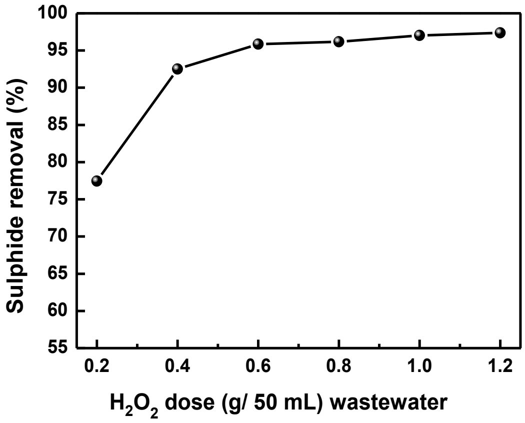


Figure 1: Sulfide removal with H_2O_2

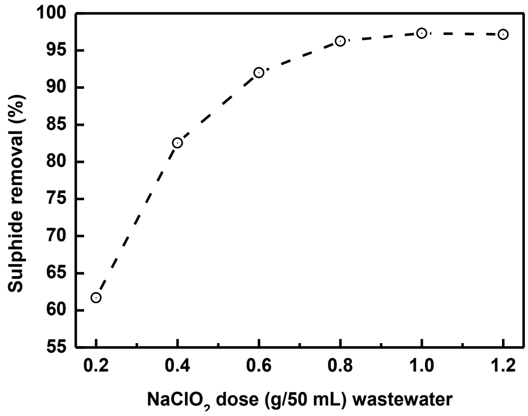
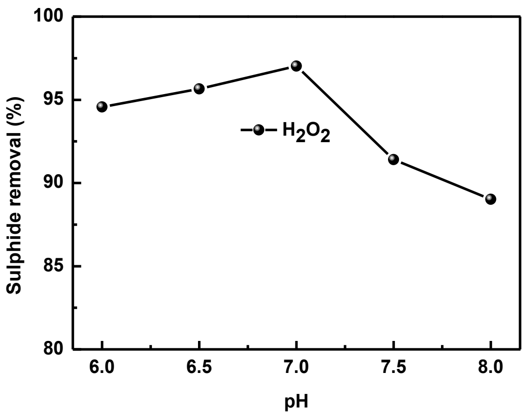


Figure 2: Sulfide removal with $NaClO_2$

3.2 Optimum pH for Sulphide Removal

The sulphide removal efficiency with increasing of pH on both oxidizers the same dose represented in Figure 3 and Figure 4.



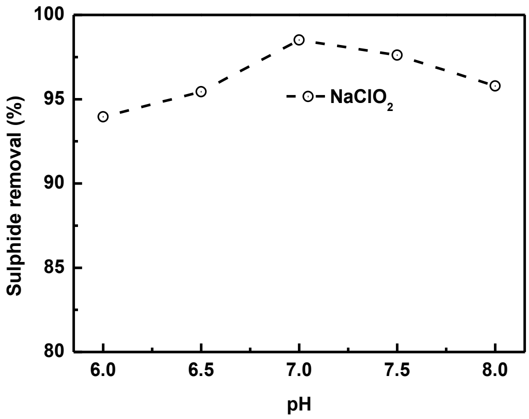


Figure 3: pH effect on sulphide removal by H_2O_2 Figure 4: pH effect on sulphide removal by $NaClO_2$

The important parameter of the process is pH which has a great contribution to the proper functioning of the oxidizers and removal of physicochemical parameters. In Figure 3, it was perceived that the maximum removal percentage at pH 7 per 50 mL of wastewater. In the same condition, the maximum percentage of sulphide removal with $NaClO_2$ was given a better result than operating with H_2O_2. The removal percentage with $NaClO_2$ and H_2O_2 were 98.5 % and 97.0 %, respectively. The maximum removal percentage was got at pH 7. When displaced from the normal pH condition (7 pH). the removal percentage was decreased. It may be caused by recreating of S^{2-} from the production of sulphur.

3.3 Efficient Comparison of Oxidizers

In the optimum and same condition, the result of the treatment process with H_2O_2 and $NaClO_2$ is compared in Table 1. Before treatment of the liming wastewater, the initial physicochemical parameters were: pH 12.3±0.04; TDS 16.26±0.04 g/L; sulphide 3666.01±9.3 mg/L; EC 33.83±0.07 mS and salinity 21.4 ±0.61 ppt. After completed all step treatment with H_2O_2 the physicochemical parameters were: pH 7.00±0.02; TDS 8.59±0.06 g/L; Sulphide 109.2±4.2 mg/L; EC 19.83±0.06 mS and salinity 10.2±0.14 ppt.

Table 1: Removal of pollution load from liming wastewater

Parameters	**Initial**	**Treatment with**		**ECR (1997)**	**Unit**
		$NaClO_2$	**H_2O_2**		
pH	12.3±0.04	7.03±0.03	7.00±0.02	6-9	-
TDS	16.26±0.04	14.94±0.18	8.59±0.06	2.1	g/L
Sulphide	3666.01±9.3	98.28±3.6	109.2±4.2	1.0	mg/L
EC	33.83±0.07	34.31±0.47	19.83±0.06	1.2	mS
Salinity	21.4±0.61	19.0±0.42	10.2±0.14	--	ppt

The physicochemical parameters, after treatment with $NaClO_2$ were: 7.03±0.03; TDS 14.94±0.18 g/L; sulphide 98.28±3.6 mg/L; EC 34.31±0.47 mS and salinity 19.0±0.42 ppt. In overall observation, it could be said that treatment with H_2O_2, sulphide removal percentage was lower but other parameters removal was higher than the treatment with $NaClO_2$. On the other hand, treatment with $NaClO_2$ the sulphide removal percentage was higher though other parameters removal percentage was lower than treatment with H_2O_2. In the case of treatment with $NaClO_2$, EC was increased. Because $NaClO_2$ react with HCl produces ClO_2 which evaporate over time. Further, $NaClO_2$ react with HCl and produce Na^+, H^+, Cl^- for counter ion. Therefore, treatment with $NaClO_2$ increased salinity.

4. CONCLUSIONS

The present study reveals that hair dissolving liming wastewater treatment with simple oxidation method. The physicochemical parameters were reduced for both the oxidizers. The pH was within the permissible level. The removal efficiency of sulfide, TDS, EC and salinity at optimized conditions for hydrogen peroxide were 97%, 47.2%, 41.4% and 52.3%, respectively. The removal efficiency of sulfide, TDS and salinity at optimized conditions for sodium chlorite were 98.5%, 8.1% and 11.2%, respectively. The EC was a little increased. The study could be useful to treat hair dissolving liming wastewater to reduce sulphide simple hydrogen peroxide oxidation method as well as to reduce the other physicochemical parameters.

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REFERENCES

Ates, E., Orhon, D. & Tunay, O. (1997). Characterization of tannery wastewater for pretreatment selected case studies. *Water Science and Technology*, *36*(2-3), 217-223.

Barman, B.C., Juel, M.A.I. & Hashem, M.A. (2017). Tannery wastewater treatment using low cost coagulants with simple coagulation-filtration process. *Engineering International*, *5*(2),75-82.

Costa, C.R., & Olivi, P. (2009). Effect of chloride concentration on the electrochemical treatment of a synthetic tannery wastewater. *Electrochimica Acta*, *54*(7), 2046-2052.

Covington A.D. (2011). *Tanning Chemistry: The Science of Leather. The Royal Society of Chemistry*, Cambridge, Northampton, UK.

CSIRO (2001). "Salinity reduction in tannery effluents in India & Australia." Project proposal to ACLAR by CSIRO textile and fibre technology Leather Research Center.

Dixit, S., Yadav, A., Dwivedi, P. D. & Das, M. (2015). Toxic hazards of leather industry and technologies to combat thread: a review. *Journal of Clean Production*, *87*, 39-49.

Gevovese, C.V. & Gonzalez, J.F. (1998). Solids removal by coagulation from fisheries wastewaters. *Water SA, 24*(4), 371-372.

Hashem, M. A., Nur-A-Tomal, M. S., Ahsan, A. & Bushra, S.A. (2018). Hair burning liming in tannery: a potential sulfide source to the environment. *Sustainable Water Resources Management, 4*(4), 1117-1121.

Hashem, M.A., Nur-A-Tomal, M.S., Ahsan, A., Momen, M.A., Hasan, M. Hasan, A. and Sheikh, M.H.R. (2017). "Sulphide Removal from the tannery liming wastewater by coagulation-electrocoagulation." Proceedings of XXXIV IULTCS Congress, Chennai, India, 283.

Hashem, M.A., Nur-A-Tomal, M.S. & Bushra, S.A. (2016). Oxidation-coagulation-filtration process for the reduction of sulfide from the hair burning liming wastewater in tannery. *Journal of Cleaner Production*, *127*, 339-342.

Hashem, M.A., Nur-A-Tomal, M.S. and Bushra, S.A. (2016). "Treatment of toxic hair burning liming wastewater from tannery by simple coagulation-filtration process." 16th Asian Chemical Congress, Dhaka, Bangladesh, 158-159.

Mondal, N.R., Hashem, M.A., Nur-A-Tomal, M.S. and Rahman, M.A. (2016). "Hair dissolving liming in tanneries enhances heavy metals to environment." 16th Asian Chemical Congress, Dhaka, Bangladesh, 154-155.

Money, C.A. (2008). Salinity reduction in tannery effluents in India and Australia. Final report on project AS/2001/005. ACLAR, Canberra, ACT.

Quadery, A.H., Uddin, M.T., Azad, K., & Chowdhury, M. J. D. (2012). Development of hair -save unhairing metal using organic thio compounds in pre-tanning stages of leather production. *Journal of Scientific and Engineering Research, 5*(12), 376-382.

Rajamani, S., Chen, Z., Zhang, S. and Su, C. (2009). "Recent Development in Cleaner Production and Environment Production in world Leather Sector." Proceedings of XXX IULTCS Congress, Beijing, China. 5.

Sahasranaman, A., and Jackson, M. (2005). "Salinity reduction tannery effluents in India and Australia: Project review." ACIAR, Canberra ACT.

Sengil, I.A., Kulac, S. & Ozacar, M. (2009). Treatment of tannery liming drum wastewater by electrocoagulation. *Journal of Hazard matter*, *167*, 940-946.

Song, Z., Williams, C.J. & Edyvean, R.G.J. (2004). Treatment of tannery wastewater by chemical coagulation. *Desalination*, *164*(3), 249-259.

Souza, F.R., & Gutterres, M. (2012). Application of enzymes in leather processing: A comparison between chemical and co-enzymatic process. *Journal of Chemical Engineering, 29*(3), 473-482.

Xu, W., Zhang, J., and Hao, L. (2009). "Hair-saving enzyme- assisted unhairing effects of sodium hydrosulfide and peroxide." Proceedings of XXX IULTCS Congress. Beijing, China.,11-14.

PRODUCTION OF ACTIVATED CARBON FROM RICE HUSK AND IT'S CHARACTERIZATION

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ABSTRACT

In recent years, worth mentioning priority has been focused on the utilization of agricultural wastes or agricultural biomass for the production of various carbonaceous materials. This study has been carried out to demonstrate the potential of utilizing rice husk for the production of activated carbon. Activated carbon is a carbonaceous, highly porous material which is widely used in water purification, gas separation, catalysis etc. In this study, production of rice husk based activated carbon has been undertaken by chemical activation with potassium hydroxide (KOH). The raw rice husk was converted into rice husk carbon by heat treatment with 600 ^{o}C. The ratio of rice husk carbon and KOH solution of 1N was kept 1:5 for activation. The activated sample again processed with heat treatment of 750 ^{o}C to obtain the activated carbon. In this study, the characterization was done by Scanning Electron Microscopy and X-Ray Diffraction analysis. The SEM images revealed the fibrous, non-porous morphology of rice husk carbon and at the same time indicated the porous structure of activated carbon. From XRD analysis, the average crystallite size for rice husk carbon was found out 4.995 nm and for activated carbon of 9.12 nm which is about 1.8 times. The interlayer spacing for the both carbon was determined to be of 0.13 nm. The approximate percent crystallinity for rice husk carbon and activated carbon was determined 24.89% and 39.11% respectively. This study shows the porous and more crystallite morphology of produced activated carbon from agricultural by-product that will help in promoting resource recovery process for agricultural wastes.

Keywords: *Rice husk, Rice husk carbon, Activated carbon, SEM, XRD.*

1. INTRODUCTION

Activated carbon is a carbonaceous and highly porous medium which is composed of a complex structure of carbon atoms. The large surface area of activated carbon is used for adsorption of toxic chemicals, dyes, various heavy metals, removal of organic and harmful pollutants, various types of petrochemicals etc. It is widely used in filtration and purification (Baccar, Bouzid, Feki, & Montiel, 2009). The impurities from gaseous and liquid media are removed through the porous network in the lattice structure of activated carbon. This porous structure of activated carbon originates a vast surface on which adsorption occurs. Usually higher internal surface area offers higher effectiveness of activated carbon. Activated carbons are usually characterized by their large surface area, high micro porosity and adsorption capacity, enabling them to be utilized as an effective adsorbent in water treatment processes (Poinern et al., 2011).

Activated carbon is a product of good market demand for its versatile uses. However, the commercial production of activated carbon is not cost effective and together with the fact that the regeneration of used activated carbon is extremely difficult, much attention has been given to synthesizing amorphous activated carbon from renewable sources (Muniandy, Adam, Mohamed, & Ng, 2014). Now-a-days a wide variety of agricultural wastes are being used as the source of production of activated carbon. Some recent examples are coconut shells (Gratuito, Panyathanmaporn, Chumnanklang, Sirinuntawittaya, & Dutta, 2008), rubber wood saw dust (Srinivasakannan & Bakar, 2004), sugar-cane bagasse (Ahmedna, Marshall, & Rao, 2000), cassava peel (Sudaryanto, Hartono, Irawaty, Hindarso, & Ismadji, 2006), cotton stalk (Girgis & Ishak, 1999), rice husk (Suzuki, Andrade, Sousa, & Rollemberg, 2007) etc. Rice husk is an agricultural waste and major by-product of rice milling industry. It is cheap and also locally available in plenty in the whole world. Rice husk is mainly composed of various organic ligno cellulosic biomass and ash. The typical composition of rice husk is listed in Table 1.1. Most of the rice husk is used as fuel and regarded as a low value energy resource. The untreated rice husk creates a disposal problem and also unfavorable for the environment. Production of activated carbon from rice husk can increase the value of this agricultural waste, reduce the disposal cost, can be used as an adsorbent and thus provide cost effective alternative to the existing commercial carbon.

Table 1.1: Main components and contents of rice husk (Guo et al., 2002).

Main composition	Content (Wt. %)
SiO_2	18.8-22.3
Lignin	9.0-20.0
Cellulose	28.0-38.0
Protein	1.9-3.0
Fat	0.3-0.8
Nutrients after full digestion	9.3-9.5

Activated carbons can be synthesized by two different processes: the “physical” activation process and the “chemical” activation process. In physical activation process, the carbonized materials are activated at high temperature in accordance with the presence of steam or carbon dioxide. In chemical activation process, the carbonized material is mixed with various activating agent such as phosphoric acid (H_3PO_4), sodium hydroxide (NaOH), potassium hydroxide (KOH), zinc chloride ($ZnCl_2$) etc. and undergoes with a proper heat treatment. A comparison of chemical activation with physical activation shows that chemical activation provides a lower reaction temperature, and its global yield tends to be greater (Mohanty, Naidu, Meikap, & Biswas, 2006).

Many studies have been undertaken for the production of activated carbon by using a wide variety of materials. Here use of rice husk for the production of activated carbon by chemical activation process is proposed. One of the main purposes of this study is to discuss the SEM images for attaining better conception about the morphology of rice husk carbon before and after activation treatment. XRD analysis is also carried out to characterize rice husk based activated carbon.

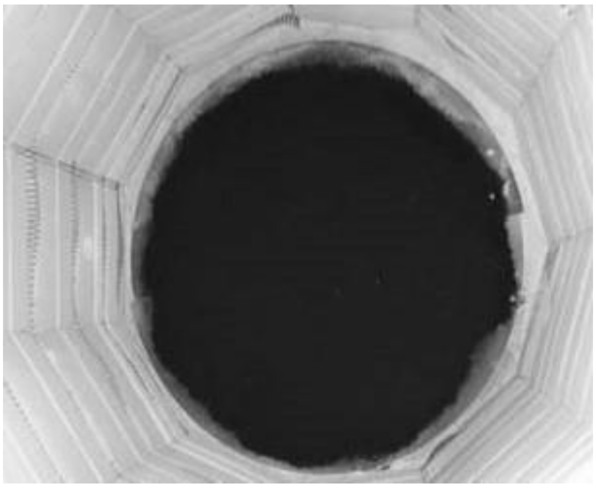
2. METHODOLOGY

2.1 Collection of Sample

Rice husk is a locally available material and is mostly available in various rice mills. The amount of this by-product is increasing every year with the increasing population. The rice husk used in this study was collected from a rice mill of Rajshahi, Bangladesh.

2.2 Preparation of Rice Husk Carbon

Raw rice husk was washed with water several times so that there was no dirt and other substances in the rice husk. It was then kept under sun shine till it was completely dried. This washed and dried rice husk was used for the preparation of rice husk carbon. This rice husk was put into the electric furnace (Model: SHTL-233) and kept for about 2 hours. The temperature was fixed at 600 ^oC. After burning at 600 ^oC for about 2 hours, the rice husk carbon was obtained. The prepared carbon is shown in Figure 1.



(a) Rice husk carbon in electric furnace

(b) Rice husk carbon

Figure 1: Rice husk carbon produced in electric furnace at 600 ^oC

2.3 Preparation of Activating Agent

Sodium hydroxide, potassium hydroxide, zinc chloride, phosphoric acid etc. can be used as activating agent. Activating agent plays the most important role for the production of activated carbon. In this experiment, potassium hydroxide (KOH) solution was used as activating agent. For the preparation of potassium hydroxide (KOH) solution, 40g of potassium hydroxide was mixed with distilled water until the total volume became 100 ml.

2.4 Activation of Rice Husk Carbon

A 20g of rice husk carbon was taken in a beaker and mixed with 100 ml KOH solution thoroughly. The ratio of rice husk carbon and activating agent was maintained 1:5 (Rice husk carbon: Activating agent = 1:5 w/v). It was stirred for about 45-60 minutes. After activation, it was oven dried at 120 ^oC for 48 hours. The activation process is shown in Figure 2.

(a) KOH solution (b) Mixing with KOH solution (c) Oven dried activated sample

Figure 2: Activation of rice husk carbon with KOH

2.5 Production of Activated Carbon

The oven dried activated sample was put into the muffle furnace (Barnstead Thermolyne 47900 Furnace). It was kept at 750 ºC for about 1 hour. This process is shown in Figure 2.6 and 2.7. After burning it was washed with distilled water several times. It was then oven dried at 110 ºC for 24 hours. Thus, the activated carbon was obtained. The flow diagram of activated carbon production is presented in Figure 3.

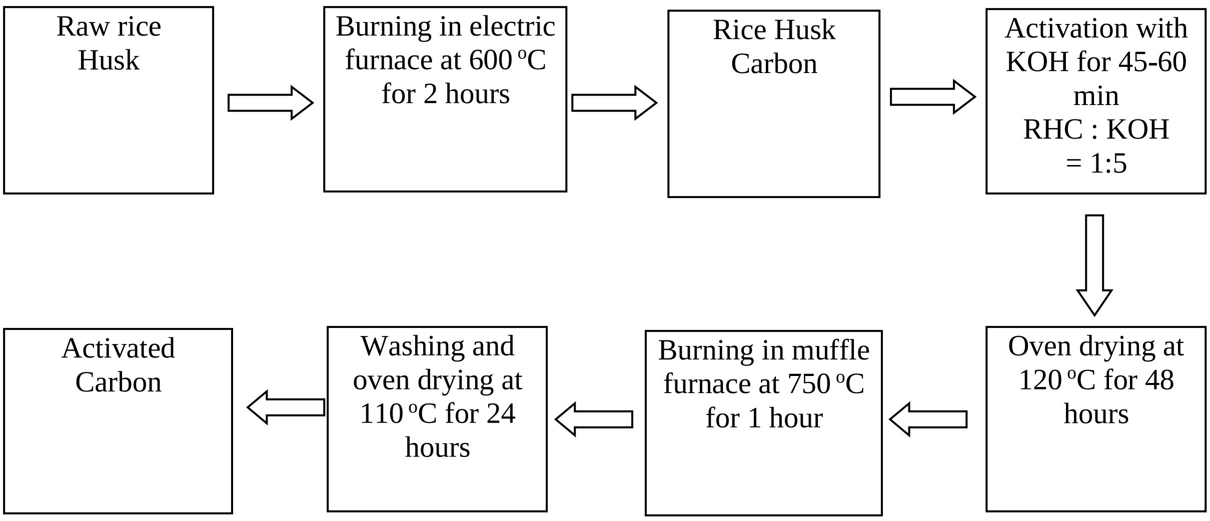


Figure 3: Flow diagram of activated carbon production process from rice husk

3. RESULTS AND DISCUSSION

Activated carbon produced from rice husk is characterized for the evaluation of morphology with scanning electron microscopy (SEM) analysis and X-ray detraction (XRD) analysis. Rice husk carbon without activated is also analyzed for comparing the change in morphology. The results are discussed in the following sections.

3.1 Scanning Electron Microscopy (SEM) Analysis

Scanning electron microscope image provides idea about the surface texture and topography of the sample. The surface of the prepared samples was investigated using Curl Zeiss (Model: EVO-18) Scanning Electron Microscope. Figure 4 represents the fibrous texture of rice husk carbon. Figure 5 indicates surface topography of rice husk carbon having only some cracks and curves. It is clear from this SEM image that, rice husk carbon is non-porous. Here only carbonization of rice husk occurs without creating any porous structure. It is due to the insufficient heat treatment and absence of any activating agent. On the contrary, surface texture of activated carbon is non-fibrous (Figure 6). Figure 7 indicates surface topography of activated carbon having some number of pores. This porous structure is formed because most of the organic volatiles are developed gradually leaving behind the ruptured surface topography of activated carbon with few numbers of pores. This transformation occurs due to the decomposition of the volatiles. The activation process in accordance with the presence of potassium hydroxide (KOH) and the high temperature is mainly responsible for this. The equation for this transformation can be written as,

$$6KOH = 2K + 3H_2 + 2K_2CO_3 \tag{1}$$

The potassium carbonate (K_2CO_3) becomes decomposed at the time of activation. At this time CO_2 gas is released. The volatile organic compounds are evolved when the reaction between the potassium hydroxide (KOH) and the carbon precursor takes place. Sufficient heat treatment plays the most important role. So, for the formation of pores, not only proper activating agent but also sufficient heat treatment is necessary. The creation of pores increases both the surface area and the pore volume and affects the efficiency of adsorption.

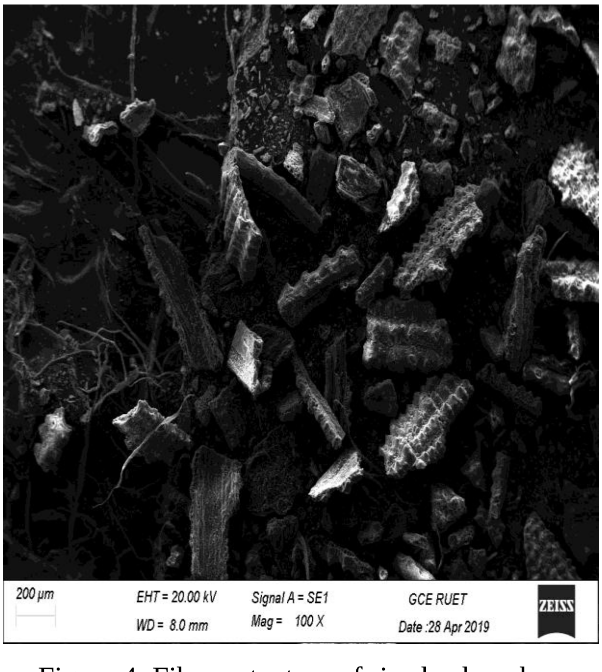


Figure 4: Fibrous texture of rice husk carbon

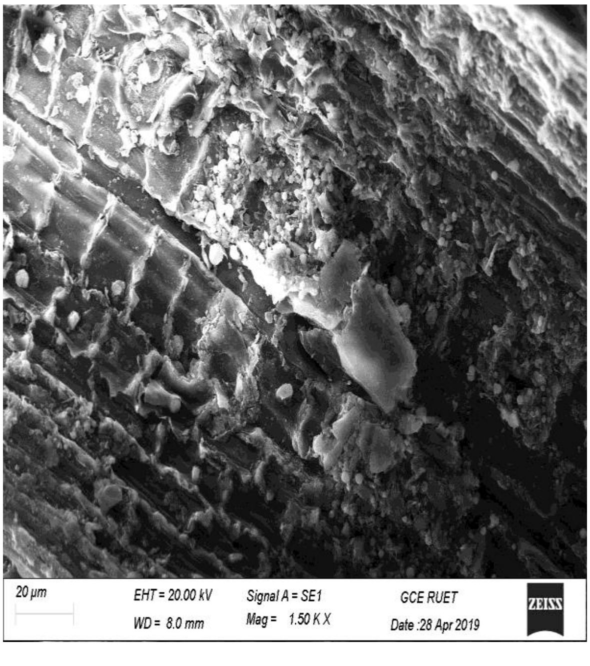


Figure 5: Non-porous surface of rice husk carbon

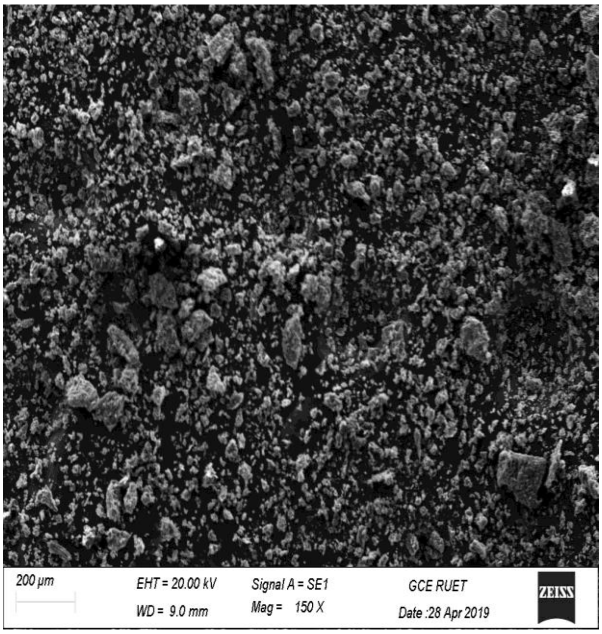


Figure 6: Non-fibrous texture of activated carbon

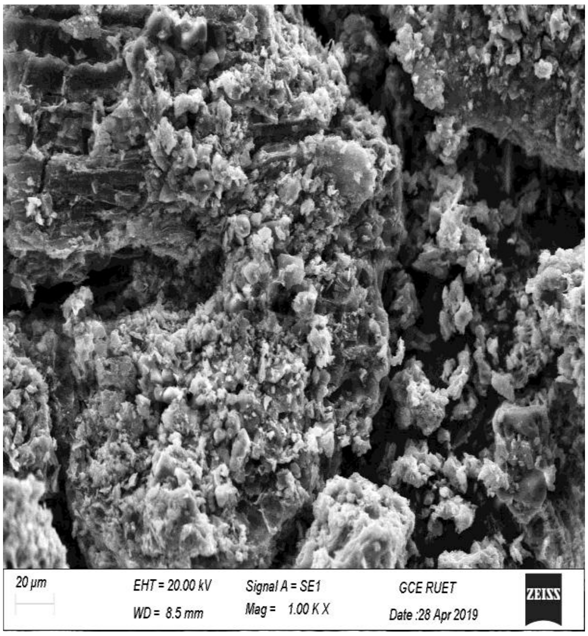


Figure 7: Porous surface of activated carbon

3.2 X-Ray Diffraction (XRD) Analysis

The X-ray diffraction method is suitable for characterization and identification. From XRD pattern, interlayer spacing, crystallite size, percent crystallinity etc. can be determined. This test was performed by BRUKER D8 ADVANCE XRD Machine. The XRD pattern of rice husk carbon and activated carbon is given below in Figure 8 and 9.

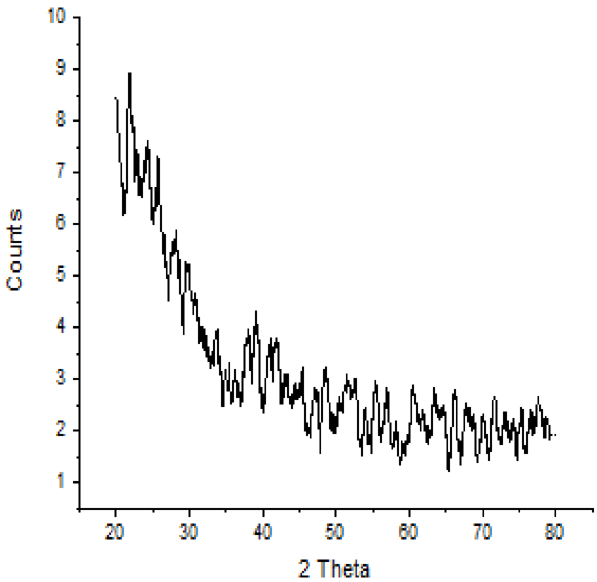


Figure 8: XRD pattern of rice husk carbon

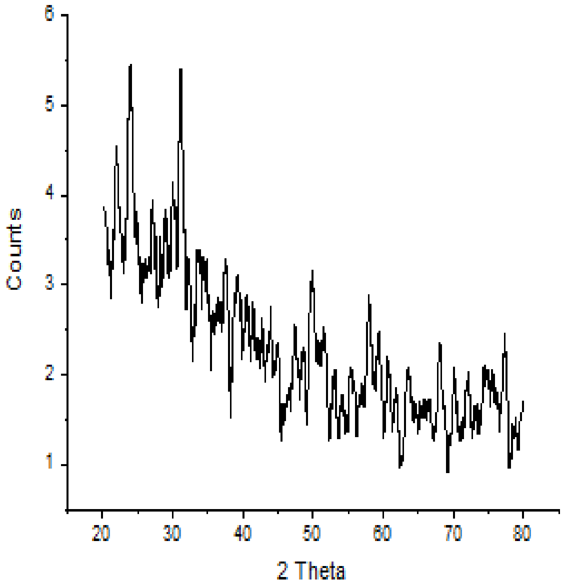


Figure 9: XRD pattern of activated carbon

Figure 8 and 9 represents the XRD pattern of rice husk carbon and activated carbon which was activated with potassium hydroxide (KOH) at a fixed activation temperature. Generally, for all XRD pattern the intensity at lowest Bragg angle is higher than the intensity at highest Bragg angle. It occurs because of structure factor. With increasing Bragg angle the interlayer spacing (d value) becomes smaller. Both the XRD patterns of rice husk carbon and activated carbon represent the amorphous nature of carbon. They represent a structure of disordered carbon materials. Their components (atoms, molecules or ions) are poorly stacked up without any regular, periodic manner. From these XRD patterns crystallite size, interlayer spacing, approximate percent crystallinity can be determined by analysis.

3.2.1 Determination of Crystallite Size from XRD Pattern

Crystallize sizes can be determined from XRD pattern by using Scherrer equation. From Scherrer equation,

$$L = (K\lambda)/(\beta \cos\theta) \tag{2}$$

Here, L= crystallite size (nm), K= Shape factor (0.9), λ= wavelength of X-Ray (0.154 nm), β= Full Width at half maximum (FWHM) (radian), θ= Bragg angle (degree).

Table 1 and 2 shows the crystallite sizes of rice husk carbon and activated carbon at various Bragg angle and finally the average crystallite size was determined. The crystallites are quite small for both samples. Usually smaller crystallites have greater ratios of surface area to volume. Smaller crystallites also improve the formability of a material. The average crystallite size of activated carbon (9.12 nm) is greater than that of the rice husk carbon (4.995 nm). The difference of this average crystallite size is not much as it was calculated in nano-meter. Again, from the SEM images, the surface morphology of activated carbon is highly porous while the rice husk carbon is non porous. So, the efficiency of activated carbon as adsorbent must be higher than that of the rice husk carbon.

Table 1: Crystallite size of rice husk carbon

Bragg angle θ (degree)	**Shape factor K**	**Wavelength λ (nm)**	**FWHM β (radian)**	**Crystallite size, L (nm)**
(23.90/2) =11.95	0.9	0.154	0.17	0.83
(24.46/2) =12.23	0.9	0.154	0.14	1.01
(40.28/2) =20.14	0.9	0.154	0.30	0.49
(46.21/2) =23.11	0.9	0.154	0.02	7.53
(62.73/2) =31.37	0.9	0.154	0.07	2.32
(77.64/2) =38.82	0.9	0.154	0.01	17.79

So, the average crystallite size of rice husk carbon = 4.995 nm.

Table 2: Crystallite size of activated carbon

Bragg angle θ (degree)	**Shape factor K**	**Wavelength λ (nm)**	**FWHM β (radian)**	**Crystallite size, L (nm)**
11.08	0.9	0.154	0.54	0.26
11.96	0.9	0.154	0.01	14.17
15.57	0.9	0.154	0.01	14.39
20.43	0.9	0.154	0.08	1.85
25.12	0.9	0.154	0.04	3.83
29.21	0.9	0.154	0.04	3.97
34.05	0.9	0.154	0.01	16.73
38.66	0.9	0.154	0.21	17.75

So, the average crystallite size of activated carbon = 9.12 nm.

3.2.1 Determination of Interlayer Spacing from XRD Pattern

Interlayer spacing is generally defined as an inter atomic spacing value. It can be determined from XRD pattern by using Bragg's law. From Braggs's law,

$$d = \lambda / 2\sin\theta \tag{3}$$

Here, d= interlayer spacing (nm), θ = incident angle (degree), λ= wave length of X-Ray (0.154 nm)

Table 3 and 4 shows the interlayer spacing of rice husk carbon and activated carbon at various Bragg angle and then the average interlayer spacing was determined. From Table 3 and 4 it is clear that, with increasing Bragg angle the interlayer spacing is decreasing. This gradual decrease of interlayer spacing occurs so that the variation of the electron density perpendicular to the diffracted plane becomes smaller as it is an important factor for the intensity formation.

Table 3: Interlayer spacing of rice husk carbon

Incident angle at peak position (degree)	**Wave length λ (nm)**	**Interlayer spacing d (nm)**
23.90	0.154	0.19
24.46	0.154	0.19
40.28	0.154	0.12
46.21	0.154	0.11
62.73	0.154	0.09
77.64	0.154	0.08

Average d= 0.13 nm

Table 4: Interlayer spacing of activated carbon

Incident angle at peak position (degree)	**Wave length λ (nm)**	**Interlayer spacing d (nm)**
22.16	0.154	0.20
23.92	0.154	0.19
31.14	0.154	0.15
40.86	0.154	0.12
50.23	0.154	0.10
58.41	0.154	0.09
68.09	0.154	0.08
77.32	0.154	0.08

Average d= 0.13 nm

3.2.2 Determination of Percent Crystallinity (Approximate)

Crystallinity is the degree of structural order in a material. An approximate calculation was done to find out the crystalline percentage from the XRD patterns by analysis. Following equation can be used to calculate the approximate crystalline percentage,

*% Crystallinity= {(Area of crystalline peaks) / (Area of all peaks)} * 100* (4)

Approximate percent crystallinity for rice husk carbon was found out 18.9% and the rest 81.1% was amorphous and for activated carbon crystallinity was 21.63% and the rest 78.37% was amorphous. So, both rice husk carbon and activated carbon exhibit mainly amorphous nature. The atoms or molecules in these carbon materials are in an irregular and unorganized state. They are disorderly stacked up due to lacking of structural characteristics. Generally, any carbon material produced from agricultural waste exhibits amorphous nature.

4. CONCLUSION

The porous surface topography of activated carbon was identified by SEM images. This porous structure clearly indicates the good adsorption capacity of activated carbon that was produced in this study. The surface morphology between rice husk carbon and activated rice husk carbon was also differentiated by the SEM images. The nature of both rice husk carbon and activated carbon was found out amorphous from XRD patterns. The crystallites of both the sample were small that represents greater ratio of surface area. This greater surface area can be used more efficiently in case of activated carbon for its porous structure.

REFERENCES

Ahmedna, M., Marshall, W., & Rao, R. (2000). Surface properties of granular activated carbons from agricultural by-products and their effects on raw sugar decolorization. *Bioresource technology, 71*(2), 103-112.

Baccar, R., Bouzid, J., Feki, M., & Montiel, A. (2009). Preparation of activated carbon from Tunisian olive-waste cakes and its application for adsorption of heavy metal ions. *Journal of Hazardous Materials, 162*(2-3), 1522-1529.

Girgis, B. S., & Ishak, M. F. (1999). Activated carbon from cotton stalks by impregnation with phosphoric acid. *Materials Letters, 39*(2), 107-114.

Gratuito, M. K. B., Panyathanmaporn, T., Chumnanklang, R.-A., Sirinuntawittaya, N., & Dutta, A. (2008). Production of activated carbon from coconut shell: Optimization using response surface methodology. *Bioresource technology, 99*(11), 4887-4895.

Guo, Y., Yang, S., Yu, K., Zhao, J., Wang, Z., & Xu, H. (2002). The preparation and mechanism studies of rice husk based porous carbon. *Materials chemistry and physics, 74*(3), 320-323.

Mohanty, K., Naidu, J. T., Meikap, B., & Biswas, M. (2006). Removal of crystal violet from wastewater by activated carbons prepared from rice husk. *Industrial & engineering chemistry research, 45*(14), 5165-5171.

Muniandy, L., Adam, F., Mohamed, A. R., & Ng, E.-P. (2014). The synthesis and characterization of high purity mixed microporous/mesoporous activated carbon from rice husk using chemical activation with NaOH and KOH. *Microporous and Mesoporous Materials, 197*, 316-323.

Poinern, G. E. J., Senanayake, G., Shah, N., Thi-Le, X. N., Parkinson, G. M., & Fawcett, D. (2011). Adsorption of the aurocyanide, $Au(CN)_2$-complex on granular activated carbons derived from macadamia nut shells–A preliminary study. *Minerals Engineering, 24*(15), 1694-1702.

Srinivasakannan, C., & Bakar, M. Z. A. (2004). Production of activated carbon from rubber wood sawdust. *Biomass and bioenergy, 27*(1), 89-96.

Sudaryanto, Y., Hartono, S., Irawaty, W., Hindarso, H., & Ismadji, S. (2006). High surface area activated carbon prepared from cassava peel by chemical activation. *Bioresource technology, 97*(5), 734-739.

Suzuki, R., Andrade, A., Sousa, J., & Rollemberg, M. (2007). Preparation and characterization of activated carbon from rice bran. *Bioresource technology, 98*(10), 1985-1991.

OPPORTUNITIES AND CHALLENGES OF MANAGED AQUIFER RECHARGE (MAR) AT DROUGHT PRONE WATER STRESSED BARIND AREA, BANGLADESH

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ABSTRACT

The study aims to focus on the opportunities and challenges of Managed Aquifer Recharge (MAR) at the drought prone water stressed Barind area, north-west region of Bangladesh. Almost three crops are produced round the year as the area is mostly flood free. The lower amount of rainfall than country-wide average as well as less percolation capacity of thick top clay layer lies above the potential aquifer at higher depth put constraint for groundwater resource development. On the other hand due to low or no flow of water in the river and gradual extraction of groundwater for irrigation causes the declination of groundwater table which demands Managed Aquifer Recharge (MAR) for the area. The MAR technique, previously known as 'artificial recharge' - a water banking system is a viable adaptation menu for subsequent recovery, future use and environmental benefits. Major opportunities are about 2000 km re-excavated *Kharies* (canals) containing about 750 nos. check dam, more than 3000 re-excavated ponds, number of *Beels* (comparatively large marshes) and other water bodies which are used to conserve runoff storm water for supplementary irrigation for about 5-7 months. The conserved water can be used for the groundwater recharge alongside irrigation. Furthermore, roof-top rain water of the office and other buildings can also be used for groundwater recharge purposes. On the other hand, major challenges obtained through the study are the highly turbid runoff storm water, sedimentation of thick clay over the bed of the canal that restricts the natural percolation, failure of conventional direct surface methods of recharge due to the presence of more than 50 ft thick top clay layer from the ground surface which has low or no percolation capacity, lack of practical knowledge on artificial groundwater recharge (MAR) for the study area, clogging of conventional MAR technique due to deposition of silty clay on the top of recharge unit. Therefore, engineering and modified MAR structures are necessary to reverse the declining trend of groundwater level as well as to restore the groundwater resources for sustainable use.

Keywords: *Managed aquifer recharge, Recharge well, Groundwater, Challenges of MAR, Opportunities in Barind area*

1. INTRODUCTION

Water is one of the most important resources on earth but its distribution on the Earth's surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground, and less than 1% is located in lakes, rivers, and swamps. Furthermore, only one percent of the water on the Earth's surface is usable by humans, and 99% of the usable quantity is situated underground (Bralower and Bice, 2012). Water scarcity is the lack of fresh water resources to meet water demand that affects every continent and was listed in 2019 by the World Economic Forum as one of the largest global risks in terms of potential impact over the next decade (WEF, 2019). One-third of the global population (2 billion people) live under conditions of severe water scarcity at least 1 month of the year. Half a billion people in the world face severe water scarcity all year round. Half of the world's largest cities experience water scarcity (WEF, 2020).

Barind tract is the most drought prone water scarce area in Bangladesh. It is a physiographic unit located in the north-western part of Bangladesh having gross area of 7,727 sq km (Rasheed, 2008). Geographically this unit lies between 24˚20'N and 25˚35'N latitudes and 88˚20'E and 89˚30'E longitudes. Barind Tract made up of Pleistocene Alluvium is also known as Older Alluvium and floored by reddish, brown, sticky Pleistocene sediment, Madhupur Clay (Ahmed, 2006). The hard red soil, typical dry climate with comparatively high temperature and less rainfall of these areas are very significant in comparison to that of the other parts of the country (BMDA, 2018). Temperature varies from 8 degrees Celsius to 44 degrees Celsius (Ahmeduzzaman, et al., 2012). Averages annual rainfall ranges from minimum 1250 mm to maximum 2000 mm and almost 80% of the rainfall occurs during June to October (IWM, 2012). Storm water is the only source of groundwater recharge as the area is flood free (IWM, 2012; Rahman, 2012). But the storm water cannot percolate easily due to top clay layer more than 15 m thick and low infiltration capacity (2-3 mm/day) (Jahan, 2010a) cause reduction of the natural recharging of groundwater (Jahan, 2015).

Due to scarcity of surface water and less rainfall, cultivation as well as irrigation of the area has become dependent on groundwater (GW). GW irrigation was started in 1985 through Barind Integrated Area Development Project (BIADP) under Bangladesh Agricultural Development Corporation (BADC). More than 15000 Deep Tube wells (DTW) have been installed in the north-west region by BMDA, BADC and private initiatives. The DTWs and Shallow Tube Wells (STW) are always engaged to withdraw groundwater for irrigation excessively and due to the over exploitation groundwater table (GWT) is going down day by day (CGWB, 2000; Bhattacharya, 2010). Due to excessive withdrawal of groundwater for irrigation, less rainfall, high temperature, low natural recharge and low flow in the major rivers in the dry season, ground water level has been falling all over the region (Imon and Ahmed, 2013). Rahman and Mahbub (2012) also observed the depletion of groundwater level in the Tanore Upazilla of the srudy area.

Continuous depletion of GWT may pose serious impact on the environment. To reverse the declining trend of GWT and to increase groundwater storage Managed Aquifer Recharge (MAR) is essential for the study area. Therefore, the aim of this study is to identify the challenges and opportunities for the augmentation of groundwater by managed aquifer recharge technique.

2. METHODOLOGY

2.1 Study area

The study area lies at godagari, tanore, nachole and niamatpur upazila under rajshahi, chapai nawabgonj and naogaon districts of barind area respectively which is shown as figure 1.

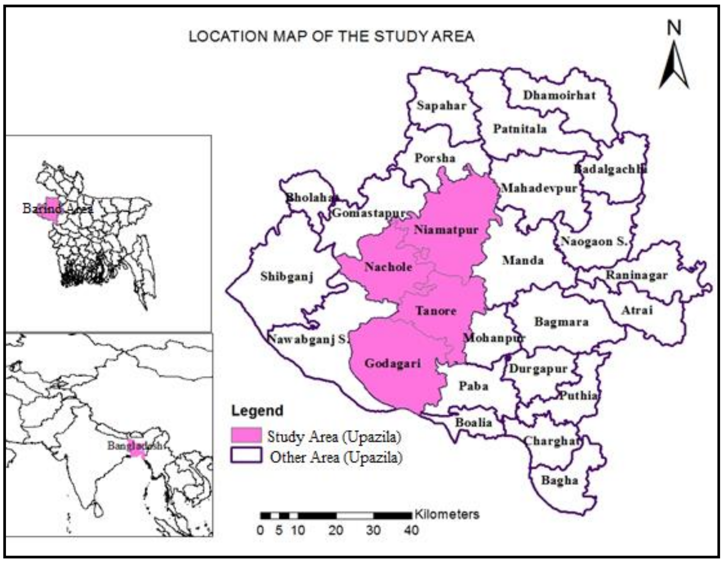

Figure 1: Location map of the study area

2.2 Data collection

To assess the challenges of MAR techniques, Rainfall and Groundwater level data, lithological information have been collected from the BMDA. Information about surface water quality, sedimentation on the canal bed as well as the clogging of top layer of the MAR unit by the silty clay has also been observed. All the data and information are checked for quality and consistency and then processed in the required format. On the other hand, to find out the opportunities of MAR technique, the information about re-excavated Khal/Kharies (canal), constructed cross dam (check dam) in the re-excavated Kharies, re-excavated ponds, Beels (comparatively large water body) and other water bodies has been collected from the zonal office of Barind Multipurpose Development Authority (BMDA). Information about office buildings has also been collected for roof top rain water harvesting and groundwater recharge.

3. FINDINGS AND DISCUSSIONS

The challenges and opportunities for the augmentation of groundwater through managed aquifer recharge stechnique in study area under Barind tract were identified based on field investigation and secondary data collected from different sources. The findings are presented with discussion in the following sections.

3.1 Challenges

The challenges those were identified in the study area are less rainfall, thick top clay layer, depletion of groundwater level, highly turbid storm water, sedimentation on cannel bed, clogging of conventional groundwater recharge well, less flow of river water and lack of practical knowledge. These challenges are elaborately discussed in the nest sections.

3.1.1 Less rainfall

Though rainfall is the main source of groundwater recharge but less and uneven distribution of rainfall is one of the main challenges of the study area for adoption of MAR techniques. The Table 1 shows that the 16 years average rainfall of the study area is 1340.56 mm which is much less than the annual average of the country (2500 mm) rainfall.

Table 1: Annual average rainfall of the Study area

Year	Annual average rainfall (mm)			
	Godagari upazila	Tanore upazila	Niamatpur upazila	Nachole upazila
2002	914.00	1756.57	928.00	1932.00
2003	869.00	1400.00	1014.00	1591.75
2004	2451.90	1632.00	904.25	1187.00
2005	1110.40	1607.00	1259.00	1141.00
2006	1290.12	1889.01	1087.81	1616.00
2007	1390.44	1790.00	1591.00	2029.00
2008	1401.10	2241.00	2295.00	1195.10
2009	932.00	1048.00	1310.00	1228.00
2010	1208.00	917.50	1262.00	987.00
2011	1440.00	1311.50	1537.00	1496.00
2012	904.00	1106.50	906.00	742.00
2013	885.00	1087.00	886.00	943.00
2014	848.00	1321.50	1631.00	1224.00
2015	1715.50	1405.00	1565.00	1740.00
2016	1025.00	1231.00	1884.00	1065.00
2017	1155.00	1248.00	1756.00	1332.00
Upazila ave.	1221.22	1436.97	1363.50	1340.55
Study area ave.	1340.56			

From Table 1 it is clear that this small amount of rain water is almost evenly occured over the different upazilas of the study area. It is obvious that a part of this small available rain water will be lost by evaporation during runoff and also from depressed land where it might accumulate if it is not possible to utilize properly. Therefore, appropriate technology is required for the proper management to attain the maximum benefit from it.

3.1.2 Thick top clay layer

For the collection of lithological characteristics of the study area sub-soil investigation in four upazilas under study area was carried out. The lithological information of four upazilas are presented as borelog in Figure 2.

The sub-soil investigation in the study area was performed up to the depth varying from 56 m to 75 m basically for the collection of lithological characteristics of the study area. The lithological bore logs show that the top layer of each location is composed of clay and it is varying from 20 m to 30 m. The highest clay layer of 30 m was found in Godagari upazila under Rajshahi district folowed by 24 m in Nachole upazila under Chapai Nawabgonj district, 21 m in Niamatpur upazila under Naogaon district and 20 m in Tanore upazila under Rajshahi district. This top thick clay layer restricts the percolation of water as well as natural recharge of groundwater. So, surface systems of mar technique would not be suitable and modification of recharge system should be adopted for groundwater recharge in the study area.

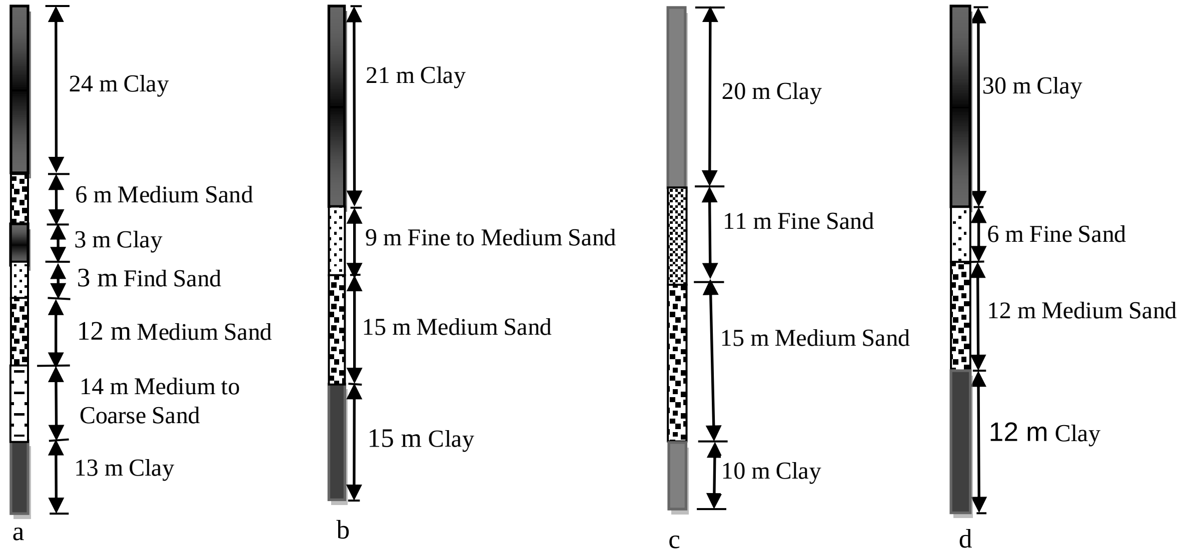

Figure 2: Bore log lithology- (a) plot no.-437, mouza-Muradpur-2, j.l. No- 148, upazila- Nachole, district- Chapai Nawabgonj; (b) plot no.-768, mouza- Nimdighi, j.l. No.- 151, upazila- Niamatpur, district-Naogaon; (c) plot no.-261, mouza-Aira- 2, j.l. No- 67, upazila- Tanore, district- Rajshahi; (d) plot no.-113, mouza- Amtoli, j.l. No- 195, upazila- Godagari, district- Rajshahi.

3.1.3 Depletion of groundwater level (GWL)

Groundwater level (GWL) of the study area is getting depleted day by day. So it is another challenge for the study area. Groundwater level records of 1st and 2nd half of January, April, July and October for the period from 1995 to 2018 are plotted on the curve for four upazilas within the study area are presented in Figure 3 to 6. Gradual declination of GWL is observed in all the upazilas of the study area.

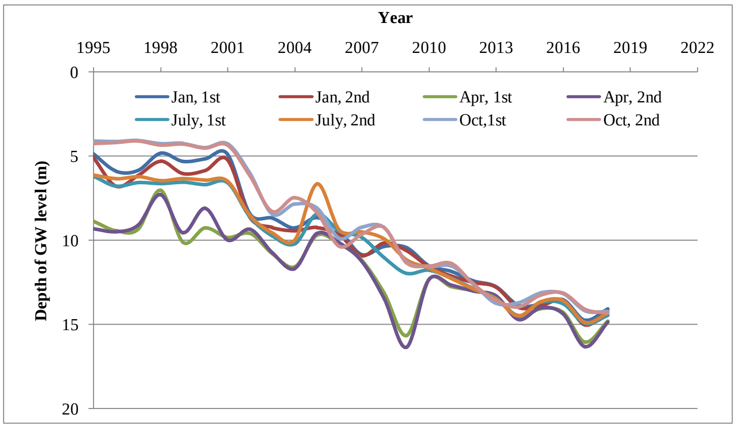

Figure 3: GWL Hydrograph at Haripur, Tanore upazila

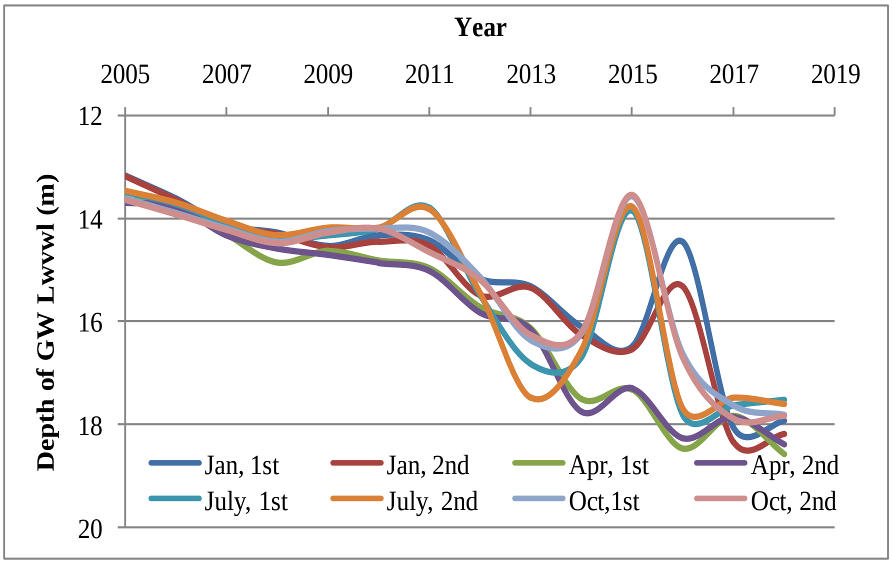

Figure 4: GWL Hydrograph at Darajpur, Niamatpur upazila

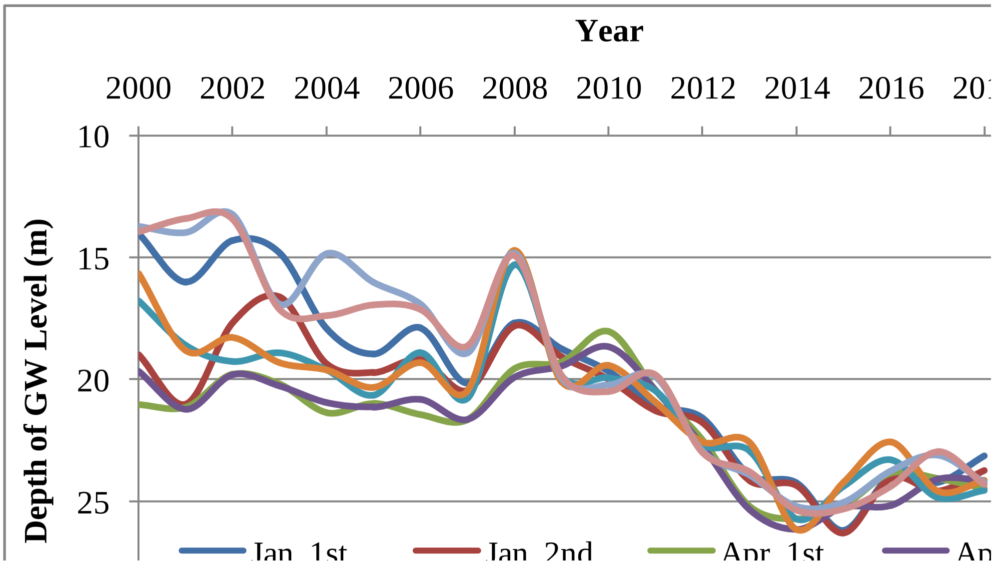

Figure 5: GWL Hydrograph at Amtoli-1, Godagari upazila

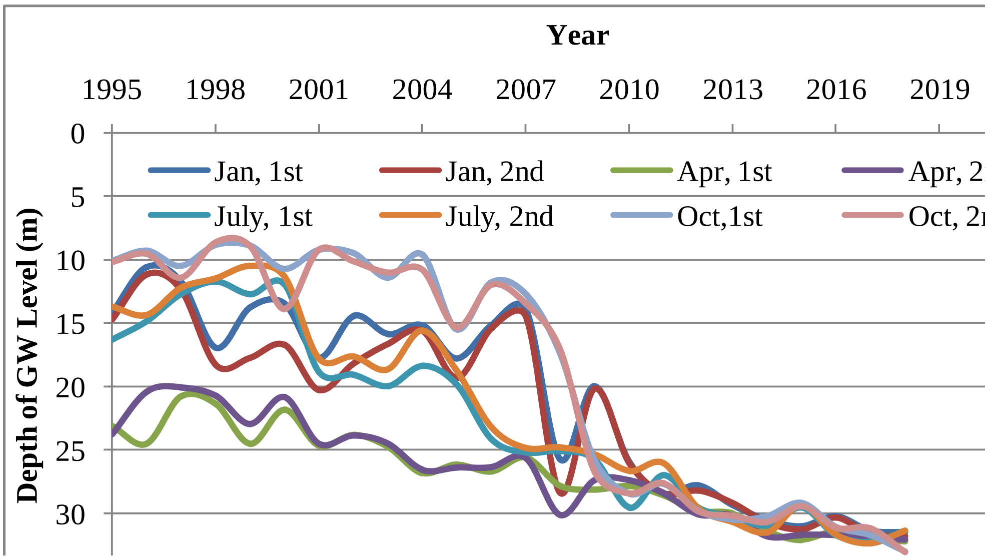

Figure 6: GWL Hydrograph at Ratipur, Nachole upazila

GWT generally goes down to the maximum depth in the month of April and goes up (gets back) to the minimum depth in the month of October. The highest depletion of groundwater varying among the upazilas from 17 m to 32 m from the ground surface. But gradual declination of groundwater level is found from the figures. To reverse the declining trend of GWL, appropriate MAR technique needs to be applied.

3.1.4 Sedimentation on the canal bed and clogging of RW

Conventional recharge well was constructed on the bed of canal for recharging groundwater during the monsoon. During the monsoon rainwater accumulated in the existing canal by surface runoff flows through. Runoff water storage facility was already built by constructing cross dam across the canal. It was thought that it could be the potential sources for recharging groundwater during the monsoon through conventional recharge well. However, it was found that sedimentation of clay materials from the turbid water on the bed of the canal as well as on the top surface of recharge well was observed. As a result, natural recharge of GW gets stopped totally and recharge rate of conventional MAR technique installed at the canal bed gradually decreases and clogging of top layer of recharge unit was occurred (Hossain, 2019). M.I. Hossain et al. (2019) mentioned that 40 mm to 80 mm thick muddy silt layer formed on the top surface of recharge unit and canal bed when canal was completely dried up. So, to overcome this challenge modified MAR technique along with filtration unit is needed for continuous and sustainable function. Figure 7 shows the clogging of conventional recharge technique and sedimentation of canal bed.

Figure 7: Clogged RW along with silted Canal bed at Godagari

3.1.5 Highly turbid runoff storm water

The canal water (surface water) of the study area was tested in different times in the laboratory of BMDA. The tested results are shown in Table 2.

Table 2: Turbidity value for the tested sample of surface water (*Khari* water)

Name of *Khari* (Canal)	Date of Testing	Turbidity (NTU)	Comments
Sharmangla, Godagari	02.04.14	400	As per the environmental conservation rule (ECR, 1997), the allowable limit for the turbidity of drinking water is 10 NTU.
	15.07.15	79	
	13.07.16	57	
	17.05.17	30	
	25.06.18	80	
Rasulpur, Niamatpur	15.07.13	68	As per drinking water standard (ECR, 1997), turbidity value will be within 10 NTU
	30.06.14	48	
	15.07.16	30	
	20.07.17	20	
	25.06.18	20	
	03.09.18	80	

The storm runoff water of the canal is highly turbid. The turbidity of Sharmangla canal varies from 30 to 400 NTU while turbidity varies in Rasulpur canal from 20 to 80 NTU that are extremely higher than that of the acceptable limit of 10 NTU. Turbidity of water is the main cause of clogging the recharge unit. For sustainable recharge of groundwater suitable filtration unit needs to be developed with RW.

3.1.6 Low flow of water in rivers

Low water flow in rivers is another challenge of the study area. In dry season water level in the rivers of the study area goes down to the bed causes very low or no flow. Due to the low water stage than GWL of the nearby aquifer causes movement of groundwater from the aquifer to the river making declination of GWL with steep sloppy toward river. Average yearly water loss from Barind across the Ganges is 13.45 Mm^3/year and from Barind across the Indian border is 7.24 Mm^3/year (IWM, 2006). So, for successful application of MAR technique, required depth of water in the river needs to be maintained.

3.1.7 Lack of practical knowledge

To get a satisfactory result on any initiative, it is necessary to have both theoretical and practical knowledge. Though MAR is not a new technology in the world but very few works have been performed in Bangladesh limiting to use of rooftop rain water only. Besides, lack of knowledgeable and experienced persons on this issue is also a problem. So to make the MAR technique a success especially in case of using runoff storm water as well as surface water, collective effort of experts, experiments in both in fields and laboratories are needed. Special training and practical visit of such type of works performed in other countries are essential.

3.2 Potential Opportunities

3.2.1 Re-excavated Kharies with cross dam (check dam)

Derelict Kharies (canals) are generally re-excavated by BMDA to increase their water conserving capacity. Cross dams are constructed in the re-excavated Kharies at different positions maintaining the certain gradient to retain the storm water. These re-excavated Kharies are used to conserve runoff storm water mainly for supplementary irrigation. In the study area there are 514 km of re-excavated Khari and 285 nos. of cross dam. And about 2000 km re-excavated Khari with 749 nos cross dam are there in the entire Barind area (BMDA, 2018). A remarkable portion of conserved water at the upstream of the cross dam can be used for groundwater recharge purpose by applying proper MAR technique. Re-excavated Kharis with RCC cross dam and rubber dam are shown in Figure 8.

Figure 8: The re-excavated (a) Sarmaongla Khari with a cross dam under Godagari upazila and (b) a rubber dam at the Barnoi river under Puthia upazila of Rajshahi district

3.2.2 Re-excavated Ponds

About 1248 nos of ponds have been re-excavated in the study area, while 3098 nos re-excavated ponds (BMDA, 2018) are there in the whole barind area. A significant portion of the conserved water in those ponds can be used for groundwater recharge with proper MAR structure alongside supplementary irrigation. The Figure 9 shows two re-excavated pond at Niamatpur upazila and Porsha upazila.

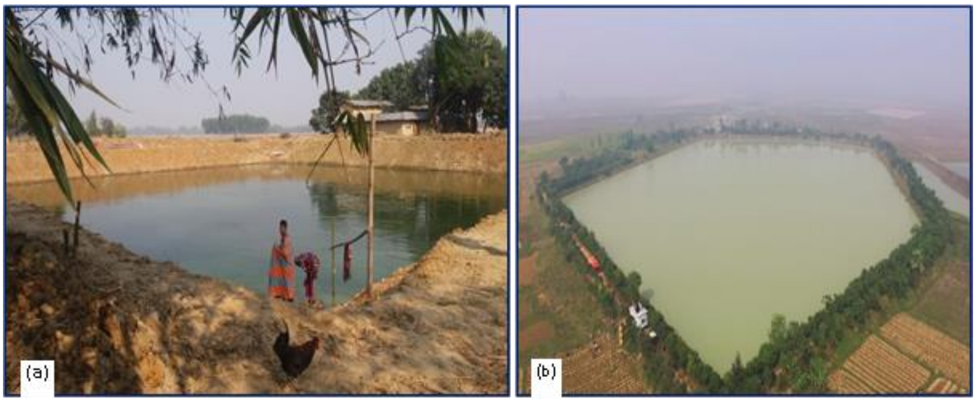

Figure 9: Re-excavated ponds- (a) Konnyapara (Re-excavated area 1.09 acre), Niamatpur, (b) Kushumkunda (Re-excavated area 17 acre), Porsha

3.2.3 Natural Beel

There are a significant number of Beels (comparatively large water body) in Barind area of which 5 nos. are in the study area. The names of those Beels in the study area are Beel Choroi, Durlar Beel (Godagatri upzila), Beel Kumari (Tanore upazila), Beel Kasba (Nachole upazila) and Chatra Beel (Niamatpur Upazila). Beels are generally located at the lower elevation where runoff storm water comes from the surroundings and storm water accumulated there. The Beels can be re-excavated to conserve more water and use for groundwater recharge using MAR technology. Figure 10 shows a natural Beel at Tanore upazila.

Figure 10: Beel Kumari beel at Tanore upazila under Rajshahi district

3.2.4 Roofs of the Office Buildings and Training Shed

At every upazila, BMDA and other Departments as well as organizations have their office buildings and training sheds/buildings within a well planned compound. Roof of these building in a close compound can be used as potential catchment for collecting the storm water. Rain water received by these buildings/sheds during rainfall can be accumulated through a common network and used for groundwater recharge through MAR technique like Recharge Well (RW) along with proper filtration unit.

4. CONCLUSIONS

Desert like drought prone barind area with less rainfall and thick top clay layer demands MAR techniques to recover the groundwater level as well as to restore groundwater as a water bank for the use in crucial period. Though there are significant number of opportunities like re-excavated canal with cross dam and rubber dam, ponds, Beels and roof top catchment to harvest rain water and groundwater recharge but lots of challenges like less rainfall, thick top clay materials, depletion of GWL, water turbidity and clogging are also the barriers to implement the MAR technique successfully. Also proper depth of water in the surrounding rivers including Ganges, Mohanonda, Atrai needs to be maintained for effective application of MAR technologies. Practical knowledge and collective efforts and pilot study program are also needed for reviving the Barind area making groundwater available with proper designed and modified MAR techniques.

REFERENCES

Ahmed, K.M. (2006). "Barind Tract". Banglapedia, National Encyclopedia of Bangladesh. Retrieved from :http://www.banglapedia.org/httpdocs/HT/G_0209.HTM

Ahmeduzzaman, M., Kar, S. and Asad, A. (2012). "A study on ground water fluctuation at BarindArea, Rajshahi". Engineering Research and Applications (IJERA), 2(6), pp 1465-1470.

Bhattacharya, A.K. (2010). "Artificial groundwater recharge with a special reference to India". International Journal of Research and Reviews in Applied Sciences,4, 2.

BMDA (2018). "Development Activities". Monthly Report FY 2017-2018. Barind Multipurpose Development Authority (BMDA), Rajshahi, Bangladesh.

Bralower, D.T and Bice,D. (2012). "Distribution of Water on the Earth's Surface".. E-education, Policy Support Unit, NASA. https://www.e-education.psu.edu/earth103/node/701

CGWB , (2000). Guide on Artificial Recharge to Groundwater. Central Ground Water Board India, Ministry of Water Resources, New Delhi, India (cgwb.gov.in/documents/ArtificialRecharge-Guide.pdf).

Imon, A.H.M.R. and Ahmed, M. (2013). "Water Level Trend in Barind Area". Malaysian Journal of Mathematical Sciences, 7(1), pp (1-15).

IWM, (2012). "Groundwater Resources Study and Decision Support System Development of Rajshahi, Naogaon, Chapai Nawabganj, Pabna and Natore Districts and Also Remaining District of Rajshahi Division through Mathematical Model Study for Barind Integrated Area Development Project", Phase-III, Final Report, Vol. 1

Jahan, C.S., Mazumder, Q.H., Adham, M.I., Hossain, M.M.A. and Haque Al-M. (2010). "Study on Groundwater Recharge Potentiality of Barind Tract, Rajshahi District, Bangladesh Using GIS and Remote Sensing Technique". Journal of Geological Society of India, 75,432-438.

Jahan, C.S., Rahman, A.T.M.S., Mazumder, Q.H. and Kamruzzaman, M. (2015). "Adaptation for Climate Change Effect on Groundwater Resource through MAR Technique in Drought Prone Barind Area, Rural Bangladesh". In S.M. Ali (Ed.), Bangladesh: Combating Land Degradation and Drought. Dhaka: Series-II, Department of Environment (DoE), Ministry of Environment (MoEF), GoB, 61-83, ISBN 978-984-33-9991-5.

Rahman, M. and Mahbub, A. Q. M. (2012). Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Tanore Upazila, Journal of Water Resource and Protection (http://www.SciRP.org/journal/jwarp).

Rahman, M. and Mahbub, A.Q.M. (2012). "Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Tanore Upazila". Journal of Water Resource and Protection, 4, 575-567. https://doi.org/10.4236/jwarp.2012.48066

Rasheed, K.B.S. (2008). "Bangladesh: Resource and Environmental Profile". A. H. Development Publishing House, Dhaka.

WEF (2019). "Global risks report 2019". World Economic Forum. Retrived from: https://www.weforum.org/reports/the-global-risks-report-2019)

WEF (2020). "Global Risks Report 2020". World Economic Forum. Retrived from: https://www.weforum.org/agenda/2017/03/building-freshwater-resilience-to-anticipate-and-address-water-c rises/

DETECTION OF WATER SALINITY AND SHORTEST PATH FOR WATER SUPPLY SYSTEM IN KHULNA CITY CORPORATION (KCC) AREA: A GIS BASED APPROACH

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ABSTRACT

It is known to all that water plays a vital role in maintaining natural eco-system. In case of Khulna region, salinity is said to be a major problem and rate of salinity in water bodies is more than other region as Khulna is a southern region of our country and saline contaminated water is a threaten for human health and survival. The main objective of the study is to investigate the physical condition of blue environmental portion throughout the Khulna City Corporation (KCC). Then it aims to detect the saline condition of the water bodies and introduce the new installation of water supply system in KCC area.

Several field surveys were conducted emphasizing on waterbodies condition and salinity for this research and also collecting primary and secondary data for generating accurate result. Collected field survey data and secondary data are recorded in digital form using ArcGIS to bring out necessary analysis. The collected data are prepared as shape files for GIS analysis. Using network analyst, first the served and unserved area of KCC is defined. Then again the unserved area is merged with the salinity raster data of KCC to identify the salinity level of an unserved area of KCC. Then in the highly saline area, a shortest path is defined using the origin, destination tools in Network analyst for water supply of low saline area.

The research highlights three core delineated areas such as high salinity area, moderate saline area and low saline area, depending on the salinity quantity of the wardwise water bodies and also ranged the saline quantity for getting results about which kind of area remain in the high saline area and which in low or moderate and also get the unserved areas of water supply by network analysis.

The paper results in showing that in total, of 0.11% area have no saline while having an area of 18.99% and 25.85% area as low and moderately saline water respectively. More than half of the area (almost 55%) contains high saline water. The paper gives the message that the main reason of unserved areas is having low class people who cannot afford the cost of water facilities and other reason is these areas are located beside riverside or these areas are only used for pisiculture and fish cultivation activities. As a result, 25% areas don’t get any community water facilities because of the above mentioned reasons and no or low saline unserved area are feasible to establish water supply facilities for the dwellers. Among these, 25%, more than 17% of unserved area are highly saline affected. The quantity of water bodies and the salinity condition for each ward are explained by charts, tables and map in the research.

***Keywords**: Blue ecosystem service, Salinity, Water supply, Network analyst, Shortest path.*

1. INTRODUCTION

The term "natural environment" refers to the environment and the conditions in which all living and non-living things exist on Earth. (Khan, et al., 2011) The common concept of the natural environment encompasses two different components:

- Ecological units that operate as natural systems (such as soil, vegetation and so on).
- Universal natural resources (such as air and water). (Leda and Anna)

Environmental inventory "is a concise overview of the ecosystem since it occurs in a region contemplating a particular proposed action. The inventory is compiled from a checklist of descriptors for the physical – chemical, biological, cultural, and socioeconomic environments. (Li, Lei, et al., 2015) The "physical-chemical environment" includes such major areas as soils, geology, topography surface-water and groundwater resources, water quality, air quality, and climatology. The inventory of the environment serves as the basis for determining the potential environmental effects of a proposed action, both beneficial and adverse (EIS). (Safety, Khalilmoghadam & Nadian, 2019) Development of the inventory represents an initial step in the environmental impact assessment process. (Forsberg and Fedrik, 2002) The natural environment is in contrast with the 'built environment' which refers to areas that have been fundamentally transformed and influenced by human activity, such as cities, towns, infrastructure, and so on. The Environmental Profiles Technique is a systematic way of defining and evaluating the environmental impacts of construction materials over their life cycle-that is, their collection, storage, use and maintenance and eventual disposal. Many aspects of an ecosystem require us in understanding a specific geographic region such as soil quality, water condition, wastewater management, air condition, slums, and other resources. (Enrique Roman-Morey, 2010) We are given KCC to survey the environmental condition of the area for the project. Our area contains 31 wards of Khulna city. We survey whole wards of KCC for evaluating the environmental condition and pollution rate of the Khulna city. This project helps us to assess the present status of air, noise, water, land, ecology and socioeconomic components of the environment and to prepare an Environmental Management Plan (EMP) with pollution control technologies to be adopted for mitigation of adverse impacts and site-specific remedial measures. The water environment includes coastal zones, rivers, lakes, estuaries, ground water, soil, water and even the atmospheres part of the hydrological cycle. The urban water environment has deteriorated sharply given the acceleration of urbanization and increase of urban population (Postel, 2002; Pei et al., 2013). In addition, the urban water environment treatment is an important task for the government to build a harmonious society. However, the urban water environment treatment involves numerous public infrastructural items, such as sewage treatment, ecological restoration, and landscape green planting. Moreover, this treatment requires highly professional quality (Han, H., Wang, Z., & Li, H. (2019))

The main objective of the study is to make a detailed inventory of water bodies and supply installation and give a tentative recommendation for the future. Although it is not a big project still the study has some limitations. Such as identifying the ward boundary and lacking of many necessary data and instruments.

2. LITERATURE REVIEW

The environment involves naturally occurring living things as well as non-living things meaning not biological. The term is mostly used on the Earth or in certain parts of the Earth. (European Commission, 2006)

Profiling of Environment means assessing the impressions of a building material, product or system during its working life, not only during its manufacture, but also during its use in a building over an average lifespan. This contains their abstraction, processing, use and maintenance, as well as their necessary dumping. (Enrique Roman-Morey, 2010)

Lucknow, capital of Uttar Pradesh, between 260 52'. N latitude and 800 56' longitude, 120 m above sea level and having a population of 22, 45, 509 as per 2001 census and has an area of 310 sq. km density 7244. sq. km. with the fundamental growth of population, transportation modes, infrastructure construction actions are increasing day by day. The vehicular population of Lucknow is extensively increasing every year. Number of vehicles were 614794 during 2002-03 while the number stands for 2003-04 at 679326 showing a growth rate of 10.5%, which is comparatively higher in comparison to the present infrastructure of the city or carrying capacity of the road. Sound exposure is steadily increasing for this phenomenon, sometimes causing discomfort and sometimes pain, noise does not cause ears to bleed, and noise-induced hearing loss usually takes years to develop. The necessary investigation was carried out to assess the ambient day and night time noise levels of Lucknow city and to bring down the pollution level through public participation and to suggest mitigate measures. (Kisku, et al., 2006)

There's been a growing interest in environmental assessments of the built environment and today we can find a large range of tools for environmental assessment of the built environment, concentrating on energy use in buildings, sick building syndrome, indoor atmosphere, building materials containing harmful substances and/or other factors in fractured or integrated ways. Two types of methods are used for qualitative and quantitative assessments of the built environment. GBTool, BREAM, and LEED are examples of common and well-known quality tools. (Hassall and Zaveri, 1978) Qualitative methods are always based on creating auditing, assigning a score to each parameter being investigated, resulting in one or more total creation of scores, certain parameters being investigated are quantitative, such as energy usage, while others are based entirely on the criteria. (Foresberg and Von malmborg, 2004)

The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on the degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Bangladesh is a diuretic country by total area of 147,570 km. The major part (80%) of the country consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than the country’s average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year.

Salinity problem received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization are becoming too pronounced in recent years to be ignored. Increased pressure of growing population demands more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus, combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy (Haque, S. A. 2006)

3. METHODS AND MATERIALS

3.1 Study Area

Khulna City Corporation (Figure 1) is selected as the study area for this project, consisting of 31 wards. Khulna city is the area having about 40% agricultural land. Generally, the environment of the area is considered as moderately good. Only 2% area within ward no. 12 & partially 24 are highly suitable for water distribution facilities (Haque & Mustafa, 2018). At a glance the area profile be

Table 1 Study Area Profile

General Information	
Name	Khulna City Corporation
Area	54.65 square km
Geographical Location	Between $22^0 45'30''$ and $22^0 54'30''$ north latitude and between $89^0 29'$ and $89^0 35'30''$ east longitude.

Population	15,00,689	
Density	67,994 per square km	
No. of Holdings	66,257	
Wards	31	
Transportation Network	No. of Roads	1215
	Total length of road	356.64 km
	Bridges	No data available
No. of Bazar	21	
Super Market	04	
Surrounding rivers	Bhoirab river and Rupsha river	
Environment and Climate Information		
Climate	Humid during summer and pleasant during winter	
Temperature	Maximum	35.5^{0}c
	Minimum	12.5^{0}c
Average rainfall	1605 mm	
No. of park	6 (include 1 modernized)	
Solid waste Generation and disposal	450 metric tons averagely	

(Source: Khulna City Corporation 2019)

3.2 Environmental State of KCC

The existing scenario of the study area, Khulna City Corporation (KCC) is collected via survey and site inventory. With the collected data from survey study, required analysis is brought out related to the environment. Besides the survey data, some secondary data have also collected. For example, the data related to temperature, annual rainfall in CM (Centimeter), DEM data, Salinity data, structural uses, road etc.

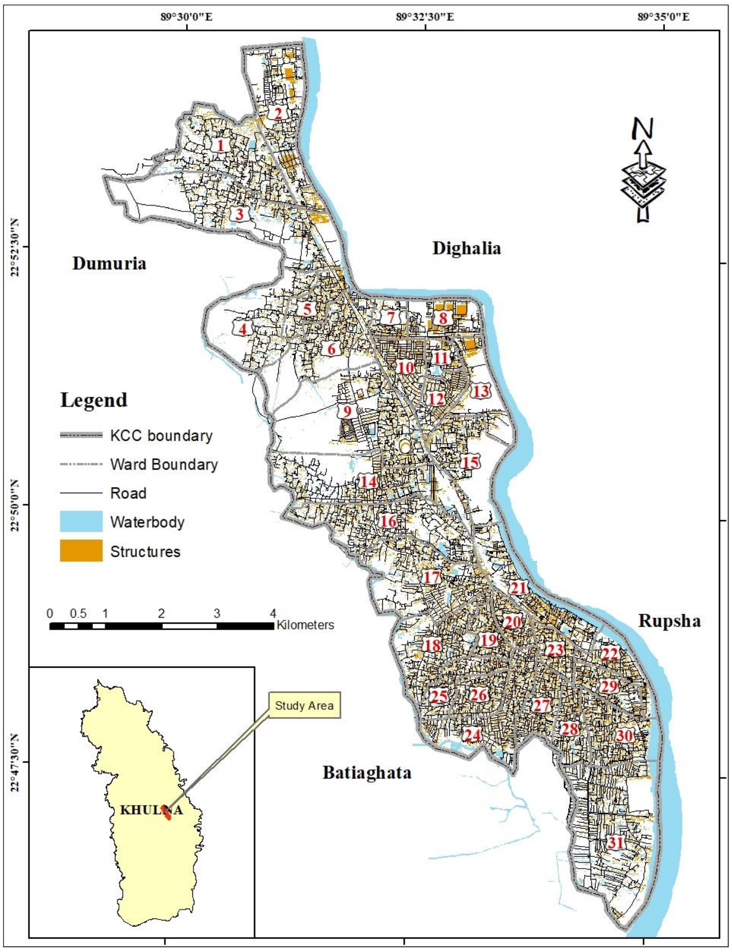

Figure 1 Khulna City Corporation (Study Area), *Source: Author 2019*

3.3 Data Collection

Required data for the analysis related to the environment of the study area are collected via social survey and site inventory. Some secondary data from different author are also collected related to the study. The data that are collected are as follows:

Table 2 Required Data

Sl No.	Data Name	Data Type	Data Source
1	Population	Secondary	KCC
2	GIS shape files	Secondary	Author
3	Site information	Primary	Field Survey

(Source: Author, 2019)

3.4 Data Preparation

Required shape files for GIS based spatial analysis are prepared. The shape files were created from the map that is provided by KCC authority. The shape files that are prepared or collected for this study are as follows:

Table 3 Data preparation for analysis

SL No	Data	Type	Co-ordinate system	Source
1	Roads	.shp	WGS 1984 46N	Author 2019
2	Structures	.shp	WGS 1984 46N	Author 2019
3	Waterbodies	.shp	WGS 1984 46N	Author 2019
4	KCC boundary & ward boundary	.shp	WGS 1984 46N	Author 2019
5	Salinity	.ppt	WGS 1984 46N	Author 2019
6	DEM (Digital Elevation Model)	.shp	WGS 1984 46N	KCC

3.5 Data Analysis and Interpretation

With the collected data, various analyses related to the environment have brought. These analyses are done and solved by ArcGIS using various analytical tools and necessary calculations. Prepared data were filtered to check error and eliminate errors. Topology check for road data were done under two criteria such as “Must not have dongles” and “Must not have so nodes”. An error that is determined is eliminated by trimming line and extending line where necessary. Besides salinity data were converted to .shp format and classified into three classes based on the salinity present on the water. The salinity range is determined depending on the experts’ opinion. Although the range (8.65-9.80 g/kg) for low saline almost brackish water and unsuitable for the household and industrial production uses, according to the experts’ whom have given their opinion we can use it as low saline for the study area as an alternative of brackish water.

Salinity Range (g/kg)	Salinity Range (mg/l)	Salinity Type
10.80 - 11.72	**10800-11720**	High Saline (Brine water)
9.80 - 10.80	**9800-10800**	Moderate Saline
8.65- 9.80	**8650-9800**	Low saline (brackish water)

(Source: Expert Opinion Survey 2019)

From the road data, a new road network data set has been prepared which contains road edges and junctions. The data set has taken the road line as edges and intersection and turning as junctions. From the prepared waterbodies and ward data, ward wise waterbodies are calculated depending on the type of the waterbodies. Then these were merged with the saline shapes to determine if the source contains saline or not. From the structural data, water supply source for drinking purposes are identified and determined ward wise. After the identification, the service area of water supply sources is determined using network analyst tools. Here the standard that used for the service area is 200m, by Private Residential Housing Regulations 2012. Then from the whole KCC, the served area is erased and the unserved area is determined. Then the served and unserved layer is merged with the salinity data set to determine the saline water sources. After that, possible shortest path to supply water to the unserved area are determined from network analyst tools. From the service area and salinity merged data, it is easier to recommend where to install new water sources for drinking and household uses.

4. FINDINGS AND RECOMMENDATION

In this research the water bodies that are determined are ditch, pond, river, khal, lake and beel. On the other hand, the water supply installation that are considered be water pump, overhead water tank, tube well and other community water sources.

4.1 Existing Waterbodies Analysis

From the field survey, about 3813 water bodies including 1028 ponds can be identified. Most of them are used for bathing, pisci-culture and also for fish production. The usage of the ponds gives an idea

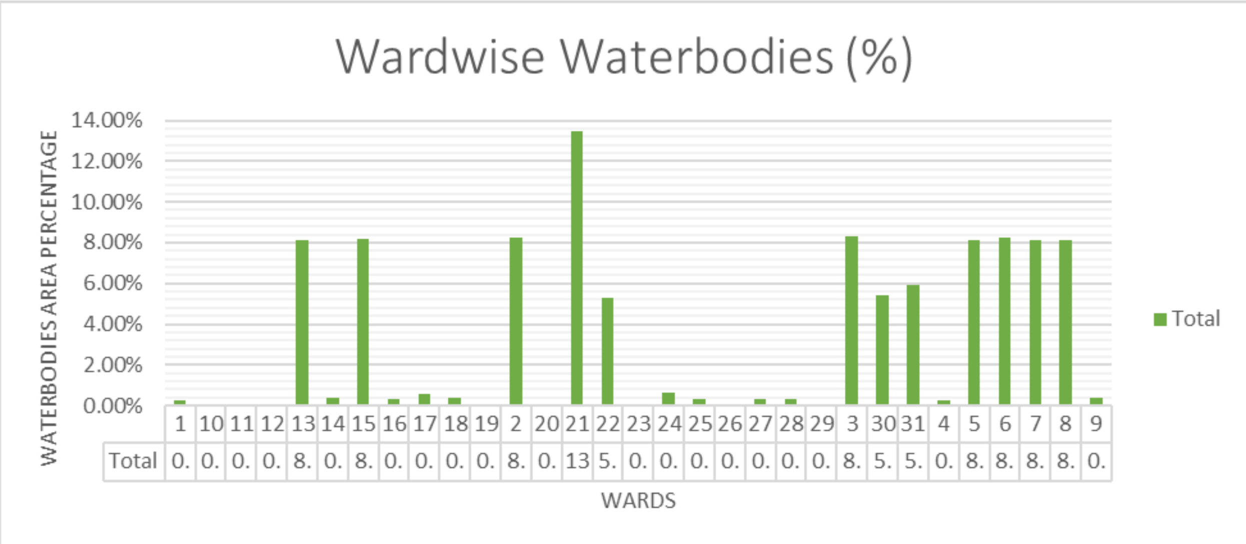

Figure 2 Ward wise Waterbodies Analysis, *Source: Author 2019*

about the quality of the water and the pollution extent of the water. The water of the pond is not potable but the ecosystem is the fish production oriented. These are opened for public uses. These waterbodies major function is during rainy weather, draining the rain water from the high land besides it.

Table 4 Ward wise Waterbodies Salinity

Wards	No Saline	Low Saline	Moderately Saline	High Saline	Grand Total
1	0.01%	4.83%	0.00%	0.00%	**4.84%**
2	0.01%	4.72%	0.00%	0.00%	**4.73%**
3	0.01%	7.93%	0.00%	0.00%	**7.94%**
4	0.01%	0.40%	3.92%	0.08%	**4.42%**
5	0.00%	0.70%	0.99%	0.00%	**1.68%**
6	0.01%	0.28%	3.84%	0.56%	**4.69%**
7	0.00%	0.13%	0.89%	0.00%	**1.02%**
8	0.00%	0.00%	2.05%	0.00%	**2.05%**
9	0.00%	0.00%	4.63%	3.05%	**7.69%**
10	0.00%	0.00%	1.76%	0.00%	**1.76%**
11	0.00%	0.00%	0.79%	0.00%	**0.79%**

Wards	No Saline	Low Saline	Moderately Saline	High Saline	Grand Total
12	0.00%	0.00%	1.43%	0.00%	**1.43%**
13	0.00%	0.00%	2.43%	0.00%	**2.43%**
14	0.00%	0.00%	0.07%	5.77%	**5.84%**
15	0.00%	0.00%	3.05%	0.55%	**3.60%**
16	0.01%	0.00%	0.00%	4.89%	**4.89%**
17	0.01%	0.00%	0.00%	4.99%	**4.99%**
18	0.00%	0.00%	0.00%	3.51%	**3.51%**
19	0.00%	0.00%	0.00%	1.07%	**1.07%**
20	0.00%	0.00%	0.00%	1.08%	**1.08%**
21	0.00%	0.00%	0.00%	3.74%	**3.75%**
22	0.00%	0.00%	0.00%	1.79%	**1.79%**
23	0.00%	0.00%	0.00%	1.11%	**1.11%**
24	0.01%	0.00%	0.00%	3.64%	**3.64%**
25	0.00%	0.00%	0.00%	1.65%	**1.66%**
26	0.00%	0.00%	0.00%	1.44%	**1.44%**
27	0.00%	0.00%	0.00%	1.76%	**1.76%**
28	0.00%	0.00%	0.00%	1.60%	**1.60%**
29	0.00%	0.00%	0.00%	1.43%	**1.43%**
30	0.00%	0.00%	0.00%	2.87%	**2.87%**
31	0.02%	0.00%	0.00%	8.45%	**8.47%**
Grand Total	**0.11%**	**18.99%**	**25.85%**	**55.05%**	**100.00%**

(Source: Author 2019)

From the table we have get results about the salinity of waterbodies wardwise and we notice that total no saline quantity is 0.11%, low saline quantity is 18.99%, moderate saline is about 25.85% and lastly the high saline quantity is about 55.05%. It is clarified that most of the waterbodies contain high saline water. Waterbodies of 31 ward contain more saline (8.47%) than other wards and on the contrary waterbodies of 11 no ward contains low saline (0.79%) than others.

4.2 Water Supply Analysis

There is community water tube well and other water source for the purpose of providing drinking water. Again, from the service area by network analysis, it is clarifying that about 25% of the area still

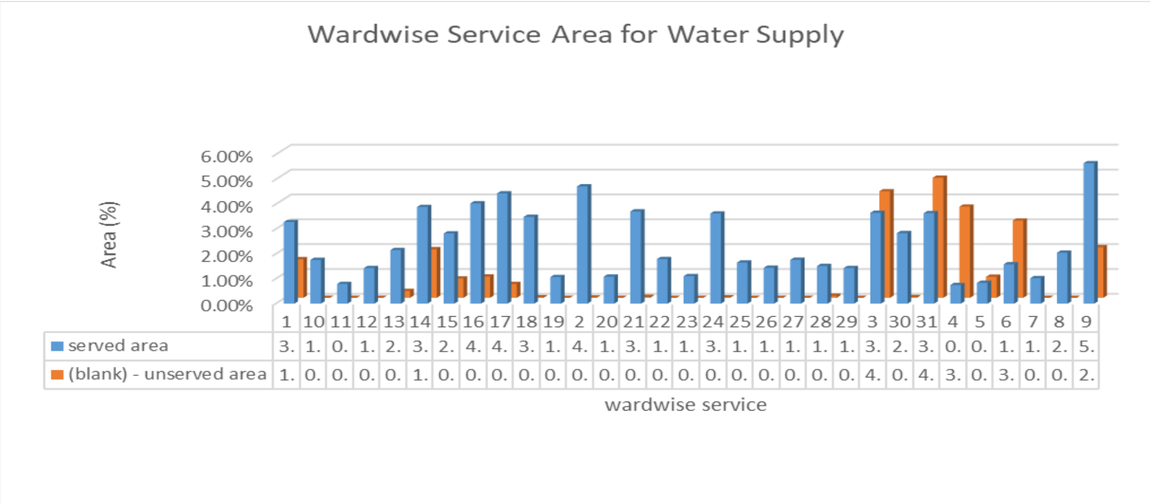

Figure 3 Ward wise Service Area for Water Supply *(Source: Author 2019)*

doesn't get the service of these community water sources. It is necessary to provide more deep tube wells or community water resources to provide optimum services in the purpose of drinking water.

Table 5 The Salinity portion of unserved area

Wards	No Saline	High Saline	Moderately Saline	Low Saline	Grand Total
1	0.03%	6.20%	0.00%	0.00%	6.23%
2	0.00%	0.06%	0.00%	0.00%	0.06%
3	0.05%	17.13%	0.00%	0.00%	17.18%
4	0.03%	0.00%	14.36%	0.32%	14.71%
5	0.00%	0.05%	3.34%	0.00%	3.39%
6	0.02%	0.00%	10.17%	2.26%	12.45%
9	0.01%	0.00%	1.43%	6.72%	8.16%
13	0.00%	0.00%	1.10%	0.00%	1.11%
14	0.01%	0.00%	0.00%	7.82%	7.83%
15	0.02%	0.00%	2.69%	0.41%	3.12%
16	0.03%	0.00%	0.00%	3.41%	3.43%
17	0.02%	0.00%	0.00%	2.20%	2.23%
18	0.00%	0.00%	0.00%	0.09%	0.09%
21	0.00%	0.00%	0.00%	0.14%	0.14%
24	0.00%	0.00%	0.00%	0.06%	0.07%
28	0.00%	0.00%	0.00%	0.33%	0.33%
30	0.00%	0.00%	0.00%	0.12%	0.12%
31	0.08%	0.00%	0.00%	19.29%	19.36%
Grand Total	**0.29%**	**23.44%**	**33.09%**	**43.18%**	**100.00%**

(Source: Author 2019)

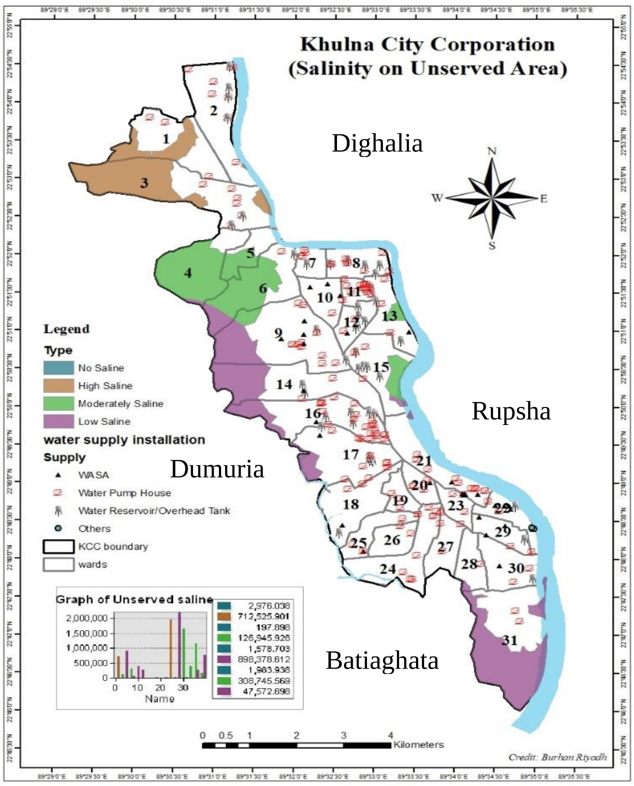

Figure 4 Unserved Area Salinity Ward wise, *Source: Author 2019*

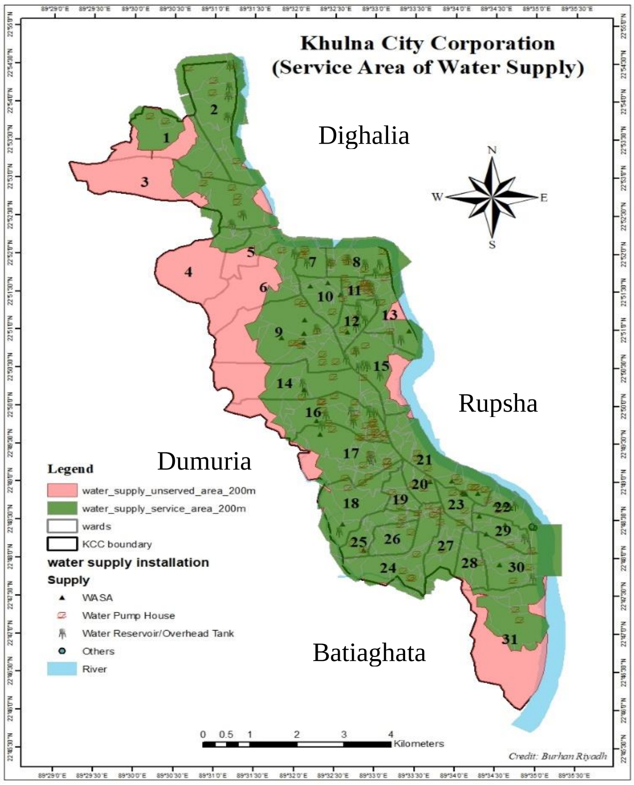

Figure 5 Service Area of Water Supply Ward wise, *Source: Author 2019*

From network analysis it is seen in Figure 4 and 5 that 25% unserved area and about 18 wards have partially unserved area. In this unserved area, we notice that 43.18% areas contain low saline. To establish more water sources for water supply, this mentioned low saline areas can be recommended, which is also shown in the map.

It is visualized from the map (Figure 6) that the shortest path from low salinity areas to high salinity areas. It allows DEM elevation for finding the shortest path and this also essential for reduce salinity problems. Following the shortest path for water supply will reduce the cost of installation of the supply system. Besides, for efficient water supply, it is necessary to follow the shortest pattern and low land.

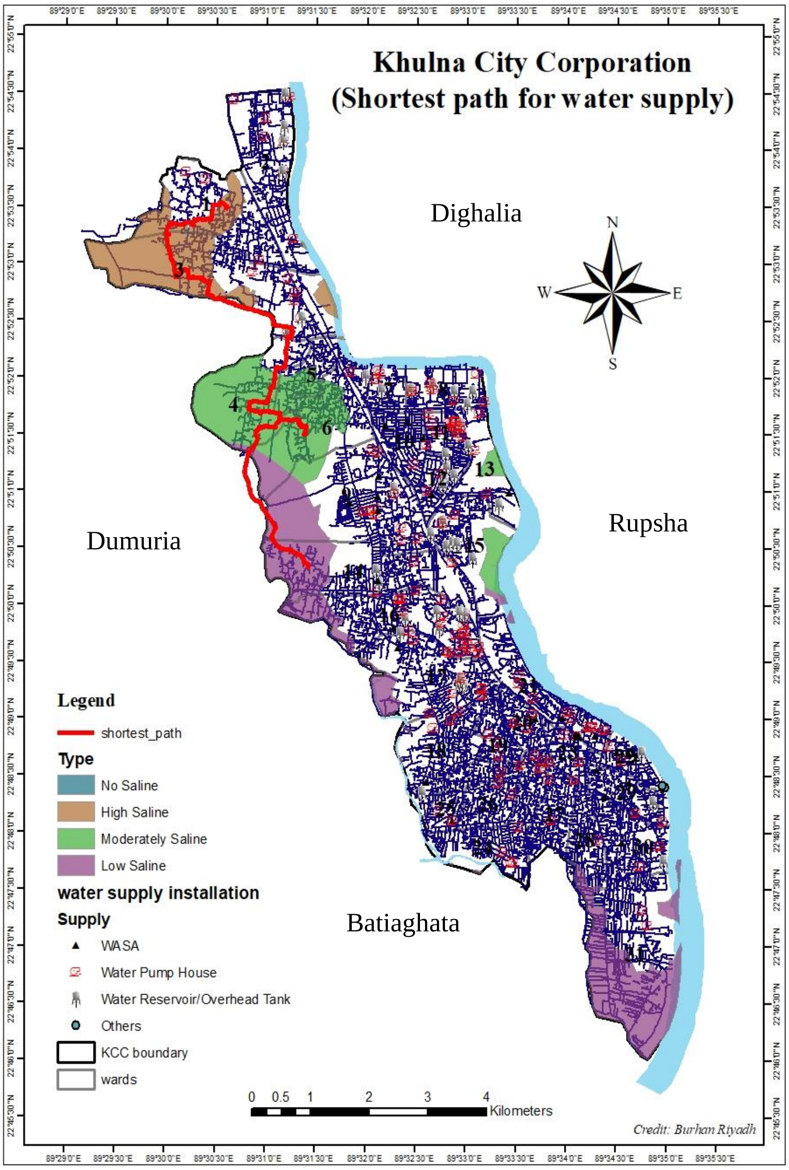

Figure 6 Shortest Path for Water Supply from Low to High Saline Zone,
Source: Author 2019

5. CONCLUSIONS

Water and soil salinity are a communal problem in different coastal districts of Bangladesh and Khulna is one of the districts where water salinity is found more than other regions. Salinity roots various types of dangerous diseases which in the future leads to death and it is also accountable for human migration. With a growing concern for rising salinity, awareness and interest in climate change impacts on water sources are also increasing. This study associates us to about the water condition for each ward and salinity condition and we become aware about particular wards which are confined in high salinity areas and these areas are threatened for human health and human living. The result shows that most of Ward 3 has a high saline than others. Almost 17.3% of the total KCC area are found as high saline in Ward 3. On the other hand, most of the area in Ward 4, 6 and 13 are low saline affected. The final result of the study suggests to define a water supply installation path newly to serve the high saline unserved areas of KCC.

REFERENCES

Enrique Roman-Morey. (2010). Environmental profile of the united nations system organizations. Joint Inspection Unit Geneva 2010.

European Comission. (2006). Environmental Profile of Rwanda. European Comission.

Foresberg, A., & Von malmborg, F. (2004). Environmental assessment of the built environment. Building Environment.

Forsberg, A., & Fedrik, v. M. (2002). Tools for environmental assessment of the built environment. ELSEVIER.

Han, H., Wang, Z., & Li, H. (2019). Incentive Mechanism for Inhibiting Developer’s Moral Hazard Behavior in China’s Sponge City Projects. *Advances in Civil Engineering*, *2019*.

Haque, M. N., & Mustafa, M. S. (9~11 February2018). Spatial location of suitable places for water distribution facilities in Khulna city, Bangladesh: application of GIS. 4th International Conference on Civil Engineering for Sustainable Development (ICCESD2018). Khulna.

Haque, S. A. (2006). Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan Journal of Botany*, *38*(5), 1359-1365.

Hassall, J., & Zaveri, K. (1978). Acoustic noise measurements. DK-2850 Naerum Denmark.

Khan, A., Ireson, A., Mojumder, S., Khusru, S., Rahman, A., & Vineis, A. (2011). Drinking Water Salinity and Maternal Health in Coastal Bangladesh: Implipications of Climatic Change. Environmental Health Perspective.

Khulna City Corporation

Kisku, G., Sharma, K., Kidwai, M., Barman, S., Khan, A., Singh, R., & Bhargava, S. (2006). Profile of noise pollution in Lucknow city and its impact on environment. Journal of Environmental Biology.

Leda, C., & Anna, M. (n.d.). Environmental Profile of Brazilian Green Coffee. Coffe Life Style.

Li, C., Lei, J., Zhao, Y., Xu, X., & Li, S. (2015). Effect of saline water irrigation on soil development and plant growth in the Taklimakan Desert Highway shelterbelt. Soil and Tillage Research, 146,99-107.

Li, H., Xia, Q., Wen, S., Wang, L., & Lv, L. (2019). Identifying Factors Affecting the Sustainability of Water Environment Treatment Public-Private Partnership Projects. *Advances in Civil Engineering*, *2019*.

Postel, S., 2002. Rivers of life: the challenge of restoring health to freshwater ecosystems. Water. Sci. Technol . 45(11), 3-8

Private Residential Housing Regulations 2012

Sefati, Z., Khalilmoghadam, B., & Nadian, H. (2019). Assessing urban soil quality by improving the method cfor soil environmental quality evaluation in a saline groundwater area of Iran. Catena, 173,471-480.

STUDY ON POLLUTANT REMOVAL IN CONVENTIONAL AND MBR SYSTEM FROM TANNERY WASTEWATER AT TIED

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ABSTRACT

This study is based on the performance of pollutants removal in the conventional and Membrane Bioreactor (MBR) system in tannery wastewater at CETP of Tannery Industrial Estate Dhaka (TIED). Tannery wastewater is characterized by Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Total Dissolved Solids (TDS), chromium, sulfides etc. The presence of pollutants create irritation and suffocating odor in the treatment plant. Membrane process is a combination of activated sludge treatment and membrane filtration for biomass retention, and are considered as key elements of advanced wastewater treatment. In recent years the use of MBRs for medium to large-scale wastewater applications is beginning to show some of the initial promises. The main factors that contributed to their development were the experience gained with pilot/smallscale projects, the drastic decrease in the cost of membranes, the availability of subsidies and the improvements in membrane performance. Currently, it has been observed that the effluent quality at CETP exceeds the ECR'97 standards. The treated water in the conventional system contains a high amount of pollutants and is very harmful to the environment and living things. It is necessary to introduce tertiary treatment at CETP. The performance of Membrane Bioreactor (MBR) for treating tannery wastewater at a laboratory scale has been evaluated in this study. The color, turbidity, EC, TDS, TSS, COD, BOD, NH_3-N and S^{2-} removal for MBR were found to be 72.19, 99.38, 26.37, 26.41, 61.85, 61.9, 77.78, 41.7, 56.5 and 96.06 % respectively. The pH, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD_5), Sulfide, and Chromium concentration from MBR outlet satisfy the allowable limits of ECR'97. These percentages indicate that MBR can successfully reduce the impurities of tannery wastewater at TIED and ensure proper effluent water characteristics for discharging in the Dhaleshwari river.

Keywords : *Tannery wastewater, Membrane Bioreactor (MBR), Treatment, Pollutant removal.*

1. INTRODUCTION

The tannery industry is recognized as one of the major polluters in Bangladesh due to the high organic loading in tannery effluents. Wastewater from the tanneries contains high Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), sulfide and suspended solids (Iqbal et al., 1998). Tannery Effluent is highly colored due to the presence of various impurities in the colloidal and suspended forms. Color caused by a colloidal form of impurities is called true color and that caused by suspended matter is called apparent color. Color is also caused by vegetable matters and coloring pigments used by tanneries (Hammer & Hammer, 2007). These impurities especially color and suspended solids can be easily removed by the Membrane bioreactor (MBR). It is a technology that has gained a considerable number of applications in the wastewater treatment process in recent years. It is a type of modification to the conventional activated sludge process under which solid/liquid separation is undertaken. Conventionally removal of large solids that may damage equipment or result in operational problems is done by physical process (preliminary treatment). The tannery effluent is treated for the removal of suspended solids (primary treatment) and followed by biological treatment (secondary treatment) for the removal of colloidal organic matter, COD and color (Hayder & Aziz, 2009). Coagulation/flocculation has been studied for leather effluent treatment to reduce COD and suspended solids (Zhi et al., 2009). A combination of both physical and chemical treatments can remove organic pollutants and nitrogenous compounds in tannery wastewater (Parag & Aniruddha, 2004). Though the physicochemical methods are effective, they are expensive, consume chemicals and produce secondary solid sludge.

Due to the complexity of the leather effluents, most of the traditional methods are inadequate for effective treatment. Thus it is necessary to develop a more economical and technically feasible compact process that effectively removes organics while reducing sludge production rate and chemical consumption. Besides, according to the monthly progress report from the Bureau of Research, Testing and Consultation (BRTC), BUET, it can be clearly observed that the present conventional system does not fulfill the requirement of treated tannery effluent quality and standards for inland surface water. Therefore, it is necessary to introduce tertiary treatment in the Common Effluent Treatment Plant (CETP). Membrane bioreactor (MBR) would be such an alternative, which can provide longer Sludge Retention Time (SRT) and requires much less reactor volume for BOD and nitrogen removal (Chiemchaisri &Yamamoto, 2005). MBR shows a higher removal rate in the tannery wastewater when compared to conventional activated sludge process (Munz et al., 2008). MBR systems offer the option of independent selection of hydraulic retention time (HRT) and sludge retention time (SRT), which permits more flexible control of operational parameters. High sludge concentrations in the bioreactor allow efficient treatment of high-strength wastewater. The retention of activated sludge containing solids and macromolecules in combination with long sludge age extends the contact time of sludge and critical classes of substrates. This allows the development of specialized, slow-growing microorganisms able to remove low-biodegradable pollutants contained in wastewater, resulting in improved removal of recalcitrant compounds (Melin et al., 2006).

The present conventional system for the treatment of tannery wastewater does not fulfill the ECR’1997 standards. Therefore, this present study was undertaken to investigate the efficiency of pollutant removal from the tannery wastewater using a Membrane Bioreactor (MBR) as a tertiary treatment with the existing conventional system.

2. METHODOLOGY

2.1 Method Of Sampling

The tannery wastewater used in this study was collected from the outlet of the Common Effluent Treatment Plant (CETP), located at Savar, Bangladesh. The primary treatment is done by chemical coagulation and the supernatant is subjected to secondary treatment by activated sludge process. The effluent was collected in plastic bottles, sealed and kept in a cool dry place before analysis. Some of the data were collected from the monthly progress report from the Bureau of Research, Testing and Consultation (BRTC) by BUET.

2.2 Frequency of Sampling

For the proper characterization, the frequency of the sampling collection process was varied. The samples were collected from January 2019 to September 2019.

2.3 Membrane Bioreactor (MBR)

The pore size of the membranes used in the MBR process was 0.04 µm. The water systems are based on the MBR MCXL2 filter, which has a membrane surface area of 8 m^2. The high packing density of the filters (185 m^2/m^3) minimizes the space requirements. It works at low aeration demand, energy cost, backflush capability and minimum maintenance requirements. Membranes are activated with NaOCl for 48 hours at a temperature between 20-30 ℃. After that, discharging NaOCl solution and filling the tank with clean water is needed. Prior to the operation and to determine permeability, a clean water test should be conducted to check whether the system is properly installed. In continuous operation, filters are operated with transmembrane pressures (TMP) between .05 to .2 (max .25) bar. It is recommended to run the system by setting the TMP and achieving an associated flow from the filtration system. Fine screening is essential to prevent debris and fibrous material from entering the membrane tank. Treated water will be filtrated by the MBR system to separate water and suspended solids.

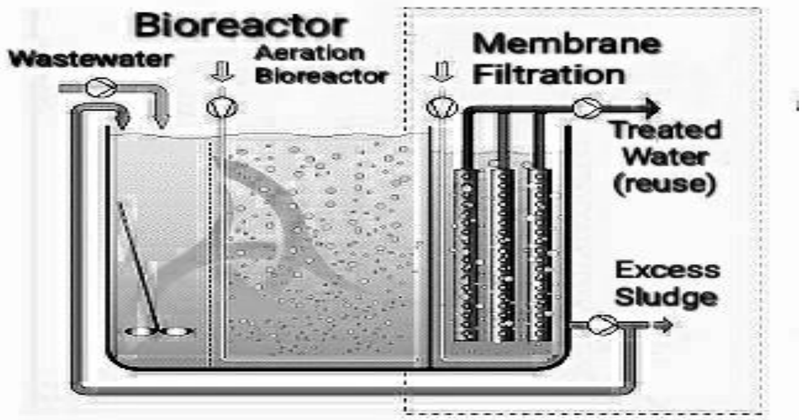


Figure 1 : Working Process of MBR.

3. ILLUSTRATIONS

3.1 Condition Of Treated Effluent in Present System

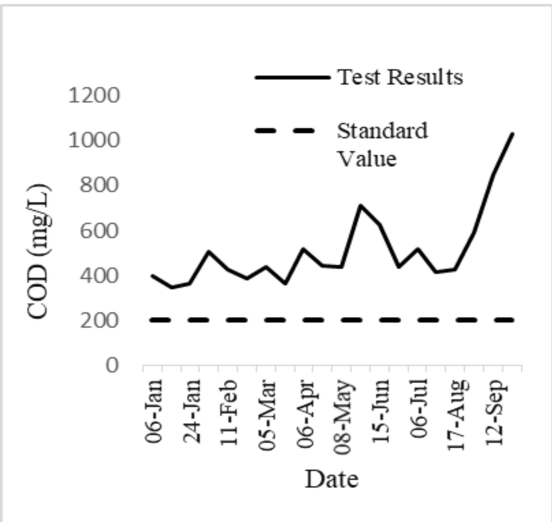
The design limit of the CETP for effluent discharge is COD < 200mg/L and BOD_5 < 30 mg/L. The parameter COD was not included in the disposal of tannery effluent in ECR'97. However, it is observed that the COD value of treated effluent doesn't satisfy the allowable limit (200 mg/L) for wastewater disposal in an inland water body as per ECR'97. Though, the design value of the treated effluent of the CETP should be < 250 mg/L. Chemicals (PAC and PAM) must be introduced to fulfill the requirements. It is to be mentioned that the Bangladesh standard for BOD_5 should be < 100 mg/L for tannery effluent. The BOD_5 of treated disposal tannery waste does not satisfy in the months of July, August and September 2019. The chromium concentration and the ammonia concentration in treated disposal don't satisfy the disposal standards. The allowable limit for S^{2-} as per ECR'97 is 1 mg/L. It is observed that the present treatment system doesn't satisfie the allowable limits of all the parameters.

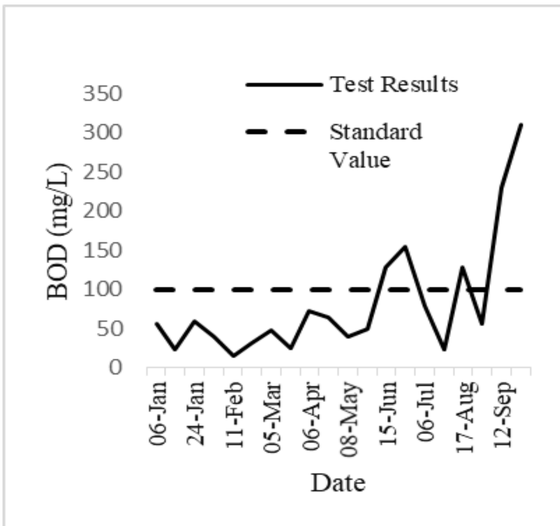
Table 1 : Characteristics of Treated Effluent (mg/L) in the CETP of Tannery Estate, Savar, Dhaka (January 2019 –September 2019)

Date	COD	BOD_5	Sulfide	Cr	pH	NH_3-N
06-Jan	400	56	0.062	4.52	7.22	70
14-Jan	345	24	0.2	5.094	7.75	67.5
24-Jan	365	60	0.425	5.3	7.65	75
03-Feb	505	40	0.05	2.52	7.7	90
11-Feb	425	16	1	2.6	7.75	120
27-Feb	385	32	0.125	1.49	7.45	62.5
05-Mar	435	48	0.025	3.77	7.6	72.5
20-Mar	365	25	0.08	3.32	7.47	62.5
06-Apr	520	72	0.02	4.98	8.23	152.5
20-Apr	445	64	0.03	2.16	7.71	62.5
08-May	440	40	0.035	7.62	7.23	30.75
20-May	710	50	0.03	17.33	7.49	30.5
15-Jun	625	128	0.035	3.48	6.67	55
24-Jun	440	155	0.04	4	7.48	125
06-Jul	515	80	0.035	1.35	7.33	130
23-Jul	415	24	0.05	4.54	7.79	105
17-Aug	425	128	0.018	8.07	7.16	3.5
29-Aug	590	56	0.025	2.9	8.08	157.5
12-Sep	845	230	0.1	16.75	8.61	285
25-Sep	1030	310	0.125	11.42	8.4	277.5

a)

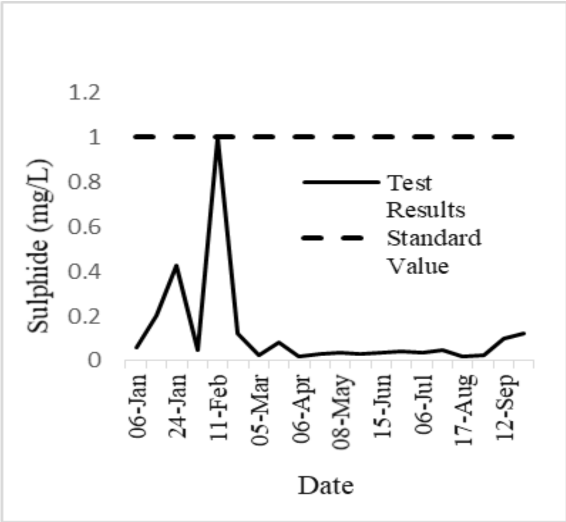
b)

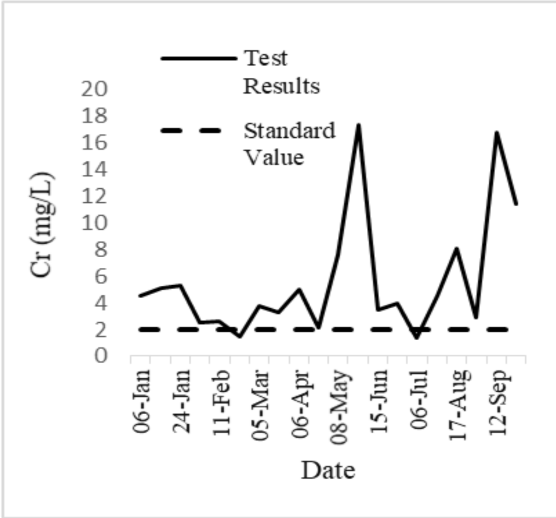




c)

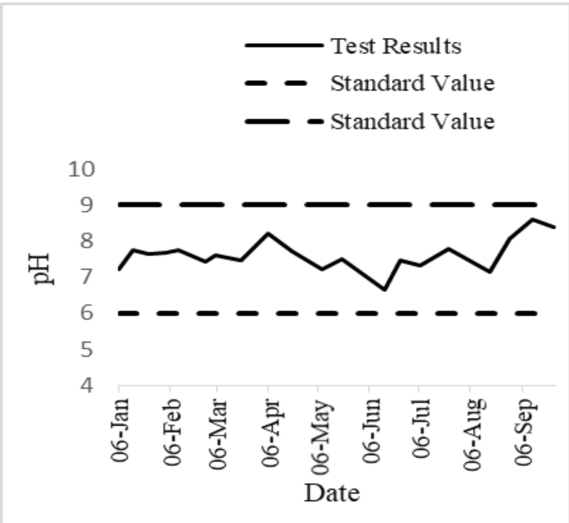
d)





e)

f)



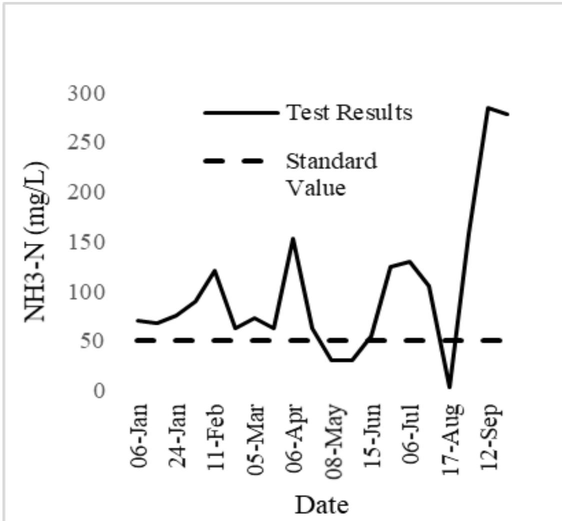


Figure 2 : Condition of treated effluent at the CETP of Tannery Industrial Estate Dhaka (TIED) in Present System a) COD, b) BOD, c) S^{2-},d) Cr, e) pH and f) NH_3-N

3.2 Performance of MBR as Tertiary Treatment

The main advantages of MBR technology compared to conventional activated sludge systems are smaller footprint and smaller reactor volume as a consequence of higher MLSS concentration and loading rate (option for low to moderate sludge age), decreased sludge production (option for high sludge age), higher and more consistent effluent quality as a result of membrane filtration, lower sensitivity to contaminant peaks.

The main disadvantages of MBRs are: relatively expensive to install, limitations imposed by pressure, temperature and pH requirements to meet membrane tolerances, membranes may be sensitive to some chemicals, less efficient oxygen transfer caused by high MLSS concentrations, the filtration pressure & flow, the backwash pressure & flow and membrane air scour flow must be recorded frequently for ensuring proper functioning.

Table 2 : Test Results of Inlet and Outlet of MBR

Parameter	Unit	Inlet of MBR (Outlet of CETP)	Outlet of MBR (Disposed into the river)	Allowable limit ECR'97 (mg/L)
pH		8.24	8.49	6-9
Color	(Pt-Co)	820	228	-
Turbidity	(mg/L)	185	1.13	-
Electrical Conductivity (EC)	(mS/cm)	12.17	8.96	-
Total Dissolved Solids (TDS)	(mg/L)	6928	5098	< 2100*
Total Suspended Solids (TSS)	(mg/L)	270	103	< 150
Chemical Oxygen Demand (COD)	(mg/L)	525	200	-
Biological Oxygen Demand (BOD_5)	(mg/L)	72	16	< 100
Ammonia Nitrogen (NH_3–N)	(mg/L)	317.5	185	-
Sulfide (S^{2-})	(mg/L)	0.115	0.05	< 1
Chromium	(mg/L)	5.75	0.226	< 2

*****There is no consideration for TDS by DoE in the present proposed allowable limits.

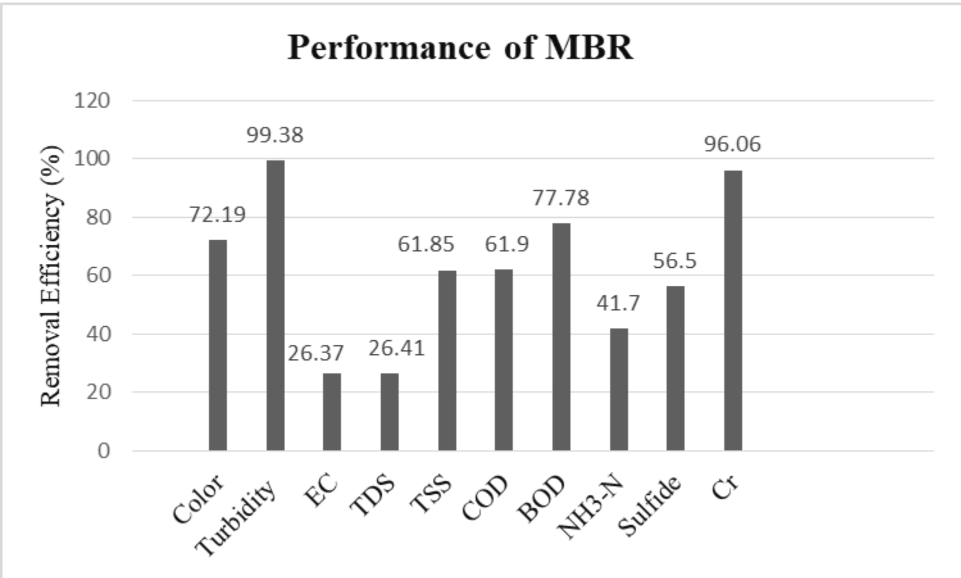


Figure 3 : Performance of MBR

The color, turbidity, EC, TDS, TSS, COD, BOD, NH_3-N and S^{2-} removal for MBR were 72.19, 99.38, 26.37, 26.41, 61.85, 61.9, 77.78, 41.7, 56.5, and 96.06 % respectively. MBR showed well performance on turbidity and Cr removal. The aerated membrane bioreactor is capable of removing organic contaminants of wastewater (Alighardashi et al., 2017). The removal efficiency of Total Dissolved Solids (TDS) is very less for MBR as the membrane cannot significantly separate dissolved particles. The pH, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD_5), Sulfide, and Chromium concentration from MBR outlet satisfy the allowable limits of ECR'97.

3.3 Inland Water Quality Standard for Effluent Disposal

Tannery industry produces leather goods by inducing a huge mass of liquid waste which should be treated before the final disposal in any surface water body. The liquid waste should maintain a minimum quality so that the treatment process can be effective enough within an affordable expense. At present, in the conventional system, the treated effluent of CETP does not satisfy all the parameters of the 'Standards For Inland Surface Water' (ECR Schedule-3, Page-205) while discharging directly in the Dhaleshwari river. So the installation of MBR as a tertiary treatment process is necessary to fulfill the standards.

Table 3 : Water Quality in the Dhaleshwari River

Parameter	**Water Quality in the Dhaleshwari River (25.09.2019)**	
	10m North from Outlet of CETP (Upstream)	**10m South from Outlet of CETP (Downstream)**
pH	7.14	6.95
BOD_5 (mg/L at 20°C)	2.2	1.6
Electrical Conductivity(μmhoms/cm)	147	237
COD (mg/L)	8.0	7.0
TDS (mg/L)	107	160
TSS (mg/L)	71	77
S^{2-} (mg/L)	0.035	0.022
Chromium (mg/L)	0.051	0.131
Chloride (mg/L)	10	28
NH_3–N (mg/L)	0.27	0.34
Color (Pt-Co)	132	100

Table 4 : Standards for Inland Surface Water (ECR Schedule-3, Page-205)

Most bacterial cells range in size from 0.2 to 10 micrometers. In this study, the pore size of membranes used in the MBR process was 0.04 μm. So most of the bacteria cells are removed from outlet effluent by using MBR and the sludge can be recycled and reused for the biological treatment process. From the monthly progress report by Bureau of Research, Testing and Consultation (BRTC), BUET in Table-2 it can be clearly observed that the present system does not fulfill the requirement of treated tannery effluent quality and standards for inland surface water. MBR at the outlet point

Parameters	**Sources of Drinking Water 0nly after Disinfection**	**Water Usable for Recreational Activity**	**Water Usable by Fisheries**	**Water Usable for Irrigation**
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
BOD_5 (mg/L at 20°C)	≤ 2.0	≤ 3.0	≤ 10 (proposed)	≤ 10.0
Electrical Conductivity (μmhoms/cm)	1200.0	-	-	2250.0 at 20°C
COD (mg/L)	6.0	-	≤ 25 (proposed)	-
TDS (mg/L)	1000.0	-	-	-
H_2S (mg/L)	0	-	-	-
Chromium (mg/L)	0.05	-	< .1 (proposed)	-
Chloride (mg/L)	600.0	-	-	-

satisfies the dischargeable limit of tannery water. Maintaining a standard discharge quality is necessary as the magnitude of pollution from the effluent is degrading the water quality of the Dhaleshwari river as well as threating the public health and the environment.

4. CONCLUSIONS

Using Membrane Bioreactor (MBR) as a tertiary treatment with the existing conventional system for the treatment of tannery wastewater increases the treatment efficiently. The BOD removal efficiency was found to be 77.78% using MBR. For COD, the removal efficiency was 61.9%, for Cr it was 96.06%, for TSS it was 61.85%, for NH_3-N it was 41.7% and for color the removal efficiency was found to be 72.19%. It is observed that the existing conventional treatment is not adequate to treat the tannery wastewater. In this study, the results showed that a tertiary treatment, using Membrane Bioreactor with the present conventional system, satisfies the ECR'1997 standards, except TDS. It can be concluded that introducing tertiary treatment is necessary for pollutant removal at the CETP of TIED. This leads to better effluent quality, more capacity for organic loading, reduced footprint and sludge production, and process flexibility towards influent variations.

ACKNOWLEDGEMENTS

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REFERENCES

Alighardashi, A., Pakan1a, M., Jamshidi, S., and Shariati, F.P. (2017). Performance evaluation of membrane bioreactor (MBR) coupled with activated carbon on tannery wastewater treatment.

Bureau of Research, Testing and Consultation (BRTC), Monthly Report, (January 2019 – September 2019), BUET, Dhaka, Bangladesh.

Chiemchaisri, C., and Yamamoto, K. (2005). Enhancement of oxygen transfer and nitrogen removal in a membrane separation bioreactor for domestic wastewater treatment, Water Sci. Technology, 51: 85–92.

Hammer, J.H., & Hammer J.H.(Jr) (2007). Water and Wasterwater Engineering .

Haydar, S., and Aziz, J.A. (2009). Coagulation–flocculation studies of tannery wastewater using cationic polymers as a replacement of metal salts, Water Sci. Technology, 381–390.

Iqbal, M., Haque, I., and Berns, J.A.S. (1998). The Leather Sector, Environmental Report, Environmental Technology Programme for Industry (ETPI), Federation of Pakistan Chambers of Commerce and Industry, Federation House, Karachi, Pakistan.

Keerthi, Suganthi, V., Mahalakshmi, M., and Balasubramanian, N. (2013). Development of Hybrid Membrane Bioreactor for Tannery Effluent Treatment.

Melina, T., Jeffersonb, B., Bixioc, D., Thoeyec, C., De Wildec, W., De Koningd, J., van der Graaf, J., and Wintgens, T. (2006). Membrane bioreactor technology for wastewater treatment and reuse.

Munz, G., Gori, R., Cammilli, L., and Lubello, C. (2008). Characterization of tannery wastewater and biomass in a membrane bioreactor using respirometric analysis, Bioresour.Technology, 99 : 8612–8618.

Parag, R.G., and Aniruddha, B.P. (2004). A review of imperative technologies for wastewater treatment oxidation technologies at ambient conditions, Adv. Environment, Res.8 , 501–551.

Wilde, W.D, Thoeye, C., and De Gueldre, G. (2005). Operational experiences and optimizations one year after start-up of the first full-scale MBR for domestic wastewater treatment in the Benelux. Submitted to 6th Aachener Tagung Siedlungswasserwirtschaft und Verfahrenstechnik, Eurogress, Aachen, Germany.

Zhi, X., Qingzhi, F., and Weilei, Z. (2009). Research on orthogonal coagulated setting and coagulation–flotation test of tannery wastewater, J. Environ. Sci. Suppl., 158–161.

TOXICITY ASSESSMENT FOR TANNERY SLUDGE CONTAMINATED SOIL, USING RED AMARANTH (AMARANTHUS CRUENTUS)

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ABSTRACT

The presence of heavy metals in the atmosphere, soil, and water, even in traces can cause serious problems to all organisms. Heavy metal bioaccumulation in the food chain especially can be highly risky to human health. A study was conducted to assess the heavy metal contamination of soil and plants in the vicinity of tanneries in the Savar at Tannery Industrial Estate Dhaka (TIED). An analysis of concentrations of heavy metals (Fe, Zn, Mn, Cu, Cr, Pb) in soil and plant samples was done. Seed germination, seedling growth (root and shoot) and heavy metal accumulation were measured. The disposed tannery waste is polluting the soil of the dumping zone and the surrounding region. In most cases, plants growing in this region are containing heavy metals. These plants are coming to the market as vegetables and fruits which upon consumption are being included in our food chain. Out of these vegetables we have chosen the Red Amaranth (*Amaranthuscruentus)* plant to assess the contamination level of heavy metals in the soil and plants grown in the tannery waste contaminated area. In this study, we have tried to show the difference in the concentration level of heavy metals between tannery waste contaminated soil and normal soil. We have also studied the level of uptake in Red Amaranth plants grown in these two types of soil. Six pots were taken for the experiment in which three pots were filled with contaminated soil of Savar Tannery State and the other three were filled with normal soil. 100 seeds per pot were sowed in June 2019. The growth period of Red Amaranth was 40 days. The order of heavy metal level in tannery soil was Co<Cd<Pb<As<Ni<Cr and in the normal soil was Co<Cd<Pb<As<Ni<Cr, which matches with the former one. The level of heavy metal concentration is higher in soil samples than vegetable samples. The heavy metal accumulation in various plant components was found in this order: roots>leaf>stem. High concentrations of heavy metals were found in plant samples near the Tannery area, which in turn will affect the food chain. This may be considered as a major environmental concern.

Keywords: *Tannery sludge, Soil, Red Amaranth (Amaranthus cruentus), Concentration, Heavy metal.*

1. INTRODUCTION

Leather and leather products rank fourth in foreign exchange income for Bangladesh. The Statistics prepared by the Export Promotion Bureau of Bangladesh for the financial year 2011-2012 shows that the leather sector earned US$765 million for Bangladesh. However, pollutant discharges have severe impacts on the social and physical environment. The Department of Environment has categorized the tannery industry as one of the most polluting industries in Bangladesh. Most tannery industries use old and inferior leather-processing methods and thereby discharge wastes without treatment. This severely affects both the environment and human health (Ahmed, 2005).

During operations, a lot of organic and inorganic chemicals/compounds are used. Many of those are not fully consumed by the processed leather. Nearly 90% of all leather produced is tanned using chromium salts (Stein & Schwedt, 1994). Generally, 8% of the basic chromium sulfate salt is used for conventional tanning. It binds with the collagenous protein to convert to leather. About 60 to 70% chromium compound is consumed by hides and skins and the rest of the amount of chromium is discharged directly from the industry which pollutes the environment (Adeel et al., 2012). Other metal pollutants of concern within the tanning industry include cadmium, cobalt, copper, barium, arsenic, nickel, lead, mercury, iron, etc. (Mwinyihija, 2010).

In 2017, the tanneries of the Hazaribagh area of Dhaka have shifted to Savar on the banks of Dhalweswari River, as Hazaribagh became one of the most polluted areas in Dhaka city and Buriganga River has become highly polluted.

Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils (Jassir et al., 2005). In Bangladeshi context, some of the major known toxic bio-accumulative metal pollutants from industrial sectors, which are particularly dangerous are Hg, Pb, As, Cr, Ni, Cu, Zn and Cd (Faisal et al., 2004). Studies have shown that heavy metals are potentially toxic to crops, animals, and humans when contaminated soil is used for crop production because heavy metals easily accumulate in vital organs and threaten growing crops and human health (Sharma et al., 2009). The intake of heavy metals through the food chain by the human population has been widely reported throughout the world (Muchuweti et al., 2006). Due to their non-biodegradable and persistent natures, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders (Duruibe et al., 2007). But the uptake of heavy metal by plants or food crops from the soil to biota and its impacts on the human health in Bangladesh has been rarely reported up to now. Further, the consumption of rice crop and vegetables are very high in Bangladesh **(**Mahfuza et al., 2015).

Red amaranth (*Amaranthus cruentus*) is one of the commonly grown leafy vegetables in Bangladesh. It is fast-growing and cheap. Hence it was chosen for the research work. Vegetables cultivated in soils, polluted with toxic metals due to industrial activities, take up heavy metals and accumulate them in their edible and non-edible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants because there is no good mechanism for their elimination from the human body (Alam et al., 2003).

2. METHODOLOGY

2.1 Soil and plant sampling

This study was undertaken to find out the heavy metal contamination of soil beside the Central Effluent Treatment Plant (CETP) at Savar and the level of transmission of heavy metal from soil to red amaranth plants.

Six pots were taken for the experiment in which three pots were filled with contaminated soil of Savar Tannery State (23°46´32.34″N, 90°14´24.42″E) and the other three were filled with normal soil, collected from Bangladesh Agricultural Research Institute (BARI - 23°59′31.15″N, 90°24′50.95″E), experimental field, regarded as the low-level pollution area. A hundred seeds per pot were sowed in June 2019. The growth period of *Amaranthus cruentus* was 40 days. Then the plants were carefully removed from the pots. Soil clinging to the plant was removed by rinsing in deionized water. The plant samples represented different parts of the plant (root, stem, and leaf). The plant samples were kept in separate polythene bags and properly labeled. The soil samples were collected from the pots and kept in the polythene bags and labeled properly. The plant and soil samples were analyzed in the Soil Science Division laboratory of BARI.

2.2 Preparation and preservation

After the delivery to the laboratory, all vegetables were washed in fresh running water to eliminate dust and dirt, possible parasites or their eggs and were finally washed with deionized water. The clean vegetable samples were air-dried and placed in an electric oven at 65°C for 72-96 hours, depending on the sample size. The dry vegetable samples were homogenized by grinding using a ceramic coated grinder. All the soil samples were spread on plastic trays and allowed to dry at ambient temperature for 8 days. The dry soil samples were ground with a ceramic coated grinder and sieved through a nylon sieve. The final samples were kept in the labeled polypropylene containers at ambient temperature before the analysis.

2. 3 Digestion and determination

One gram dry plant or soil sample was weighed into a 50-ml volumetric flask, followed by the addition of a 10 ml mixture of analytical grade acids HNO_3 : $HClO_4$ in the ratio of 5:1. The digestion was performed at a temperature of about 190 ºC for 1.5 hours. After cooling, the solution was made up to a final volume with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a VARIAN model AA2407 (USA) Atomic Absorption Spectrophotometer(AAS).

3. ILLUSTRATIONS

3.1 Soil Characteristics

The absorption of heavy metal is controlled by soil characteristics. The pH of the tannery soil and normal soil was found 8.26 and 6.87, respectively. The organic matter concentration was 4.07% in the tannery soil and in the normal soil, it was 1.03%. The concentration of nutrients in both types of soil are shown in Table 1.

Table 1: Physical and Chemical properties of the soil.

Soil properties	**Nutrient status**	
	Tannery soil	**Normal soil**
pH	8.26	6.87
OM (%)	4.07	1.03
Total N (%)	0.115	0.085
Exchangeable Ca (meq/100 g soil)	7.4	0.65
Exchangeable Mg (meq/100 g soil)	2.5	2.3
Exchangeable K (meq/100 g soil)	0.3	0.25
Available P (mg kg^{-1})	10	13.1
Available S (mg kg^{-1})	11	12
Available Cu (mg kg^{-1})	1.3	2.0
Available Fe (mg kg^{-1})	45	57
Available Mn (mg kg^{-1})	8.1	9.6
Available Zn (mg kg^{-1})	2.56	2.89

Soil properties	**Nutrient status**	
	Tannery soil	**Normal soil**
Available B (mg kg^{-1})	1.9	2.0
Available Pb (mg kg^{-1})	12.7	5.66
Available Cd (mg kg^{-1})	2.12	1.14
Available Cr (mg kg^{-1})	6946	324
Available Ni (mg kg^{-1}	355.5	112
Available Co (mg kg^{-1})	8.02	5.08
Available As (mg kg^{-1})	15.13	9.08

The concentrations of all six of the heavy metals examined in this study were found to be higher in the tannery soil (Table. 2).
The Pb concentration in the tannery soil was 4.78 times higher than the normal soil. In the case of Cr, the concentration was 4.95 times higher in the tannery soil than the normal soil. Similarly, for Cd the concentration was 1.62 times higher, for Ni, the concentration was 3.87 times higher, for Co the concentration was 1.74 times higher and for As it was found that the concentration was 3 times higher in the tannery soil than the normal soil.

Table 2: Heavy metal concentration of the soil.

Heavy Metal	**Tannery Soil (mg kg^{-1})**	**Normal Soil (mg kg^{-1})**
Pb	12.8	5.7
Cd	12.7	5.66
Cr	6946	324
Ni	356	112
Co	8.02	5.08
As	15.13	9

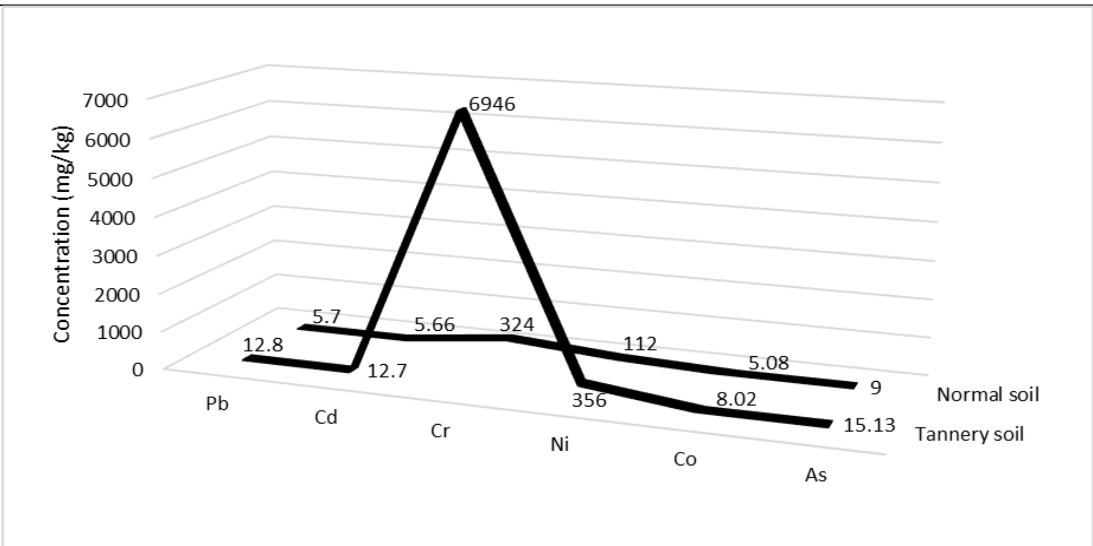

Figure 1: Heavy metal concentration of tannery soil and normal soil.

3.2 Plant Growth

For the germination test, 50 seeds/petri dishes were taken. Out of them 39 germinated in the Savar soil and 21 germinated in normal soil. 100 seeds/pot were sowed. The average No. of plant/pot for the tannery soil was 21 and for the normal soil, it was 41. The length of root shoot and fresh weight, dry weight information are shown in Table 3.

Table 3: Growth attributes of red amaranth grown in the tannery soil and in the normal soil.

Treatment	**No. of Plant/ pot**	**Shoot Length (cm)**	**Root length (cm)**	**Fresh wt. (g/10 plant)**			**Dry wt. (g/10 plant)**		
				Shoot	**Root**	**Leaf**	**Shoot**	**Root**	**Leaf**
T_1: Tannery soil	21	14.47	5.67	12.12	1.21	11.62	1.23	0.13	1.21
T_2: Normal soil	41	23.67	7.53	60.21	6.11	59.31	6.05	0.62	6.00

3.3 Accumulation of Heavy Metal into Plant Tissue

For all heavy metals, the concentrations were found higher in the roots. Roots are the point of entry into the plant, so it can be the possible reason. The level of heavy metal concentration is higher in the soil samples than the vegetable samples. The level of heavy metals in the vegetable is generally lower than the soil samples (Demirezen & Aksoy, 2006). Such results might be attributed due to root activity, which seems to act as a barrier for the translocation of metals (Davies & White, 1981; Yusuf et al., 2003).

The levels of uptake of heavy metals in samples from the tannery soil were higher than those from the low-level polluted (BARI) area. Several studies have indicated that vegetables grown in the heavy metals contaminated soils have higher concentrations of heavy metals than those grown in the uncontaminated soils (Jassir et al., 2005).

The low concentration of Cd in plant tissues is probably because of the presence of the low Cd concentration in the soil (Table. 2). On the other hand, the high concentration of Cr in the plant tissues is maybe due to the fact that Cr concentration in the soil was the highest among these metals. The mean concentrations of Pb, Cd, Cr, Ni, Co, and As in the whole plant (roots, stem, and leaf) are shown in Table 4.

Table 4: Heavy metal concentration (Pb, Cd, Cr, Ni, Co, and As) in plant components (mg kg^{-1} of dry wt.) of red amaranth.

Treatment	**Heavy Metal**	**Soil (mg kg^{-1})**	**Plant parts (mg kg^{-1} of dry wt.)**			
			Root	**Stem**	**Leaf**	**Total plant**
T_1: Ternary soil	Pb	12.8	6.03	2.21	4.39	4.21
T_2: Normal soil		5.7	1.90	0.49	1.23	1.21
T_1: Ternary soil	Cd	12.7	0.51	0.28	0.38	0.39
T_2: Normal soil		5.66	0.37	0.10	0.25	0.24
T_1: Ternary soil	Cr	6946	1839	1057	1469	1455
T_2: Normal soil		324	385	212	285	294
T_1: Ternary soil	Ni	356	245.3	89.1	160	164.8
T_2: Normal soil		112	62.5	20.9	44.1	42.5
T_1: Ternary soil	Co	8.02	2.29	1.42	1.72	1.83
T_2: Normal soil		5.08	1.39	0.69	1.07	1.05
T_1: Ternary soil	As	15.13	0.87	0.28	0.51	0.54
T_2: Normal soil		9.08	0.27	0.18	0.17	0.18

For all the metals, the uptake into the plant roots was highest. The uptake of heavy metals was the lowest in the leaf parts. The heavy metal accumulation in various plant components was found in this order: roots > leaf > stem.

In this study, the heavy metal accumulation concentration of Cr was very high in the plant than the permissible limit set by WHO/FAO (Figure.2). The concentration of Ni was found higher in the plant grown in tannery soil. The concentration of other heavy metals, Pb, Cd, As was found a bit higher than the permissible level. The accumulation concentration of Co was lower than the maximum permissible level.

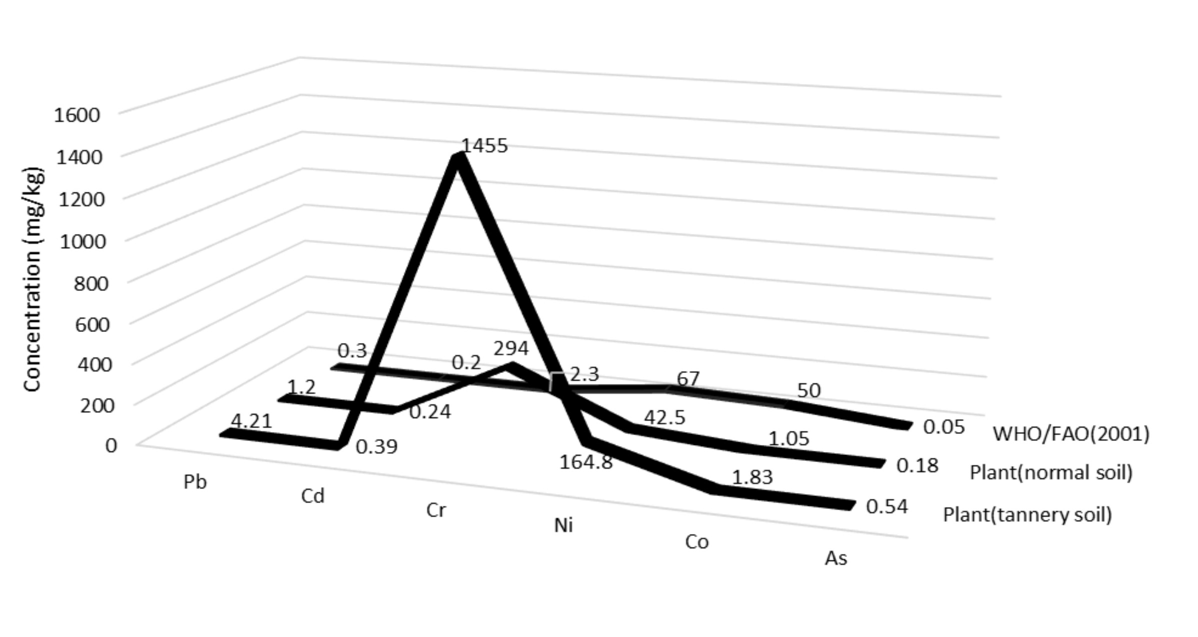

Figure 2: Total concentrations of heavy metal in the vegetables and maximum allowable limits.

4. CONCLUSIONS

From the test results, it is clear that red amaranth plants accumulated heavy metals from soil and the concentration varied among different parts of plants (root, stem, and leaf). The heavy metal accumulation was highest in the roots of the plant, lower in the leaf and lowest in the stem of the plant. In both tannery soil and normal soil, the concentration of Cr was found highest. And the order of heavy metal level of both soil was found to show a similar trend. The order was: Co<Cd<Pb<As<Ni<Cr. Further research can be conducted to prove the level of heavy metal accumulation in different species of plants and their impact on the food chain.

REFERENCES

Adeel, S.S., Wajid, A., Hussain, S., Malik, F., Sami, Z., Haq I.U., Hameed A. & Channa, R.A. (2012). Recovery of chromium from tannery wastewater by use of bacillus subtilisin Guranwala. *Pakistan. Journal of Pharmacy and Biological Sciences,* 2(2): 36-45.

Ahmed J. (2005). Hazaribag tannery area: its pollutional impact on the environment. The Observer Magazine. 23–24.

Alam, M.G.M., Snow E.T. & Tanaka. A. (2003). Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *The Science of the Total Environment.* 308: 83-96.

Alloway, B.J. (1996). Heavy metal in soils. Halsted Press, John Wiley & Sons Inc., London.

Davies, B.E. & White, H.M. (1981). Trace element in vegetables grown on soils contaminated by base metal mining. *Journal of Plant Nutrition* 3**:** 387-396.

Demirezen, D. & Aksoy, A. (2006). Heavy metal levels in vegetables in turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. *Journal of Food Quality* 29**:** 252-265.

Duruibe, J.O., Ogwuegbu, M.D.C. & Egwurugwu, J.N. (2007). Heavy metal pollution and human bio toxic effects. Int. J. Phys. Sci. 2(5): 112-118.

Faisal, I., Shammin, R. & Junaid, J. (2004). Industrial pollution in Bangladesh. World Bank Report.

Jassir, M.S.A., Shaker, A. & Khaliq, M.A. (2005). Deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh City, Saudi Arabea. *B. Environ. Contam. Tox.* 75: 1020-1027.

Mahfuza, S., Sultana,Y.N., Jolly, S., Yeasmin, A. & Islam, M.T. (2015). Transfer of heavy metals and Radionuclides from soil to vegetables and plants in Bangladesh.

Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D. & Lister, J.N. (2006). Heavy metal content of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: Implication for human health. Agri. Ecosys. Environ. 112: 41-48.

Mwinyihija, M. (2010). Ecological Diagnosis in the Tanning Industry, *Springer Science and BusinessMedia LLC* 2010, p. 18.

Sharma, R.K., Agrawal, M. & Marshall, F.M. (2009). Heavy metals in vegetables collected from production and market sites of tropical urban area of India. Food Chem. Toxicol. 47: 583-591.

Stein, K. and Schwedt, G. (1994). Chromium speciation in the wastewater from a tannery. *Fresen J Anal. Chem,* 350:38-41.

Yusuf, A.A., Arowolo, T.A. & Bamgbose, O. (2003). Cadmium, copper and nickel levels in vegetables from industrial and residential areas of Lagos City, Nigeria. *Food & Chemical Toxicology* 41: 375-378.

A STUDY ON LAND USE/LAND COVER MAPPING AND SPATIO-TEMPORAL CHANGE DETECTION AROUND THE SOUTHERN PART OF DHAKA METROPOLITAN DEVELOPMENT PLAN (DMDP) USING REMOTE SENSING TECHNIQUE

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ABSTRACT

Land use/land cover is an important component in understanding the interactions of the human activities with the environment and thus it is necessary to monitor and detect the changes to maintain a sustainable environment. Many researchers have carried out the similar work in this field adopting different technologies. The purpose of the study is to create a land use/land cover map and investigate the spatio-temporal change in land use around the southern part of DMDP. In this study, satellite remote sensing technologies have been adopted using ArcGIS 10.2.2.

The total study area covers about 211.78 km^2. The two satellite images of Landsat 5 TM (13 December, 2003 and Landsat 8 OLI (28 March, 2019), path-137 and row-44 were downloaded from the earth explorer. Supervised classification technique has been used with Maximum Likelihood Classification algorithm within ArcGIS 10.2.2 environment for image classification. The land use and land cover analysis on the study area has been attempted based on thematic mapping of the area consisting of water bodies, vegetation, urban and non-urban using the satellite image. Another major land use class, Matuail landfill site inside Dhaka South City Corporation was identified separately in the land cover map. The sixteen year time gap between 2003 and 2019 illustrates a major changes in land use. Vegetated area has decreased from 77.57% to 45.5% due to deforestation and non-urban area has increased from 2.3% to 14.93% which indicates an increase in bare lands. Water covered area also decreased from 6.03% to 4.64%, may be due to population growth. There has been a significant change in urbanized area which was due to an increase in population resulting in an increase of urban area by 20.84%. Finally, the accuracy of the result was assessed with the help of Google Earth historical images and an error matrix was created to calculate a variety of accuracy matrices (user and producer accuracy) for the afore-mentioned years. For accuracy assessment, high resolution topographic map would have served better purpose.

Due to expansion of cities in all directions resulting in rapid growth of urbanization, built up and non-urban area has increased and encroached the vegetation and water covered areas. However, as this study applies a 16-years interval for the spatio-temporal change detection from 2003 to 2019, further researches are demanded to investigate the temporal scale problem in all temporal analysis including spatio-temporal modelling and forecasting.

Keywords: *Land use; Land cover; Remote Sensing; Satellite Image; Supervised classification.*

1. INTRODUCTION

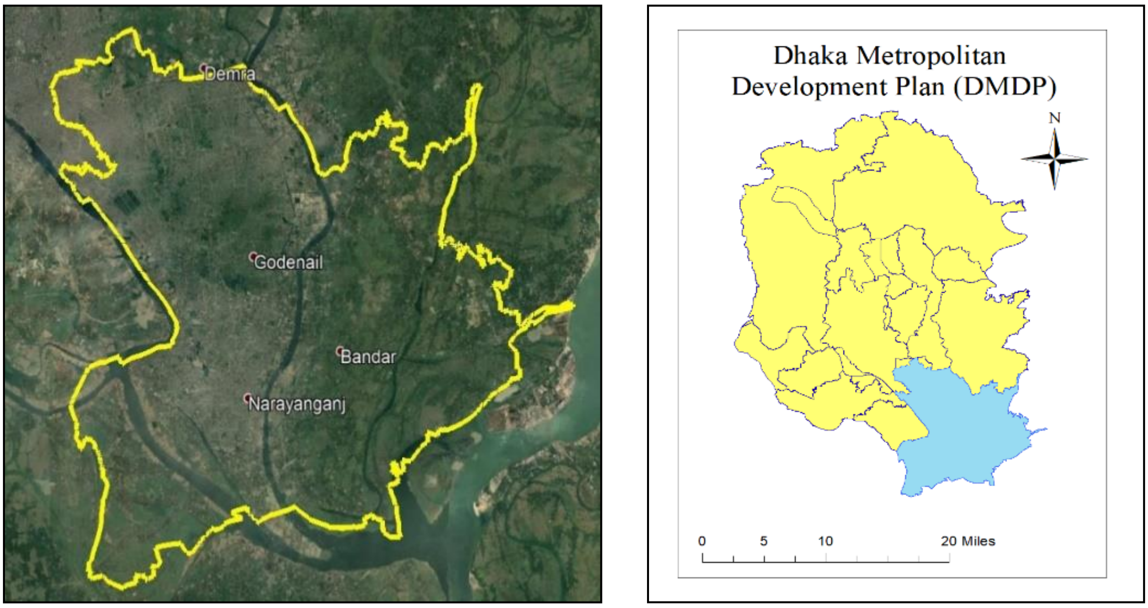
The demand of information on land cover, land use and their changes is increasing at the global, regional and national levels to support policy decisions and regulate management processes. In contrast to survey data, aerial and satellite imagery can be used to monitor the spatial extent of changes in land cover (i.e., conversion) or land conditions. Satellite imagery offers contiguous spatial coverage, facilitates better repetition and replaces costly and slow data collection of different land cover and provides statistical information of the area object [Andualem et al. (2018)]. Remote sensing technologies have made substantial contribution in deriving land cover information and correlating to land-use statistics. Availability of satellite images with different spatial and temporal resolutions have made it possible to map land cover at different scales and carry out analyses of the changes over last three decades. Specifically, remote sensing change detection analyses can be used to identify areas of rapid change to target management efforts. Repeated satellite images and/or aerial photographs are useful for both visual assessment of natural resources dynamics occurring at a particular time and space as well as quantitative evaluation of land cover changes [Gautam et al. (2003)]. A number of deforestation and degradation studies have been conducted in tropical forests using coarse and high-resolution remote sensing data. The temporal evaluation of forest changes based on satellite imagery is becoming a valuable set of technique for assessing the degree of threat to ecosystem GIS on the other hand provides environment to analyze digital data useful for change detection, database development, and modeling of its future change and data dissemination for effective management planning. In the context of Reducing Emissions from Deforestation and Degradation (REDD), Remote-sensing methods are considered to be appropriate for most developing countries to assess historical and future deforestation rates, i.e., forest area change. The latest and accurate information on land use/cover is a prerequisite to the management and planning of urban areas. In the absence of such information, sustainable urban development cannot be achieved and may lead to the mismanagement of scarce resources. Land use and land cover change mapping will help to take up clear strategies for managing natural resources and monitoring environmental changes [Andualem et al. (2018)]. Urban expansion has brought serious losses of agriculture land, vegetation land in the recent years. Unplanned urban land expansion is responsible for a variety of urban environmental issues like decreased air quality, increased runoff and subsequent flooding, increased local temperature, deterioration of water quality, etc. Knowledge of drainage, land use/land cover and hydro-geomorphology and other terrain attributes are important for planning and management activities. Remote Sensing and GIS both from the conventional sources has proved to be an effective tool in planning for Land and Water Resources management. Land and Water Resources Management will imply utilization of land and water resources for optimal and sustained production with the minimum hazard to natural resources and environment. [Land use]

An attempt is made in this study to map out and monitor the status of land use/land cover change and analyze the changes with respect to baseline. The purpose of this study is to create the land use/land cover map and investigate the spatio-temporal change in land use around the southern part of DMDP between the year 2003 and 2019 by adopting Remote Sensing Technique using ArcGIS 10.2.2.The specific objectives of the study are:

- To create a land use map by using Landsat satellite image.
- To monitor the land use changes of the study area.

2. STUDY AREA

Our study area includes Narayangonj Sadar, Bandar, Godenail, Narayanganj Paurashava, Siddhirganj Paurashava and Demra. The rivers in and around this area are the Buriganga to the west, the Meghna river to the east the Ichamati river (local name of the Dhaleshwari in this part) to the south-west, the Sitalakhya and the Old Brahmaputra river crossing through the area north to south. The Dhaleshwari crosses the southwest part and then flows along the southern boundary ultimately draining into the Meghna River. Figure 1 (a) shows the location of our study area in Google Earth.



(a) (b)

Figure 1: (a) Extent of study area; (b) Location of the study area inside DMDP

Our study area also covers Matuail landfill which is located about eight kilometers from Gulistan in the south of Dhaka. It is one of the two landfills serving Dhaka city. Spanning 100 acres, the site is used by the Dhaka South City Corporation (DSCC) to dispose of its municipal solid waste. Now 23 years old, it will reach capacity in a year at most. The Amin Bazar site, used by the Dhaka North City Corporation (DNCC), has already expired last year. Putrid waste swarming with flies and rodents towers in hills tens of meters high. Starting off with an open dump of 50 acres in 1995, a further 50 acres were added to Matuail in 2006. In the initial landfill area, there is a mountain of waste, up to 70 feet (about 21 meters) high, which is closed to further dumping. In the adjacent 50 acres, there is an almost 60 feet (about 18 metres) pile of waste. [DAP,2010]

3. METHODOLOGY

In this study, the observation is limited in detecting the changes in urban land use in a rapidly changing area of the southern part of Dhaka Metropolitan Region by comparing the percentage of land use area calculated from classified images of two different years. The images used in this observation are from Landsat 5 TM and Landsat 8 OLI sensors dated December, 2003 and March, 2019 respectively of path 137 and row 44 which are downloaded from Earth Explorer. In case of Landsat 8 OLI, there are nine spectral band (band 1 to band 9) in which band 8 is a panchromatic band and band 9 is a cirrus band which are not used in classification. In case of Landsat 5 TM, band 1 to 5 and band 7 are spectral band. From Landsat 5 TM band 1 to 5 and band 7 (resolution 30m) and from Landsat 8 OLI band 1 to band 7 (resolution 30m) are used to make composite image for further classification process. There are two image classification techniques used for land cover classification, namely Supervised classification and Unsupervised classification. In this study, the supervised classification technique was used to map the land use cover in desired classes.

A schematic flow diagram showing the methodology adopted for this study is given below, which includes data collection, data processing and preparation, data analysis and final output.

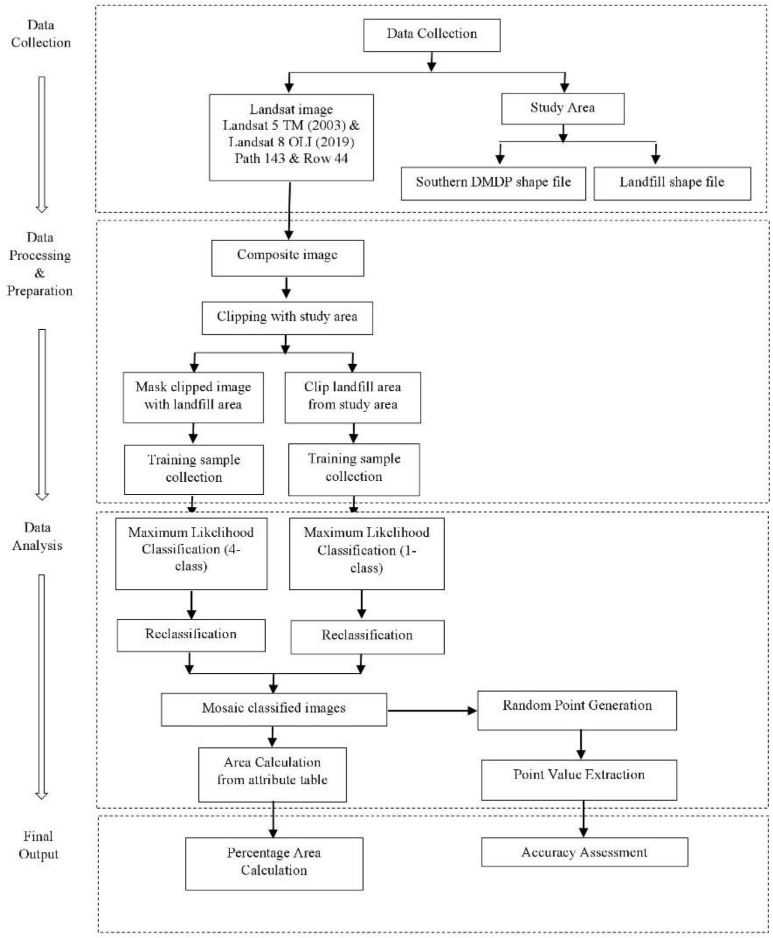


Figure 2: Methodology Flow Chart

3.1 Data Collection

Landsat 5 TM images of December, 2003 and Landsat 8 OLI images of March, 2019 of row 44 and path 137 with the cloud cover less than 10% and spatial resolution 30m X 30m covering southern part of Dhaka Metropolitan Region were downloaded using Earth explorer from the United States Geological Survey website (http://earthexplorer.usgs.gov). All the downloaded images are in *.tif format. The foot print are 170 km North-South by 185 km East-West. Landsat 5 contains six spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7, and one thermal band (Band 6, spatial resolution 120m). For Landsat 8 the satellite carries two different sensors. The Operational Land Imager (OLI) contains nine spectral band (Band 1 to 9) including a pan band and a cirrus band and the Thermal Infrared Sensor (TIRS) contains two thermal band (Band 10 & 11). For this study, the concerned bands are the spectral bands, thermal band is not necessary for image classification. The downloaded folder of the scene also contains metadata file, ground control point and other necessary file.

3.2 Data Proccessing and Preparation

For further analysis of the Landsat images, processing is required which contains merging of the spectral bands to make a composite image and clipping the composite image with the desired study area shape file. In this study, the sanitary landfill situated in Matuail, which is inside the study area, is clipped with a landfill shape file and classified as an individual class. So, the landfill needed to be masked from the clipped area. Before classify the images with maximum likelihood classification, training sample of similar pixels were collected from the processed images. To simplify the training sample selection process, band combination is required for better selection of different classes.

3.3 Data Analysis

After pre-processing of the image has been done, the data is ready for further classification process which includes Maximum Likelihood Classification, mosaicking of classified image, area and percentage of area calculation.

3.3.1 Maximum Likelihood Classification

Maximum Likelihood Classification is a remote sensing classification system in which unknown pixels are assigned to classes using contours of probability around training areas using the maximum likelihood statistics. In this case, from the training sample collected in image processing phase, a signature file (.gsg format) is made before classification. By giving input of the signature file in Maximum Likelihood Classification from Classification toolbar, all cells in the output raster will be classified with each class having equal probability weights attached to their signatures. The masked study area was classified in four classes and the landfill area was classified in one class individually with their own signature file showed. Then the two classified image (masked study area and landfill area) was being reclassified separately in five land classes. When the classification for both four classes and landfill classes were done individually, the two images needed to be mosaicked into one image or more like stitched together by mosaicking technique to get the whole area of five land classes. Description of the following five land use/land cover classes are tabulated below:

Table 1: Description of land use/land cover classes

Code	Land Class	Description
1	Water	This class of land cover describes the areas covered with water either it is river, ponds or man-made dams, water treatment plant etc.
2	Vegetation	It describes the areas with any kind of green vegetation such as ever green trees, cultivated crop lands, cultivable bare lands etc.
3	Urban	This class describes the land covers with buildings, transportation infrastructures which includes commercial, industrial, residential buildings, roads and highways, bridges etc.
4	Non-urban	This class includes the areas that cover bare lands, low lands and under construction lands.
5	Landfill	This is the only land use class which remains constant and covers the area of Matuail sanitary landfill situated in Matuail.

3.3.2 Area and Percentage Area Calculation

After mosaicking the classified images, the five classes are finally combined into one image. Area of each classes are then calculated from the pixel count provided in the attribute table of the image. A new field is created in the attribute table for area calculation. The following formula is used to calculate the area by using field calculator.

$$Area = Count*Cell\ size(X\ \&\ Y)/1000000 \qquad (1)$$

Cell size or pixel size for both Landsat 5 and 8 images are 30m*30m. The area is then converted to kilometers. After calculating the area of individual classes the data is then copied to a Microsoft excel work file. And the percentage of the area of each classes are calculated for the two different data of the two mentioned dates with the formula given below:

$$Percentage\ of\ area = (Individual\ land\ use\ area/Total\ area)*100 \qquad (2)$$

The result are then compared with graphical representation to show the changes in land use that occur in between the following time period.

3.3.3 Accuracy Assessment

To determine how well the classification process is performed, Accuracy Assessment of the classified image is done by generating a set of random points in the study area. The value for each point is then identified using the Google Earth historical imageries. After that the point values are extracted and compared with the raster values to find the accuracy of the classification method [Andualem et al. (2018)]. The percentage of accuracy of the classified image in comparison with Landsat data was calculated by the following formula.

$$Accuracy(\%) = \frac{Number\ of\ points\ with\ similar\ values}{Total\ random\ point} \times 100 \tag{3}$$

Error matrices for the two different year were developed with the output data which allows us to be able to calculate a variety of accuracy metrices from our data such as User accuracy and Producer accuracy by the following formulas:

$$User\ accuracy = \frac{Total\ number\ of\ correct\ pixel}{Total\ number\ of\ pixel\ actually\ classified\ in\ the\ category} \times 100 \tag{4}$$

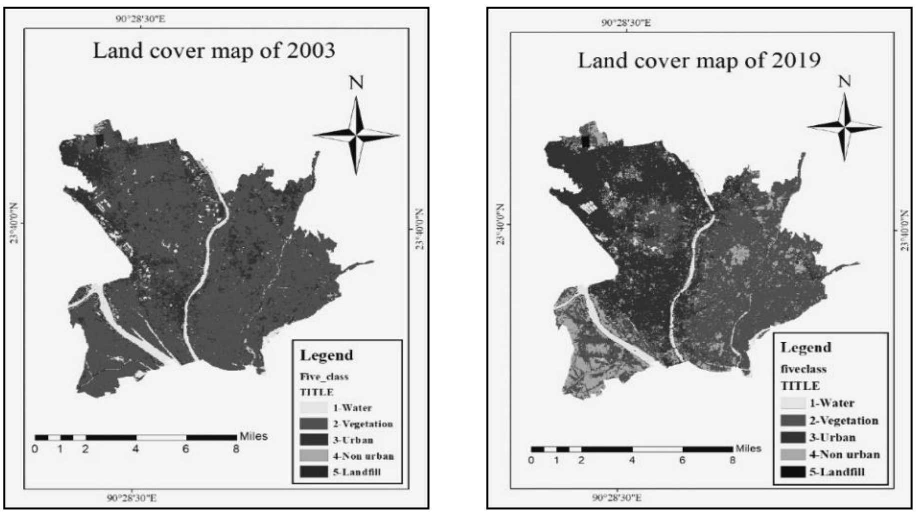
$$Producer\ accuracy = \frac{Total\ number\ of\ correct\ pixel}{Total\ number\ of\ reference\ pixel\ in\ the\ category} \times 100 \tag{5}$$

3.4 Final Output

This study focuses on the analysis of spatio-temporal change detection by land use and land cover mapping through the time series Landsat satellite images. Following the step by step classification and quantification procedures, two land use and land cover maps of 2003 and 2019 were produced by supervised classification process using Maximum Likelihood Classification algorithm. Land cover change detection was obtained within ArcGIS 10.2.2 environment. Five major types of land cover classes were identified within the study area which are water, vegetation, urban, non-urban and landfill site.

3.4.1 Change Detection in Land Use and Land Cover

From the differences between two classified image of 2003 for Landsat 5 TM and 2019 for Landsat 8 OLI, it can be observed that there is a considerable growth in urbanization and decrease in vegetation classes. Areas that cover water also decreased and non-urban areas increased. The land cover map of the two different years are given in figure 3 (a) and (b).



(a) (b)

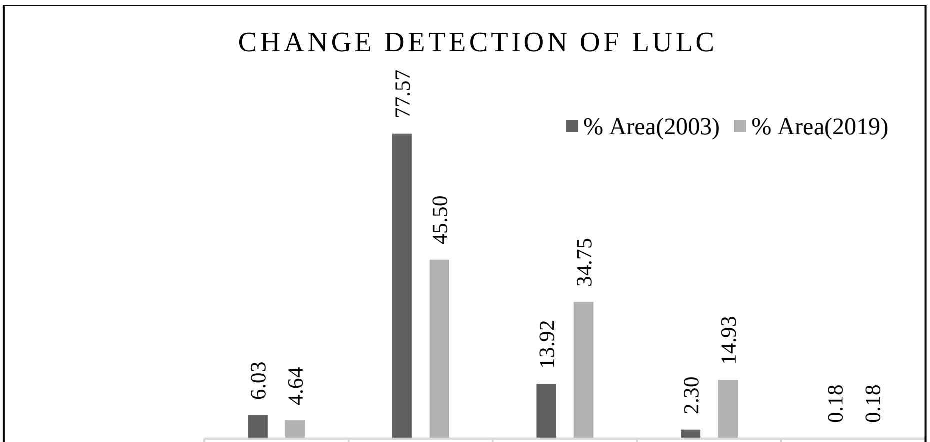
Figure 3: (a) Land cover map of 2003; (b) Land cover map of 2019

Table 2 shows the difference in percentage of area between the different land cover classes in the gap of 16 years.

Table 2: Differences between land class areas of 2003 & 2019

Land cover class	Land cover area of 2003		Land cover area of 2019		Difference (in %)
	Area(km²)	%Area	Area(km²)	%Area	
Water	12.78	6.03	9.82	4.64	-1.40
Vegetation	164.28	77.57	96.35	45.50	-32.07
Urban	29.47	13.92	73.60	34.75	20.84
Non-urban	4.87	2.30	31.63	14.93	12.63
Landfill	0.38	0.18	0.38	0.18	0.00

A graphical representation for the percentage of area changes in between the year 2003 and 2019 is shown in figure 4.



	1-Water	2-Vegetation	3-Urban	4-Non urban	5-Landfill
% Area(2003)	6.03	77.57	13.92	2.30	0.18
% Area(2019)	4.64	45.50	34.75	14.93	0.18

Figure 4: Change detection of LULC

From the above graph, the changes in land cover in the year gap of 16 years (from 2003 to 2019) is clearly visible. Percentage area of vegetation in 2003 is 77.57% (164.28 km²), whereas in 2019 it is 45.50% (96.35 km²). Also the percentage area of urban land in 2003 is 13.92% (29.47 km²) and in 2019 is 34.75% (73.60 km²). This indicates urbanization and also deforestation of the concerned area. Non-urban area of 2003 is 2.30% (4.87 km²) which also increased up to 14.93% (31.63 km²). This indicates the increase in bare land and under construction areas.

3.4.2 Accuracy Assessment

From equation (3), total accuracy of the classified Landsat images for the year 2003 and 2019 were calculated.

For the year 2003, total random point generated was 100 but 99 were inside the study area.

$$Accuracy\ (\%) = \frac{78}{99} \times 100 = 78.8\%$$

And for the year 2019, total random point generated was 100 and all the points were inside the study area.

$$Accuracy\ (\%) = \frac{84}{100} \times 100 = 84\%$$

The error matrix for the two different year including User accuracy and Producer accuracy calculated from equation 4 and 5 were shown in the following table.

Table 3: Error matrix showing classification accuracy of 2003

Land cover class	1-Water	2-Vegetation	3-Urban	4-Non urban	Total	User Accuracy
Water	3	1			4	75
Vegetation	4	66	6	4	80	82.5
Urban	1	3	8	2	14	57.1
Non-urban				1	1	100
Total	8	70	14	7	99	
Producer Accuracy	37.5	94.3	57.1	14.3		78.8

Table 4: Error matrix showing classification accuracy of 2019

Land cover class	1-Water	2-Vegetation	3-Urban	4-Non urban	Total	User Accuracy
Water	4				4	100
Vegetation		39	2	2	43	90.7
Urban	1	3	37	1	42	88.1
Non-urban		4	3	4	11	36.4
Total	5	46	42	7	100	
Producer Accuracy	80	84.8	88.1	57.1		84

5. CONCLUSION

This paper presents the result of the land use change detection of a particular study area for the period of 16 years (2003-2019). The land use land cover mapping and change detection had been done from satellite images using maximum likelihood classification pattern classification algorithm. The result from the study clearly indicates:

1. The decrease in number of vegetation and water area with the increment of urban and non-urban area between the year gaps.
2. It is clear that, urbanization is increasing gradually and therefore vegetation and grasslands are decreasing in the concerned area. The growth of urbanization also affect the decreasing rate of water.
3. Increase in non-urban area indicates the further growth of urbanization as this category includes bare land and under construction lands.

The land use map created in this study can serve as an effective managerial tool for urban planner and environmental scientists. It also gives a thorough idea about the land surface temperature as the land surface temperature is closely related to land use pattern. So the result of this study can contribute useful information for studying Land Surface Temperature (LST).

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REFERENCES:

Accuracy Assessment. Retrived from: <http://gis.humboldt.edu/OLM/Courses/GSP_216_Online/lesson6-2/metrics.html> (June 30, 2019)

Andualem, T. G., Belay, G., and Gaudie, A. (2018).

"Land Use Change Detection Using Remote Sensing Technology" J Earth Sci Climate Change 2018, 9:10 DOI: 10.4172/2157-7617.1000496

Gautam, A., P., Webb, E., L., Shivakoti, G., P., and Zoebisch, M. (2003). "Land use dynamics and landscape change pattern in a mountain watershed in Nepal" Agriculture, Ecosystem & Environment, Volume 99, Issue 1-3, October 2003, Pages 83-96 DOI:10.1016/s0167-8809(03)00148-8

Land use. Retrived form: <https://en.wikipedia.org/wiki/Land_use> (June 14, 2019)

Data analysis: Maximum Likelihood Classification. Retrieved from: <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/maximum-likelihood-classification.htm> (June 3, 2019)

Preparation of Detailed Area Plan (DAP) for DMDP Area: Group-B, RAJUK. [n.d.]. [PDF file].Retrieved from: <http://www.rajukdhaka.gov.bd/rajuk/image/dap/groupB_Report/Reports_B.pdf>

ASSESSMENT OF THE APPLICABILITY OF TANNERY SLUDGE COMPOSTING IN BANGLADESH

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ABSTRACT

Chromium rich tannery sludge can be utilized through composting though heavy metals can be leached to the surrounding environment which isn't determined yet in Bangladesh. This research is carried out to find out the suitability of prepared tannery sludge (TS) compost in terms of pH, moisture content, organic matter, NPKS (Nitrogen, Phosphorous, Potassium and Sulphur), water solubility and the extent of bioavailability of heavy metals. Tannery sludge were mixed with cattle manure and domestic waste at different ratio for composting through preparing trapezoidal shaped piles. The composting process was evaluated during 80 days with monitoring the parameters at 20 days interval. Results indicate that the organic content was reduced from 46 to 39% for the suggested pile, pH value and NPKS content was in satisfactory level for composting. In addition, the water solubility of heavy metals increased with the increasing period of composting. In this study, concentration of Zn, Ni, Cd, Cu, and Pb were far below the standard value for composting whereas the very high Cr concentration (26,558-51,182 mg/kg) during 80 days composting was found to be exceeded the standard limit. Therefore, the presence of Cr in huge amount in compost discouraged the usability of tannery sludge compost in farming in Bangladesh.

Keywords: *Chromium, bioavailability, NPKS, heavy metals, compost.*

1. INTRODUCTION

Tannery sludge is seemed to be muddy, soft and thick in nature and produced mainly from the tannery effluent treatment process. Processing of leather through tanning process evolve a large amount of waste water that carries a massive amount of suspended solids, resulting in huge amount of tannery sludge. In Bangladesh, per year 85,000 tons of wet salted raw hides and skins are utilized for tanning (Paul et al. 2013). If all tanneries ETP (effluent treatment plant) become operational, then the amount of the partly dried sludge will be nearly about 19,000 tons (Juel et al. 2017). It contains eminent concentrations of heavy metals such as Cr, As, Pb, Ni, Cu, Cd, and Zn for using different syntans, basic chromium salt, dyes, tanning agents, retanning agents, pigments etc. in the leather processing (Juel et al. 2017; Mizan et al. 2016; Alam et al. 2019). It has the capability to contaminate soil, groundwater, surface water and conferments leading to a significant threat to the natural resources and environment if it is not managed suitably (Thomson et al. 1999). These detrimental heavy metals in sludge having non-biodegradability nature, lingering biological half-lives, potentiality to accumulate in biological systems which may cause complications to human health (Juel et al. 2017; Wilson and Pyatt. 2007; Singh et al. 2004).

Due to the nature of tannery sludge there is no certain universal utilization process for sludge management in the world. A number of solution have been proposed, tested, practiced and applied for semi-pilot, pilot and industrial scale. Several studies have shown that tannery sludge can be stabilized effectively in construction materials like bricks concrete, tiles, ceramic and some other engineering materials (Montañés et al. 2014; Basegio et al. 2002; Juel et al. 2017; Giugliano and Paggi, 1985) but no one process mentioned previously have been suited and developed at certain level that can meet the industrial need. Furthermore, treatment processes of this hazardous tannery sludge is still need more attention (Alibardi and Cossu, 2016).

Proper management of solid waste ia a big challenge througout the world. In Bangladesh, generation of solid waste (Sewage sludge, domestic waste, wood-chips etc) other than tannery sludge is near about 8000 tons per day, which is enhancing with the increase of urban population. However, managing these huge amount of waste in Bangladesh is hardly observed in a organized and scientific way. Although some steps have been taken to mitigate the issue which includes the practice of waste gathering, recycling, extrusion, land filling and incineration. Among them the most common practice is to dump the tannery sludge in a land known as landfills which is not a good practice in Bangladesh due to its limited space. Further, this huge amount of sludge when dumped in land makes the soil sterile and the crops can not grow properly (Juel et al. 2017). By incineration of tannery sludge harmful gasses like greenhouse gas, carbonaceous gas etc. are produced continuously which is a threat to environment, human being and animals. Despite the gas emmision, large quantity of energy is needed for incineration which is quite impossible to support for our country in terms of cost effectiveness. In addition, it is a matter of big concern that around 50 percent of waste remains uncollected and untreated that may contaminate water, air and is also liable for greenhouse gas emission and diseases. (Anwarul et al. 2015).

On the other hand, as a low cost method and efficient solid waste management system composting is recognized worldwide. In this system, labile organic matter is degraded by biological aerobic decomposition to water vapor, carbon dioxide (CO_2), ammonia (NH_3), inorganic nutrients and stable organic substance containing humic like materials that helps to process organic matters of different sources, such as sewage sludge, animal manure, agro-industrial wastes (Dinel et al. 2004). It allows waste firstly to the reduction of mass and volume then to be disposed off providing an environment that contains nutrient rich growth medium for plants as manure. Ahmed et al. (2007) had worked on chemical and physicochemical characterization of tannery sludge compost. Their analysis shows that all necessary parameters attain comparatively stable levels providing the maturity and stability of the decisive compost, and elicited that microorganism can be spontaneously soaked by the biodegradation of components. Akinci et al. (2013) outlined about the beneficial use of tannery wastewater treatment sludge compost where the tannery sludge was composted by mixing with other wastes of tannery.

In Bangladesh, there are very rare works done on tannery sludge composting. The aim of this study is to know the applicability and suitability of composting the mixture of tannery sludge, cattle manure and domestic waste for cultivation purposes which will be evaluated by measuring NPKS concentration, organic substance degradation and total heavy metal content.

2. MATERIALS AND METHODOLOGY

2.1 Materials

2.1.1 Collection of tannery sludge, domestic waste and cattle manure

Tannery Sludge (TS) samples was collected from Superex Leather Ltd, Uttar dihi, Phultola, Khulna, Bangladesh. The collected TS was damp in condition and muddy in color. The sample was collected in clean plastic sacks. Domestic wastes (DW) were collected from Rokeya Hall, KUET that includes rotten tomato, cauliflower, ladies' finger, papaya, string bean, red amaranth, eggplant etc. Clean polyethylene bag was used for the collection of DW. Another component of the mixture, cattle manure (CM) was collected from the house of a local habitat of Teligati, fulbarigate, Khulna. Plastic sack was also used to collect the cattle manure.

2.1.2 Chemicals

For the extraction process and other tests carried out in this study, a set of analytical grade chemicals were used that includes 70% Nitric acid (HNO_3), 30% Hydrogen peroxide (H_2O_2), Concentrated sulfuric acid (H_2SO_4), Sodium hydroxide (NaOH), Boric Acid (HBO_3), Acetic acid (CH_3COOH), Barium chloride ($BaCl_2$) etc.

2.2 Methodology

2.2.1 Composting

The collected tannery sludge was crushed to make small in particle size and domestic waste were cut into small pieces to make suitable for composting. TS, DW and CM were mixed thoroughly at a distinct ratio for different piles. Ratios of mixture of tannery sludge: cattle manure: domestic waste were 4.5: 4.0: 1.5 (Pile 1); 6.0: 3.0: 1.0 (Pile 2); 10.0: 0: 0 (Pile 3). All the piles were maintained for a fixed measurement, environment and formed a trapezoidal shape with 70cm long, base width 25cm, and top (height) width 30cm. Pile 3 have been considered as the control pile for composting. The total period of composting was decided for 80 days. Every pile was agitated and turned manually after every 10 days from the beginning and agitated piles contained approximately 50 kg of different waste combinations. The similar method for composting was followed by some authors (Singh et al. 2013; Das and Kalamdhad, 2011; Dhal et al. 2012). The samples for chemical test and analysis were collected after every 20 days.

2.2.2 Sample analysis

2.2.2.1 pH, EC and TDS, moisture content, organic content determination

Collection of compost sample for test was done by taking sample from five different positions of the prepared pile with the help of a sampler. After sampling, all five samples were mixed thoroughly for its homogenization and baked at 105°C for 24 hours. This dried sample was used for the determination of moisture content and organic content. 10g of dried sample was taken and diluted to 100ml by distilled water in a conical flask which was covered and kept in a shaker for 2 hours at 120 rpm for determining pH, EC and TDS. Another10gm of sample was taken in the crucible and kept in the oven at 105°C for 24 hours. The sample was cooled, stored in a desiccator for 15 minutes and finally weighted for moisture content determination. Then another dried sample was kept in a furnace at 550°C for 2 hours. The sample was cooled and stored in a desiccator and finally weighted for organic content determination.

2.2.2.2 Water Solubility Determination

Ground and powdered 2.5gm of sample was weighted and diluted with 50ml of distilled water for maintaining sample and solution ratio at 1:20. Then the container was kept in a shaker at 100rpm for 2hours to determine the solubility of compost in the water (Singh et al. 2013).

2.2.2.3 Heavy metal Determination

In a beaker, 1g dried compost sample was taken. 10 mL of HNO_3 was mixed in the sample and covered with watch glass. Then heat was applied in the sample at 95 ± 5°C and refluxed for 15 minutes except boiling. Then 5 mL of conc. Nitric acid was added and again refluxed for 30 mins. The addition of 5 mL HNO_3 was continued until no brown fumes were evolved from the sample. Brown fumes indicate incompletion of digestion procedure with HNO_3. Again, by covering the sample with watch glass, it was heated at 95°C ± 5°C for two hours to reduce the volume of the solution to approximately 5 ml. Sample was cooled to add 2 mL water and 3 mL 30% H_2O_2 and warmed for initiating peroxide reaction. Successive addition of H_2O_2 (not more than 10mL of H_2O_2) was continued with warming until the effervescence was minimal or the sample appearance was unchanged. When the peroxide reaction seemed to be completed, final sample volume was reduced to 5 mL by applying heat. Then the sample was allowed to cool, diluted with water and filtered through a 0.45 µm filter paper (Juel et al. 2017). Cr, Zn, Cu, Ni, Cd and Pb concentration were determined by Atomic Absorption Spectrophotometer (AAS) (Shimadzu AA 7000).

2.2.2.4 NPKS Determination

Dried and ground 30g of sample was taken for NPKS determination by following Kjeldahl method (Nitrogen analysis), Flame Photometer or by an Atomic Absorption Spectrophotometer method (Potassium analysis), Ascorbic acid method (Phosphorous analysis) and Turbidity metric method (Sulphur analysis).

3. RESULTS AND DISCUSSIONS

3.1 Physico-chemical characteristics of the compost

Figure 1 depicts the pH variation of the different piles of compost which ranges from 6.7 to 8. The optimum pH for the development of bacteria and mold are 6.0–7.5 and 5.5-8.0 respectively (Amir et al. 2005). Initially (1-20 days) the pH was slightly higher for all piles, exceptiionally high pH was observed for pile 1 upto 20 days in this study. This increase of pH might occur due to the release of NH_3 during composting from the degradation of protein because this pile contained the highest percentage of proteinous organic matter which is in the agreement with other research (Singh et al. 2013). This increasing trends ceased at 40 days and followed a constant pH around 7.4 for all of the piles. Whereas, for pile 3, sudden pH fall (6.7) was observed at 40 days which might be the result of formation of CO_2 and organic acids evolved from the microbial metabolism, although this pH is not harmful for composting (Haimi and Hutha, 1986). In addition, adequate aeration was supplied in all piles through turning the piles by maintaining 10 days interval as such level of CO_2 decreased which forced to increase pH in the compost and made an obligation to proceed anaerobic conditions (Haug et al. 1993).

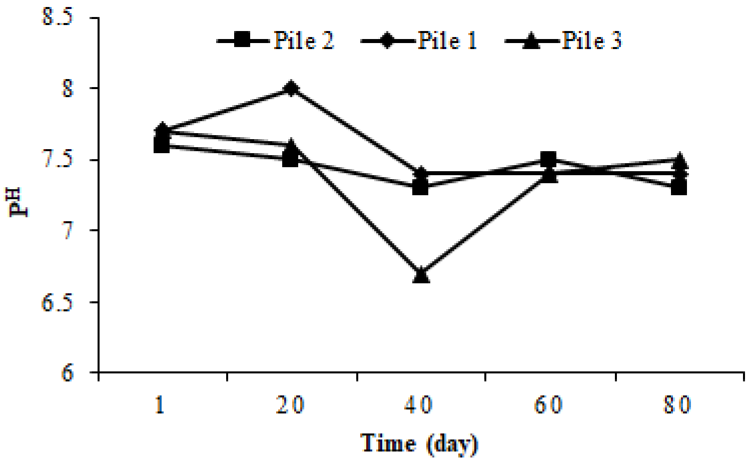

Figure 1: Variation of pH during composting process

Moisture content variation is shown in figure 2. Initial moisture content of TS, CM and DW were 59%, 74% and 91% successively (table 1). In pile 1, 2 and 3, MC were 71.30%, 67.30%, and 61% which reduced to 55%, 48%, and 48.57% after the whole period of composting (80days) respectively. The trend of moisture content loss is almost same for all of the piles and order of MC for the three piles in this study is following: pile 1>pile 2> Pile 3. That implies that high proportion of CM and DW led to increase the moisture content of compost. However, optimum MC for composting was observed for all piles. In this research, moisture content of pile 1, 2, and 3 was in a decreasing order which is in congruence with the other study (Amir et al. 2005).

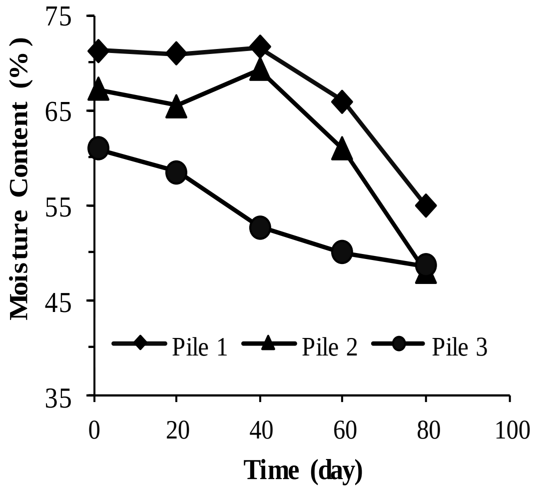

Figure 2: Variation of moisture content with period of composting for different piles.

Organic matter which is the most significant part of a compost due to its nutrient value were in the range 32-48% (Figure 3). From the figure 3, the organic content decreases with the increase of days of composting. The loss of organic content took place for the decomposition and transformation of organic matter. During composting, organic matter is also converted into stable humic compounds (Amir et al. 2005) which is considered as a potential source of nutrients and poses the pH buffering capacity and also capable to interact with inorganic metal ions (Singh et al. 2009). In this research, the lowest organic content was found for pile 3 (32%). A significant organic matter loss was noticed for all the piles (Figure 3). However, the organic content was in suitable conditions for all the piles in this work. Similar result was found by other research of composting (Singh et al. 2013).

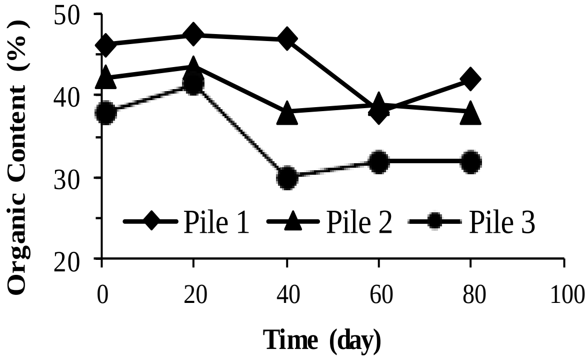

Figure 3: Variation of organic content with period of composting for different piles.

Nitrogen, phosphorous, potassium and sulphur are the vital element of plants and vegetables. Nitrogen helps in making structure of protein inside plants and assist the photosynthesis process, when phosphorous acts as the key structure compounds and catalysts for inner biochemical reaction in plants, phosphorous and sulphur are responsible for plants growth (Othman et al. 2012). Figure 4 represents the NPKS concentration of 80 days compost. In this study, 0.64 - 0.94 mg/kg N, 5.6 – 13 mg/kg P, 18 – 27 mg/kg K, and 13 – 22 mg/kg of S were noticed in the prepared compost which is suitable for the plant's nutrition. The amount of NPKS in pile 1 were 0.90, 6.20, 27, and 22 mg/kg respectively, which is higher than pile 2 and 3 because of the high amount of organic matter in pile 1 with respect to pile 2 and 3 except for the nutrient P in pile 3. The high amount of P in pile 3 might be happened for the high content of P in tannery sludge. The probable source of P may be the use of salt during leather processing.

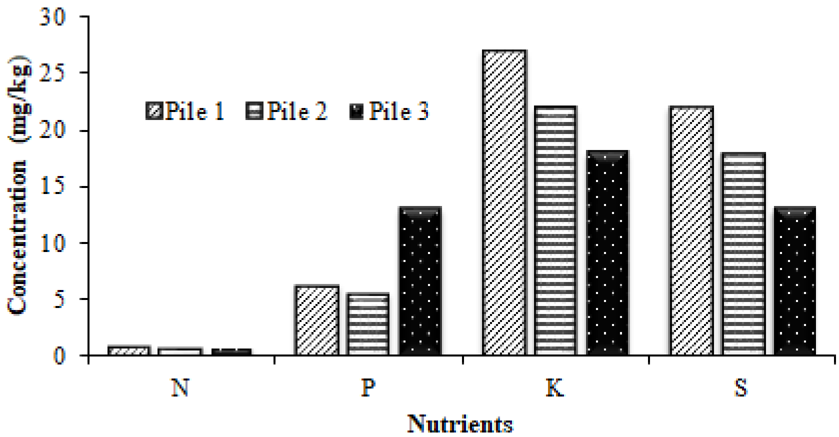

Figure 4: Concentration of NPKS after 80 days.

Table 1: Characterization of tannery sludge, cattle manure and domestic waste.

Ingredients	Moisture content (%)	pH	Organic content (%)	Electrical conductivity (µS)	Total Dissolve Solid (mg/L)
TS	59	5.8	36	1167	535
CM	74	6.2	45	1357	624
DW	91	6.7	85	678	540

Table 2 illustrates electrical conductivity of the compost with respect to time. It has been revealed that a decreasing order of EC in pile 1 is observed up to 60 days but increased during 80 days composting. After 60 days, the organic content loss was noticed more than 80 days composting (Figure 3) which signifies that the organic matter converted into humic substances and interacted with the metal ion to form compound that led to lowering the EC. On the other hand, during 80 days for pile 1 and 2, the organic matter increases somehow that prompted to increase in EC. Further, an increasing trend of EC was found for pile 3 as this pile consists of TS which contain a huge amount of inorganic substances.

Table 2: Variation of EC (µS) during composting process.

Pile	**No of days**				
	01	20	40	60	80
Pile 1	1199	934	862	727	828
Pile 2	996	822	876	892	1134
Pile 3	850	973	1555	1383	1042

The TDS of tannery sludge, cattle manure and domestic waste were 535, 624, 540 mg/L (table 1). During composting, TDS followed a lowering trend upto 60 days for pile 1 and 2 (Table 3) while TDS value maintained the increasing order for pile 3 ranging 455 to 668 mg/kg during 60 days. Interestingly, during 80 days TDS value for pile 1 and 2 increases, whereas for pile 3 the value decreases from 668 to 555 mg/kg (Table 3).

Table 3: Variation of TDS during the composting process (all values are in mg/kg).

Pile	**01**	**20**	**40**	**60**	**80**
Pile 1	535	443	413	396	563
Pile 2	453	398	424	403	506
Pile 3	455	463	744	668	555

Concentration of heavy metal during 80 days composting is focussed in table 4. It is revealed that Cr concentration in pile 1, 2, and 3 was found to be 26,558 to 51,182 mg/kg, which exceeded the standard limit 900 mg/kg set by DoE, Bangladesh of 2nd grade compost for sludge. Ni, Pb, Zn, and Cu concentration were within standard limit. The heavy metal Cd is also above the set standard limit showing risk for compost utilization. The availability of this high amount of Cr is for the use of basic chromium salt in leather tanning which make a huge Cr containing effluent that is being discharged in the effluent treatment plant. Thus the main challenge for the composting by tannery sludge is the enormous concentration of Cr in compost.

Table 4: Concentration of heavy metals (mg/kg) after 80 days

Pile	**Cr**	**Pb**	**Zn**	**Cd**	**Cu**	**Ni**
Pile 1	26558	28	1031	12	23	4
Pile 2	44320	57	1424	32	35	6
Pile 3	51182	77	1750	51	42	9
Standard[a]	900	900	2500	10	800	200

[a]DoE, Bangladesh, 2015

Table 5 elucidate about the water-soluble metal concentration during 80 days composting. From the table 5, only the metal Cr for pile 1 and 2 possessed the higher solubility in water. Solubility in water increases the probability of heavy metal contamination in surface water, food chain and leaching to the ground water which may lead bioaccumulation further (Liu et al. 2008). The solubility of metal Zn, Cd, and Ni were in negligible amount after the composting period in this research. Pb and Cu were not found to be soluble with water in any piles of compost during 80 days. This result is in the agreement with other study (Singh et al. 2012).

Table 5: Concentration of water-soluble metals (mg/kg) during 80 days

Pile	Cr	Pb	Zn	Cd	Cu	Ni
Pile 1	5.88	ND	0.12	0.56	ND	0.28
Pile 2	29.64	ND	0.56	ND	ND	ND
Pile 3	1.56	ND	0.06	0.46	ND	0.06

ND = Not Detectable; detection limit = >0.001mg/L

4. CONCLUSIONS

The tannery sludge that is housed with extra chromium has the probability to cause severe environmental burden by polluting surface water, groundwater, soil etc. This study was an approach to prepare compost by which tannery sludge can be utilized to a large extent in Bangladesh. Considerably higher levels of major nutrients NPKS were found in compost compared to chemical fertilizer and compost prepared by respective organic wastes for plant growth. The observed pH, moisture content was in a well manner for composting. Organic content which plays a vital role in the composting and plant growth mechanism also was in line. But the heavy metal concentration of prepared compost after 80 days especially Cr was manifold (30) greater than the standard permissible limit set by DoE, Bangladesh. Furthermore, the high concentration and water solubility of Cr discouraged the use of tannery sludge compost in farming and plantation. The reason for higher concentration of heavy metal Cr may be due to the initial higher concentration of Cr present in tannery sludge. However, if the initial concentration of heavy metal in tannery sludge can be reduced by means of onsite Cr removal or any other process then composting by this process may bring attention to apply in agricultural purpose.

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REFERENCES

Ahmed, M., Idris, A. and Omar, S.R.S. (2007). Physicochemical characterization of compost of the industrial tannery sludge. *J. Eng. Sci. Technol*., **2**, (1) 81-94.

Akinci, G., Dikmelik, Y., Kaman, Y.N. (2013). Composting and Beneficial Use of Tanner Wastewater Treatment Sludges DOI: 10.1016/j.compag.2013.07.006.

Alam, M.S., Han, B., Al-Mizan. and Pichtel. J. (2019). Assessment of soil and groundwater contamination at a former Tannery district in Dhaka, Bangladesh. Environ. Geochem. Health. https://doi.org/10.1007/s10653-019-00457-6.

Alibardi, L. and Cossu, R.. (2016). Pre-treatment of tannery sludge for sustainable landfilling. Waste Manage. 52, 202–211. http://dx.doi.org/10.1016/j.

Amir, S., Hafidi, M., Merlina, G. and Revel, J.C. (2005). Sequential extraction of heavy metals during composting of sewage sludge. *Chemosphere*, **59**, 801–810. DOI: 10.1016/j.chemosphere.2004.11.016.

Basegio, T., Berutti, F., Bernardes, A., Bergmann, C.P. (2002). Environmental and technical aspects of the utilisation of tannery sludge as a raw material for clay products. J. Eur. Ceram. Soc. 22, 2251–2259. http://dx.doi.org/10.1016/S0955-2219(02)00024-9.

Das, A. and Kalamdhad, A.S. (2011). Evaluation of water hyacinth compost stability using respirometric techniques. *Int. J. Res. Chem. Environ.*, **1** (1), 109-113. DOI: 10.4491/eer.2012.17.2.069

Dhal, G.C., Singh, W.R., Khwairakpam, M. and Kalamdhad, A.S. (2012). Composting of water hyacinth using saw dust/rice straw as a bulking agent. *Int. J. Environ. Sci.*, **2** (3), 1223-1238. doi:10.6088/ijes.00202030009

Dinel, H., Marche, T., Schnitzer, M., Pare, T. and Champagne, P. (2004). Co–composting of paper mill sludge and hardwood sawdust under two types of in–vessel processes, Journal of Environmental Science and Health, Part b: Pesticides, Food Contaminants and Agricultural Wastes, Vol. 39 (1), 2004, 139–151. DOI:10.1081/pfc-120027445.

DoE, Bangladesh, (2015). Bangladesh Standards and Guidelines for Sludge Management.Liu, S., Wang, X., Lu, L., Diao, S. and Zhang, J. (2008) Competitive complexation of copper and zinc by sequentially extracted humic substances from manure compost. Agr. Sci. China, 7 (10), 1253-1259.

Giugliano, M., Paggi, A. (1985). Use of tannery sludge in brick production. Waste Manage. Res. 3, 361–368. http://dx.doi.org/10.1016/0734-242X(85)90129-6.

Haimi, J. and Hutha, V. (1986). Capacity of various organic residuesto support adequate earthworm biomass in vermicomposting.*Biol. Fertil. Soils,* **2,** 23–27.

Haug, R.T. (1993). The practical handbook of composting engineering. Lewis Publishers, Boca Raton. DOI: https://doi.org/10.1201/9780203736234

Juel MAI, Mizan A. and Ahmed T. (2017). Environmental and technical aspects of recycling of tannery sludge in brick production, 5th International Conference on Solid Waste Management in South Asian Countries.

Juel MAI, Mizan A. and Ahmed T. (2017). Sustainable use of tannery sludge in brick manufacturing in Bangladesh, 60, 259-269. DOI: 10.1016/j.wasman.2016.12.041

Kalamdhad, A.S., Singh, Y.K., Ali, M., Khwairakpam and Kazmi, A.A. (2009). Rotary drum composting of vegetable waste and tree leaves. *Bioresour. Technol.*, **100,** 6442–6450. DOI: 10.1016/j.biortech.2009.07.030

Mizan, A., Zohra, F.T., Ahmed, S., Nurnabi, M. and Alam, M.Z. (2016). Low cost adsorbent for mitigation of water pollution caused by tannery effluents at Hazaribagh. *Bangladesh J. Sci. Ind. Res.* 51(3): 215-220.

Montañés, M.T., Sánchez-Tovar, R. and Roux, M.S. (2014). The effectiveness of the stabilization/solidification process on the leachability and toxicity of the tannery sludge chromium. J. Environ. Manage. 143, 71–79. DOI: 10.1016/j.jenvman.2014.04.026

Othman, N., J.M. Irwa, N. and Roslan, M.A. (2012). Composting of food waste, International Journal of Integrated Engineering, Vol. 4 (2), 2012, 39–48.

Paul, H.L., Antunes, A.P.M., Covington, A.D., Evans, P. and Phillips, P.S. (2013). Bangladeshi leather industry: an overview of recent sustainable developments. SLTC J. 97, 25–32.

Singh, CR ., He, H.,Yamamoto, Y. and Asano, K. (2004). Efficient incorporation of eukaryotic initiation factor 1 into the multifactor complex is critical for formation of functional ribosomal preinitiation complexes in vivo. *J Biol Chem* 279(30):31910-20

Singh, J. and Kalamdhad, A.S. (2013). Bioavailability and leachability of heavy metals during water hyacinth composting, Chemical Speciation & Bioavailability, 25:1, 1-14.DOI: 10.3184/095422913X13584520294651.

Singh, S.; Kushwaha, B. P. ; Nag, S. K. ; Mishra, A. K. ; Singh, A. ; Anele, U. Y. (2012). *In vitro* ruminal fermentation, protein and carbohydrate fractionation, methane production and prediction of twelve commonly used Indian green forages. Anim. Feed Sci. Technol.,178 (1/2): 2-11

Singh, Y.K., Kalamdhad, A.S., Ali, M. and Kazmi, A.A. (2009). Maturation of primary stabilised compost from rotary drum composter. *Resour. Conserv. Recycl.,* **53,** 386–392. DOI:10.1016/j.resconrec.2009.02.004

Thomson, J.C., Azariah, J., Viji, A.G.R. (1999). Impact of textile industries on river Noyyal and riverine groundwater quality in Tirupur, India. Environ. Monit. Assess. 18, 359–368.

Wilson, B., Pyatt, F.B. (2007). Heavy metal dispersion, persistence, and bioaccumulation around an ancient copper mine situated in Anglesey, UK. Ecotoxicol. Environ. Saf. 66, 224–231. DOI: 10.1016/j.ecoenv.2006.02.015.

COMPARATIVE STUDY OF FAECAL SLUDGE TREATMENT METHODS EMPLOYED IN THREE MUNICIPALITIES OF BANGLADESH

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ABSTRACT

Onsite sanitation and disposal of human wastes are largely unregulated in Bangladesh. According to a field survey, the annual faecal sludge generation in Khulna, Jhenaidah and Kushtia municipalities had been found to be 710000 m3, 58705 m3, and 104581 m3, respectively. In order to reform the way that human waste is being disposed of safely in these municipalities, faecal sludge treatment plants (FSTPs) have been constructed and already started their operations. The main aim of this study is to identify and compare the methods adopted in these treatment systems. In Khulna & Jhenaidah FSTPs, constructed wetland systems comprising vertical flow followed by subsurface horizontal flow treatment process have been adopted. Moreover, unplanted drying beds are used to collect dry sludge for bio-energy. Nevertheless, Kushtia municipality has developed the FSTP involving sludge settling-drying bed with co-composting facilities and coco-peat filter. Field and laboratory investigation have been carried out for determining the treatment efficiency of these FSTPs. Infrastructural failure has been detected in wetland walls due to settlement of soil and infestation of foxes in Jhenaidah FSTP. While, plantation damages in vegetation system caused by burrowing animals is found in Khulna FSTP. In all three FSTPs, BOD_5 and Total Solids removal efficiency were over 95% and 97%, respectively and fecal coliform never exceeded the allowable limit 1000 N/100ml in final effluent. Kushtia FSTP is earning profit by selling co-compost and now planning to develop a local compost market.

Keywords: Faecal sludge treatment, Constructed wetlands, Drying beds, Coco-peat filter.

1. INTRODUCTION

Sanitation is a vital piece of health and development around the world. The lack of safe sanitation access has profound implications worldwide. The consequences of almost 2.6 billion people in the world using unsafe toilets or practicing open defecation are devastating to their health and to their financial and personal well-being (Chowdhary & Kone, 2012). It also contributes to the fact that 0.7 billion people worldwide do not have access to safe drinking water, as precious water is polluted with the people's own excreta (Harada et al., 2016). In response to the lack of access to sanitation, the United Nations defined the target of Goal 17 of the Sustainable Development Goals (i.e., SDGs) to halve the proportion of the population without access to improved sanitation facilities during the period from 2015 to 2030 (United Nations, 2019). Worldwide there is an increasing interest and awareness of faecal sludge management (FSM) issues, particularly in Africa and Asia (Oxfam, 2016; WRC, 2015). Bangladesh is a striking example of the rapid progress in access to sanitation where open defecation has been reduced from 29% in 2000 to 1% in 2017 (UNICEF & WHO, 2019). However, the inability to sustain use of existing toilets and unsafe disposal of faecal sludge pose the next challenge in improving health and economic situation of urban populations. The national regulatory framework demands the City Corporations/Municipalities to take the responsibility of FSM but it is not being done due to lack of proper understanding of the subject and lack of resources. As a result, accumulated sludge overflows into nearby drain and causes dangerous impact on public and environment health. The water and faecal born disease burden are higher in urban slums than rural areas mostly due to unhealthy and unhygienic conditions from poor sanitation (Stevens et al., 2015).

Faecal sludge (FS) needs to be safely contained onsite, and then the accumulated faecal sludge needs to be safely emptied, transported to a treatment plant, treated, and used for resource recovery or disposed of safely (Harada et al., 2016). There are plenty of technologies available to treat FS; however, the same level of operational information is not available to all of them based on their different levels of implementation. FS treatment technologies that are covered in an operational level of detail are settling tanks, unplanted drying beds, planted drying beds, co-treatment with wastewater, co-composting of FS together with municipal solid waste; co-treatment of FS in waste stabilisation ponds; and deep row entrenchment (Ronteltap et al., 2014). Onsite sanitation and disposal of human wastes are largely unregulated in Bangladesh. In response to this situation, many innovations have been started to contribute to faecal sludge management properly. According to a field survey, the faecal sludge volume generated in Khulna, Jhenaidah and Kushtia municipalities were found to be 710,000 m^3; 58,705 m^3; and 104,581 m^3 per year, respectively (SNV, 2018). In this context, various methodologies have been employed for the establishment of faecal sludge treatment plants (FSTPs) in these three municipalities. Constructed wetland systems along with drying beds have been adopted in Khulna & Jhenaidah FSTPs while sludge settling-drying bed with coco-peat filter technique is used in Kushtia FSTP. The goal of this study is to deliberate in details the different methods implemented in these FSTPs and compare their performance with regards to treated effluent quality as well as operation and maintenance (O & M) aspect.

2. METHODOLOGY

2.1 Study area

The location of study FSTPs are in Khulna, Kushtia, and Jhenaidah. Khulna is the third largest industrial city of Bangladesh with a density of 32,859 persons per square km (KCC, 2019). Khulna FSTP is located at Rajbandh-2 which is 4 kilometers distance from the "Zero Point" of KCC. The plant covers an area of 4500 m^2 and adopts constructed wetlands system. Kushtia Municipality is a Class 'A' Municipality with 42.79 sq.km area and 3, 75, 149 population. Kushtia FSTP is located at Baradi and adopts faecal sludge settling-drying beds system. Jhenaidah Municipality is a Class 'A' Municipality with nine wards and an area of 32.4 square km. The population of Jhenaidah is 157,822 with a density of 3,987 per square km (FSM Survey, 2014). Jhenaidah FSTP is located at Nagarbathan and adopts constructed wetlands system with drying beds. The location of the study area is presented in Khulna division map.

Figure 1: Khulna Division Map

2.2 Case scenario

2.2.1 Scenario 1- Khulna FSTP:

For faecal sludge treatment, there are constructed wetlands and drying bed system Faecal Sludge Treatment Plant (FSTP) at Khulna which has been designed to treat up to 15% of total generated faecal sludge (SNV, 2018). Khulna FSTP built in 2017 with 6 units CW (constructed wetlands) as pre-treatment, 2 units of percolate CW as post-treatment and 6 units drying beds. The CW for FS is designed for 6 units of VF (vertical flow) type that are planted with emergent macrophytes. It has capacity to receive 30 m^3 (average) FS per day per bed, which is collected from septic tank and peat latrine. At first raw FS is emptied from the tanker into the screening chamber to remove any grit and debris. FS from the chamber enters into the respective constructed wetland. Leachate from the constructed wetland then flows under gravity to the planted filter bed for further treatment. Then raw FS from CW is discharged into the unplanted sludge drying beds. Leachate from the unplanted drying bed is then flows into planted filter bed for further treatment. The bed is filled to its full capacity and is kept for drying for 2-3 weeks. After the sludge is dried, it is collected for composting or briquette production. Further treated leachate from UPDB and CW in the planted filter bed post treatment is discharged into the canal in Khulna FSTP. Figure 2 illustrates a flow diagram of treatment mechanism of constructed wetland process in FSTP.

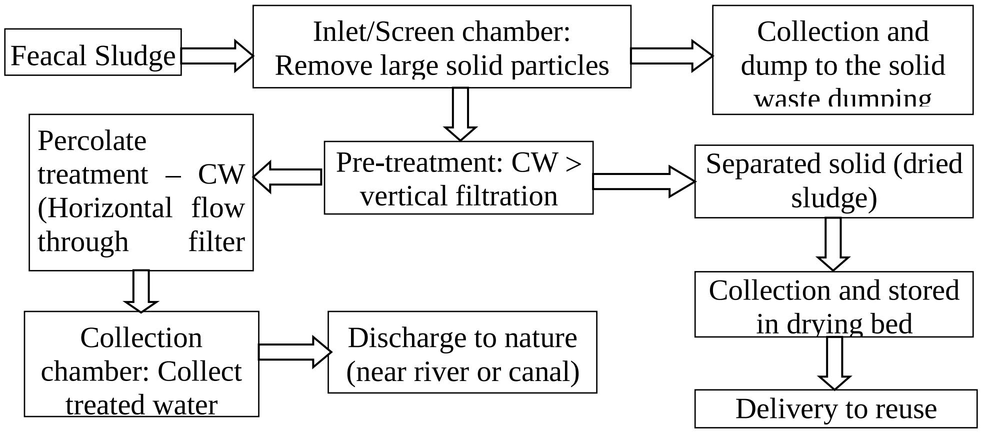

Figure 2: Flow chart of FS constructed wetland plant

2.2.2 Scenario 2- Jhenaidah FSTP:

Another planted wetland system for fecal sludge treatment was built at Jhenaidah municipality in 2012 but never been operated. Furthermore, this FSTP was renovated with 5 units CW (constructed wetlands) and 3 units drying beds in 2016 which has got the capacity to treat up to 18% of total generated faecal sludge (SNV, 2018). CW enables to receive 36 m^3 FS per day in average. Solid particles are removed by filtration and gravitational settlement in planted CW. Percolate from CW treating FS is further treated by unplanted CW. Finally treated effluent from UPDB and CW in the planted filter bed post treatment is discharged into a stream of Nabhaganga river in Jhenaidah FSTP. The tratment technology used for Jhenaidah FSTP has been mentioned in Figure 2.

2.2.3 Scenario 3- Kushtia FSTP:

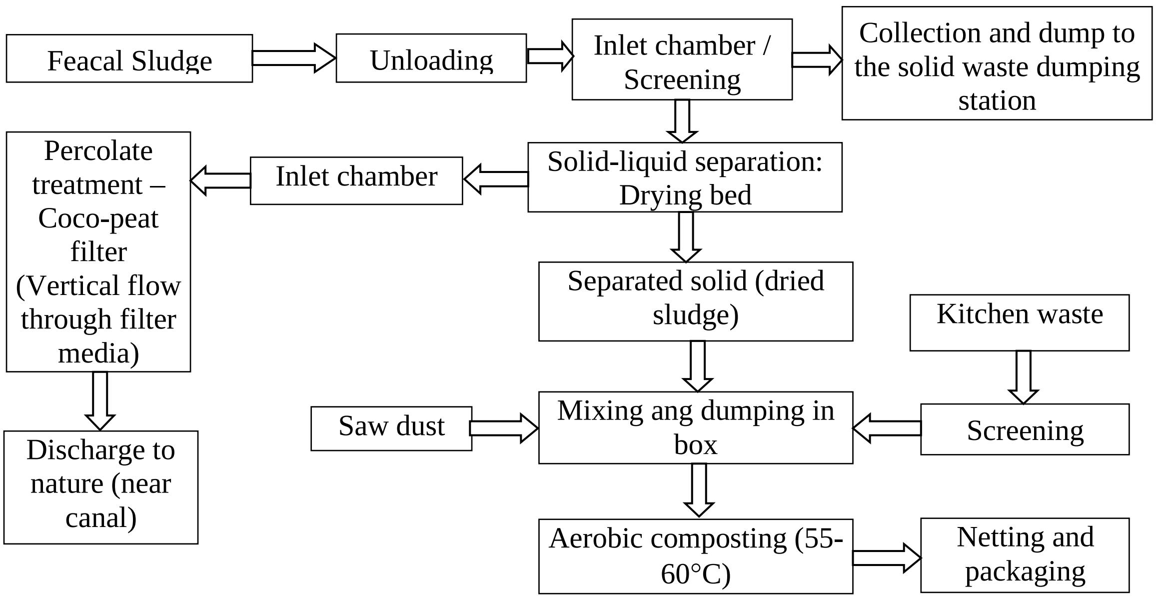

Figure 3: Flow chart for FS and Kitchen waste co-composting process

Kushtia municipality started managing faecal sludge though co-composting technology since 2012. FSTP have two drying bed and capacity of the two bed is about 18 m3 (9*2 m3) per day in 2 drying bed as input and 9-ton compost as output per month. Faecal sludge collected by vacutugs from municipality area is taken to FSTP for its proper treatment. Faecal sludge which is dumped to the drying beds is used for dewatering. After dewatering process, the percolate is transferred into the connected percolate tank. The percolate is pumped into the cocoa peat filtration unit for further treatment. On the other hand, municipality also collects kitchen waste from individual household and dumping at FSTP site. After screening of kitchen waste, it is dumping with semi dry sludge and other materials for co-composting in a box. Ratio of compost production materials is 40% faecal sludge, 55% kitchen waste and 5% saw-dust of each dumping box. It was needed to take 40-45 days for decomposition of biodegradable organic matters and in this process different layer had been overturned @ 10-15 days interval for ensuring better aeration. Temperature around 55-60°C had been maintained for the removal of pathogen and finally the end product was collected. Figure 3 shows the flow chart of scenario-3.

2.3 Sample collection and laboratory tests:

Inlet and outlet samples were collected from each of three municipalities FSTPs. After collection, samples were transported to laboratory following standard methods for testing different water quality parameters. Detailed laboratory tests were done to determine the effectiveness of the treatment unit. The performances of the treatment unit were analysed with respect to various water quality parameters such as BOD_5, NO_3, TS, TSS TC and FC following standard methods as shown in table 1.

Table 1: List of Water Quality Parameters for Laboratory Analysis

Serial No.	Water Quality Parameters	Standard Methods (SM) of Analysis
1	Biochemical Oxygen Demand (BOD_5)	SM 5210 B
2	Total Solids (TS)	SM 2540 B
3	Total Suspended Solids (TSS)	SM 2540 D
4	Nitrate (NO_3)	SM 4500 NO_3 E
5	Total Coliform (TC)	SM 9222 B
6	Fecal Coliform (FC)	SM 9222 D

3. RESULTS AND DISCUSSION

The laboratory test results reveal the present condition of faecal sludge treatment plant and its level of treatment efficiency. Table 2 represents the quality of inlet and outlet samples which is collected from Khulna, Jhenaidah and Kushtia FSTPs. The raw faecal sludge (influent) was very high in organic load, nutrients and pathogens. One of the objectives of this study is to check the removal efficiency of the harmful contaminants from wastewater before discharging it to nearby watercourses. To check this, the allowed standard value for disposal into inland surface water bodies of these water quality parameters are also listed in Table 2 for comparison (ECR, 1997) and it shows that all important parameters are within the ECR'97 limits. Figure 4 shows the treatment efficiency of the three FSTPs to evaluate the effectiveness of the adopted methodologies. Biochemical Oxygen Demand (BOD_5) is employed to determine the removal of biodegradable organic substances due to microbial decomposition. The standard value of BOD_5 for disposal to inland water bodies is 40 mg/L. From figure 4, it is clear that after the treatment of raw faecal sludge the removal efficiency of BOD_5 in all cases was found to be over 95%. Further from table 2, it is clear that total solids and total suspended solids in treated water had been decreased remarkably after treatment in each case. Total solids concentrations were found to be approximately 97% reduced after final percolate treatment in three FSTPs. Nevertheless, total suspended solids in Kushtia FSTP was found to be 90 mg/L which also satisfied the standard limit 100 mg/L (ECR, 1997) for disposal into inland water bodies but it is very close to standard limit.

Table 2: Results of influent and effluent water quality from FSTPs

Parameters	Units	Khulna FSTP		Jhenaidah FSTP		Kushtia FSTP		Standard limit (*ECR 1997)
		Inlet/ Raw sludge	Outlet/ Final treated	Inlet/ Raw sludge	Outlet/ Final treated	Inlet/ Raw sludge	Outlet/ Final treated	
BOD_5	mg/L	615	22	895	32.5	844	37.5	40 mg/L
Total Solids	mg/L	72870	484	47260	410	48420	1140	---
Total suspended solids	mg/L	29010	40	18904	50	19368	90	100 mg/L
NO_3	mg/L	94	2.96	176	1.8	163	22	250 mg/L
Total coliform	N/100 mL	180000	460	174000	760	152000	430	---
Fecal coliform	N/100 mL	120000	140	121000	240	105000	210	1000N/ 100mL

* ECR 1997: The Environmental Conservation Rules (1997) for Wastewater Disposal into Inland Surface Water Bodies

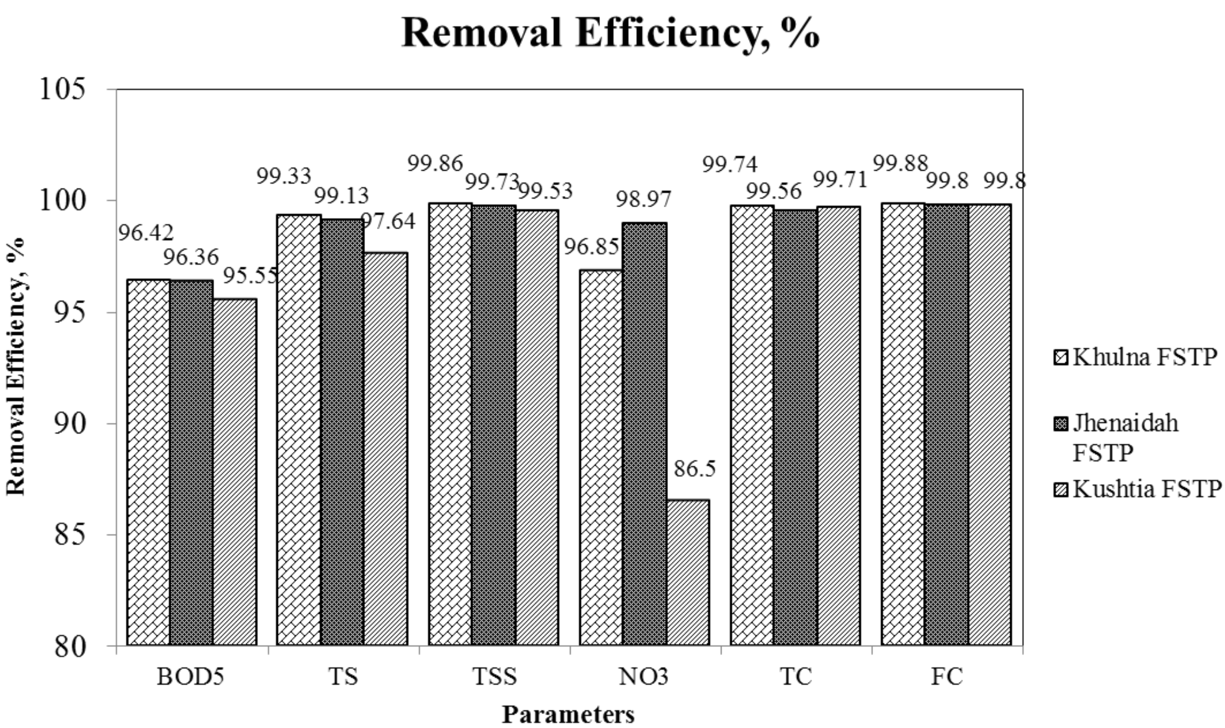

Figure 4: Treatment efficiency of three FSTP

Table 3: Operation and maintenance assessment of three FSTPs

Operation and Maintenance	Action/Notice		
	Khulna FSTP	**Jhenaidah FSTP**	**Kushtia FSTP**
1) Screening/ unload			
Racking of garbage	Yes (Irregularly used). Bar screening is irregularly used to separates garbage from influent. However, sometimes screening is not used because of clogging due to highly concentrated faecal sludge and other pollutants.		Yes Locally made plastic container screen is used to separate garbage from influent
Collection of garbage	Yes. Garbage entrapped in screening are collected. If garbage is not collected, it clogs the filter media.		
Cleaning	Yes. Collected garbage is cleaned before use.		
2) Storage and Mixing			
Mixing condition	No. Mixing is not done at FSTP	No. Mixing is not done at FSTP	Yes Dry sludge is mixed with kitchen waste.
Pumping condition	Yes. Influent discharges to the CWs by pumping.	Yes. Influent discharges to the CWs by pumping.	Yes. Influent faecal sludge is pumped to settling tank.
3) Feeding for CW	Full capacity is not utilized due to receiving small volume of faecal sludge.		X
4) Feeding for Unplanted CW/DB	Depending on concentration of influent	Unplanted CW is using as primary percolator due to CW infrastructural failure	Exceed the feeding capacity in drying bed
5) Plant monitoring	Canna and Heliconia have plenty growth.	No plantation right now because of CW infrastructural failure and clogging of filter media	X
6) Retaining of percolate water	Meet ECR’97 standards	Clogging occurs in CW	Meet ECR’97 standards
7) Plant harvesting	Cutting and taking the debris out	Replantation is required	X
8) Nuisance of animal	Burrowing animals have been identified in cutting down HDPE sheet.	Foxes are making hole in CW walls	No infestation of animals
9) Sludge harvesting			
Drying Bed	Yes For briquette production	Yes Collecting for reuse	Yes For co-composting

For nitrate (NO_3), after final treatment, the removal efficiency was found to be 96%, 86% and 98% respectively, in Khulna, Kushtia and Jhenaidah FSTPs. The acceptable limit for nitrate disposal is 250 mg/L (ECR’97). Although, the treated effluent for all three FSTPs had far less nitrate than the standard value but Coco-peat filter process in Kushtia FSTP showed lower removal percentage with 22mg/L nitrate in final effluent. Furthermore, all three FSTPs had remarkable performance for the removal of microorganisms (TC & FC). According to Environmental Conservation Rules, 1997, the number of coliform counts must be within 1000 per 100 mL of disposing water and FSTPs final treated samples always meet that the standard limit. Treated final effluent from all three FSTPs clearly denoted that the water quality parameters have been improved significantly. The removal efficiency in both constructed wetland methods and coco-peat filter was over 90%.

A field survey was done to illustrate and compare the operation and maintenance of the treatment technology used in three FSTPs. Based on field observation; it seems that clogging is the most common problem due to irregular/avoiding screening operation before loading into constructed wetlands. Therefore, the influent does not well settle with primary treatment before flowing into the wetlands. Infrastructural failure and soil settlement took place frequently within 2-3 years. That's why proper maintenance deemed very important for fruitfully carrying out the treatment methods. Composting is the most common resource recovery method from faecal sludge as an organic fertilizer and soil conditioner; as the organic matter increases the water retaining capacity of soil and contains essential plant nutrients (Cheng et al. 2017). There is other resource recovery scheme like briquette production in Khulna FSTP which needs to explore proper market channel.

The initial operations of all three FSTPs have to be confirmed by unobstructed flow of sludge which is free of grit or garbage. In Khulna and Jhenaidah FSTPs, bar screening is irregularly used because of clogging due to highly concentrated faecal sludge and other pollutants. In Jhenaidah FSTP, unplanted constructed wetland is used for primary treatment of raw sludge and replantation is required in constructed wetlands due to infrastructural failure. In present condition, the estimated volume of faecal sludge is not coming to Khulna and Jhenaidah FSTPs that's why all beds cannot be used equally. On the contrary, in Kushtia FSTP, the capacity of raw sludge treatment is exceeding and the rest of the faecal sludge is being released into a pond near the plant. Moreover, maintenances of all operations in FSTPs are very important to hold on which would confirm the long-term sustainability.

4. CONCLUSIONS

Two different cases of faecal sludge treatment plants (FSTPs): Constructed Wetlands (CWs) and Drying Beds systems, in three municipalities have been studied from different viewpoints. Infrastructure failures and settlement of earthen embankment had been visible in Khulna and Jhenaidah FSTPs within 2-3 years. Moreover, Khulna FSTP was designed to treat up to 15% of total generated faecal sludge while Jhenaidah FSTP had the capacity to treat up to 18% of total generated faecal sludge; but so far, only a small portion of its capacity is in use. Treatment efficiency of these existing treatment plants are good and still providing their services. From laboratory experiment it is also seen that; the treated effluent was within the standard limit with satisfactory level for releasing into inland water body. In all three FSTPs, BOD_5 removal efficiency was varied in the range of 95%-97%. Furthermore, total suspended solids in final effluents were found to be 40mg/L, 50mg/L and 90mg/L respectively, in Khulna, Jhenaidah and Kushtia FSTPs which fall within the acceptable limit 100mg/L as per ECR'97. Kushtia FSTP showed lower removal percentage with 22mg/L nitrate in final effluent. Microbial (TC & FC) removal efficiency in the treated effluent was found to be approximately 99% in all three FSTPs. Fecal coliform in final effluent never exceeded the acceptable limit 1000 N/100ml. From the entire study, it seems that the adopted methodologies in all three FSTPs achieved the safe use of final effluent and productive to support human well-being and broader sustainability of the environment.

ACKNOWLEDGEMENTS

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REFERENCES

Andreoli, C. V., Sperling, M. von, & Fernandes, F. (Eds.). (2007). Biological Wastewater Treatment Series, Sludge treatment and disposal (6th volume). London: IWA Publication.

Cheng, S. K., Zheng, L., Zhao, M. Y., Bai, X., Li, Z. F., Mang, H. P. (2017). Assessment of two faecal sludge treatment plants in urban areas: Case study in Beijing." Int J Agric & Biol Eng, 2017; 10(3): 237–245.

Chowdhary, S. & Kone, D. (2012). Business Analysis of Fecal Sludge Management: Emptying and Transportation Services in Africa and Asia, Seattle, WA: Bill & Melinda Gates Foundation.

FSM Survey (2014). Draft report on baseline study on fecal sludge management of residential premises, SNV and Khulna University, Bangladesh.

Harada, H., Strande, L., & Fujii, S. (2016)," Challenges and Opportunities of Faecal Sludge Management for Global Sanitation".

KCC, (2019). Basic Statistics of Kulna City Corporation, Official Website of KCC. http://www.khulnacity.org/Content/index.php?pid=30&id=32&page=About_KCC [Accessed August 10, 2019).

Oxfam, (2016). Septage Management Leader"s Guidebook - Philippines Edition. Oxfam, UK.

Ronteltap, M., Dodane, P. H. & Bassan, M. (2014). Overview of faecal sludge treatment technologies.

SNV (2018); http://www.snv.org/update/urban-sanitation-bangladesh-component-4-treatment-disposal-and-reuse/ [Accessed August 20, 2018]

Stevens, L., Islam, R., Morcrette, A., Brosse, N. De La, & Mamun, A. Al. (2015). "Faecal Sludge Management in Faridpur, Bangladesh: Scaling up Through Service Level Agreements". 38th WEDC International Conference, Loughborough University, UK.

United Nations, (2019) Sustainable Development Goals and Beyond (2019). Available at: https://sustainabledevelopment.un.org / [Accessed September 25, 2019].

UNICEF & WHO, (2019). Progress on household drinking water, sanitation and hygiene 2000-2017. Special focus on inequalities. New York: United Nations Children's Fund (UNICEF) and World Health Organization (WHO), 2019

WRC, (2015). The Status of Faecal Sudge Management in Eight Southern and East African Countries. WRC Report No. KV 340/15, prepared for the Sanitation Research Fund for Africa (SRFA) Project of the Water Research Commission (WRC), Pretoria, South Africa, ISBN 978-1-4312-0685-8

PEOPLES' PERCEPTION OF RAINWATER HARVESTING TO MEET NON-POTABLE WATER DEMAND AT KUET, KHULNA

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ABSTRACT

Water scarcity is becoming one of the biggest challenges of the future. Bangladesh is also facing acute water shortage even though frequency of rainfall event is quite high here. Coastal regions of Bangladesh such as Khulna faces lack of fresh water due to presence of salinity. KUET is a residential accommodation providing university without any municipal water supply connection. Therefore, the university authority extracts and treats groundwater before supplying it to its beneficiaries. Rain water harvesting is an alternative way of water sources in order to meet non-potable water demand. Also, it acts as a backup for the emergency purpose. The rain water which is being wasted in every rainfall event can be collected and reused for many purposes. By practicing rainwater harvesting, the need for water for the everyday purpose could be fulfilled at a certain rate.In this study, the perception of the people about rainwater harvesting was assessed at KUET campus. Mainly data were collected against various parameters including practice of rainwater harvesting at home, acceptance of rainwater harvesting to meet non-potable water demand, water savings and safety of rainwater, particular use of harvested rainwater at home, rainwater as an auxiliary water source at KUET, expected contribution to install rainwater harvesting at KUET etc. Sample size of the study area was determined as 198 (including students, faculties and staffs). After analyzing collected data, it was found that, a large portion of respondents practice rainwater harvesting at house and they also think harvested rainwater can be used as non-potable consumption without any treatment. It was also found that people were more likely to use rainwater for washing purposes. Besides, respondents were found to have interest in contribution of certain amount of money to install rainwater harvesting system at university campus.

Keywords: *KUET, Non-potable, Perception, Rainwater harvesting, Water demand.*

1. INTRODUCTION

The demand of water is increasing day by day with increase of rapid urbanization. Though Bangladesh is blessed with plenty amount of rainfall with an average of at least 2425 mm in most parts of the country per year (Quadir & Saha, 2016), it is also facing water shortage problem.In Bangladesh, both in rural and urban area people often do not get the available amount of water. In the urban area, especially female from lower income group have to collect water from a particular water source as they do not get all time water connection from municipal water supply authority. Municipal authorities are trying to fulfil water demand of people as per their requirement but as water is a limited resource there is a gap between water demand and supply. In rural areas particularly in the coastal region such as Khulna, amount of salinity in water is increasing (Ahmed, Kadir, & Ahmed, 2014). Moreover, supply water of Khulna WASA is not enough to fulfill daily water demand. In Khulna only 20 percent of urban area has been covered by public water supply system (Islam, Arif, & Noman, 2015). Khulna city dwellers are facing the need of fresh water. Some of the city dwellers have already arranged to lift water by using bore wells, pumps etc. but the ground water level is depleting and so wells and pumps could not work well.

KUET is one of the public engineering university of Bangladesh which is situated in Khulna region. Being located in the coastal region, university also faces problems to manage safe and fresh water to meet non-potable water demand of the university beneficiaries. Moreover,the university doesnot have any municipal water supply connection.At present, the university have their own arrangement where water is being extracted from ponds and after that it goes to university's treatment plant before being supplied to its beneficiaries. This involves a huge amount of financial cost to university authority as well as the ground water level is also depleting day by day due to continuous water extraction. In this situation, rainwater harvesting is the most effective system along with existing water supply system to meet the non-potable water demand of the university effectually. Rain Water Harvesting(RWH) is an substitute and effective way to meet water demand especially for non-potable uses. The rain water which is being wasted can be collected and reused for many purposes. Also, Rain Water Harvesting System(RWHS) is economically cheaper in construction compared to other sources, i.e. well, canal, dam, diversion, etc. (Jyotiba & Regulwar, 2013). By using rainwater, water demand can be minimized to some certain level. In large institutions like university where water demand is at large scale, rainwater can act as a supporting source for supplying water in order to reduce ground water extraction as well as reduce pressure from municiapl water supply authorities. Peoples' perception is very important before installing any kind of new system in thier locality. In this paper, peoples' perception on rainwater harvesting at KUET campus was assessed through a questionnaire survey. The structure of questionnaire was designed into two parts- one for the students of KUET and another one for faculties, officers and staffs of KUET. The questionnaire was organized in such a way to bring out the insight of people on rainwater harvesting. This questionnaire survey mainly focused on practice of rainwater harvesting at home, acceptance of rainwater harvesting to meet non-potable water demand, water savings and safety of rainwater, particular use of harvested rainwater at home, rainwater as an auxiliary water source at KUET, expected contribution to install rainwater harvesting at KUET etc.

2. METHODOLOGY

2.1 Study Area

KUET is situated in the district of Khulna with area of around 101 acres. The campus is situated at Fulbarigate, the northwest part of Khulna. The campus is around 15 kilometer away from the zero point of Khulna City, which is very much associated with the significant downtown areas by open and wide streets. It is at around 12 km from the Inter-District Bus Terminal and roughly 14 km from the Khulna Railway Station. At present, in KUET, there are three faculty, three institutes and twenty departments. Every year number of department is increasing and so number of infrastructures and facilities is also increasing. Number of students is also increasing every year. Currently 5700 students are studying, 318 faculties and 557 officers and staffs are working in the university.

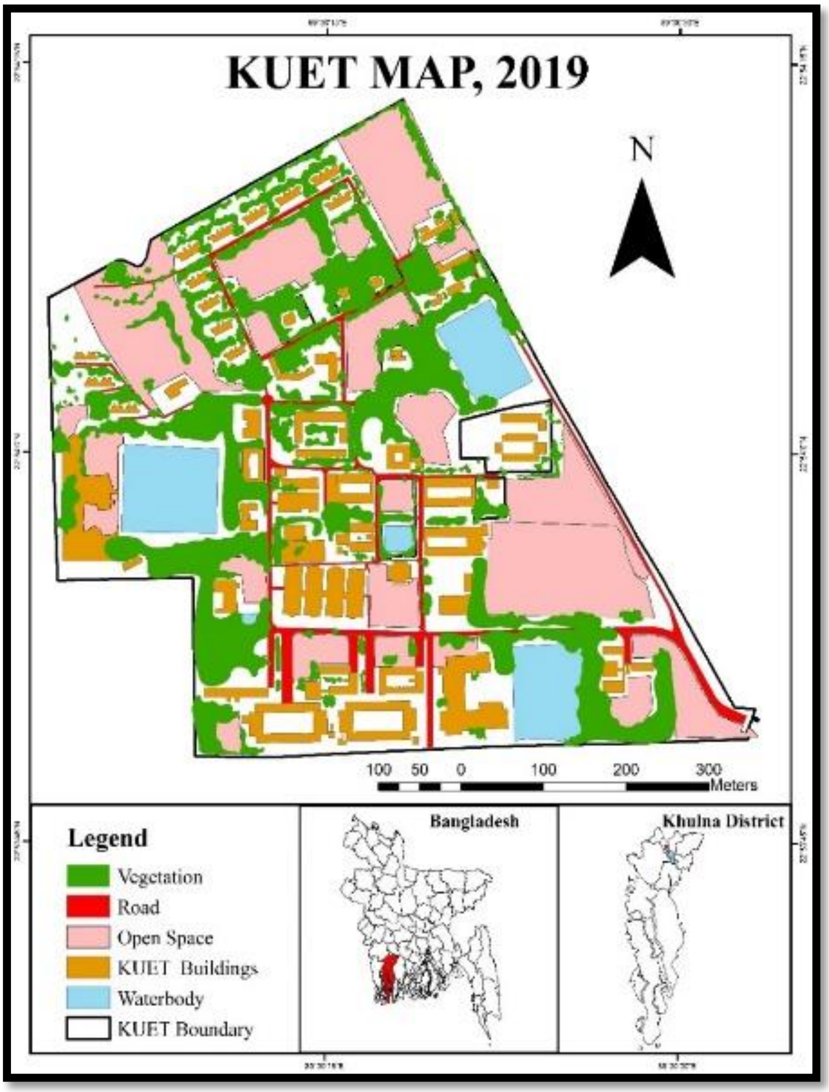

Figure 1:Map of KUET (Study Area)

Inside the university campus boundary, there are seven halls for students and eighteen quarters for faculties and officers and staffs. Moreover, there are three dean houses and a house for VC and a dormitory building for bachelor faculties of the university. The university also have some buildings such as- a central computer center, a medical center, student welfare center and cafeteria for the students.

2.2 Determination of Sample Size

It was quite difficult to study entire population of the study area. Hence, sample size was determined to know about the whole residents of KUET. In addition to the purpose of the study and population size, three criteria usually used to determine the appropriate sample size: the level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured (Miaoulis & Michener, 1976). Yamane (1967) provides a simplified formula to calculate sample sizes (Israel, 1992). The formula given by Yamane is given below:

$$n = \frac{N}{1+N(e^2)} \quad (1)$$

Where n is the sample size, N is the population size, e is the level of precision in this formula. This formula was used in this study to calculate the sample size of the study area. In calculating sample size, population size is used as 6575 persons including all students, faculties and staffs of the university.

Precision level is assumed as ± 7% as the survey would be done only to know about the perception of people on rainwater harvesting. Confidence level is assumed as 95%. By using equation given by Yamane (1967), the sample size of the study area is given below:

$$
\begin{aligned}
n &= \frac{N}{1+N(e^2)} \\
&= \frac{6575}{1+6575\times(.07)^2} \\
&= 197.937834 \\
&\approx 198
\end{aligned}
$$

2.3 Preparation of Questionnaire and Questionnaire Survey

A questionnaire survey was completed keeping focus on the point to know about the perception of people on rainwater harvesting. A draft questionnaire was prepared at first. The structure of questionnaire was designed into two parts- one for the students of KUET and another one for faculties and officers and staffs of KUET. The questionnaire was organized in such a way that it would bring out the insight of people on rainwater harvesting. After testing the draft questionnaire from field, a questionnaire was finalized for this study and questionnaire survey was completed inside the campus boundary.

3. ANALYSIS AND FINDINGS

3.1 Knowledge on Rainwater Harvesting among KUET Students

Water scarcity is very common in least developed countries and in developing nations. Rainwater harvesting is becoming a common practice for coping with water scarcity problem. Rainwater harvesting an alternative water supply option is a common practice in countries like Bangladesh where the annual precipitation is high (Sultana, 2007).

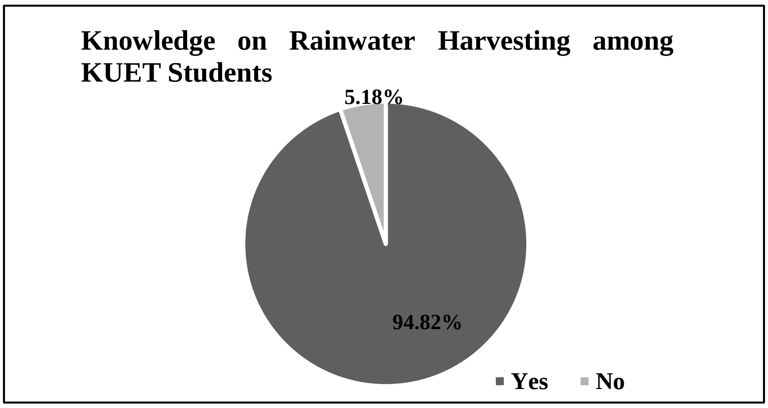

Figure 2: Knowledge on Rainwater Harvesting Among University Students

From analysis, it was found that students who are from small cities and rural areas knows more about rainwater harvesting. They usually harvest rainwater in the monsoon period and stores that harvested rainwater in gallons or jars to use it in cooking purposes later. From figure 2, it can be said that 94.82% of KUET students have knowledge of rainwater harvesting. They know how and why rainwater is collected. RAJUK has already made regulations which require buildings of Dhaka to harvest and reuse rainwater (Chowdhury, 2017).Therefore, students from Dhaka city also knows and some of them have the practice of rainwater harvesting in their buildings.

3.2 Practice of Rainwater Harvesting at Home

Rainwater harvesting has become a common practice nowadays. Rainwater harvesting system has already been introduced in many cities especially the coastal areas in Bangladesh (Bari & Hassan, 2016). This is an ancient practice for collecting and storing rainwater for further use in future. People usually use harvested rainwater for cooking purposes.

At KUET, 65.47% of students were found to have practice of rainwater harvesting at their home. At their home, their family members collect rainwater during monsoon period specially. All of them collects rainwater in small scale that means they collect rainwater for using it in daily life works.

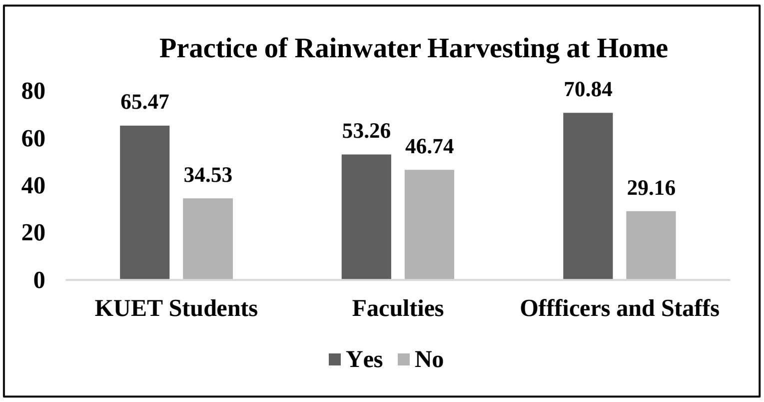

Figure 3:Practice of Rainwater Harvesting at Home

70.84% officers and staffs of KUET were found to have practice of rainwater harvesting.They also collect rainwater in small scale. They do not have any established structural system for collecting rainwater. They generally places their jars or water drums on the rooftop to collect rainwater directly and usually filter the rainwater before having it for potable consumption. They mostly stores rainwater to use collected water even in summer season. Faculties of KUET also captures rainwater in a small scale. 53.26% of them are found to have practice of rainwater harvesting at home. Like officers and staffs, they also do not have any established infrastructural system for collecting and storing rainwater. They normally collects rainwater in jars or water gallons and use it for potable purposes such as cooking.

3.3 Particular Use of Harvested Rainwater At Home

Rainwater harvesting is being practice from ancient times. In Bangladesh it is not a new concept. Different organizations such as WaterAid, RAiN forum is working on rainwater harvesting in Bangladesh and they have already established some projects regarding rainwater harvesting in some rural areas of Bangladesh.

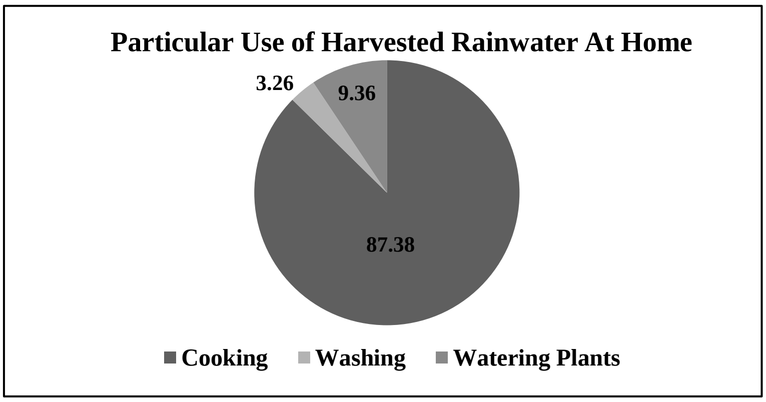

Figure 4: Particular Use of Harvested Rainwater At Home

At KUET, it was found that 87.38% of respondents generally use collected rainwater for cooking purpose. They thinks that rainwater is best for cooking rice or making tea after having some filtration. Washing utensils and watering plants are also done by them by using rainwater. Rainwater for watering plants is used by 9.36% of respondents and they expressed that rainwater works as natural manure to plants and so they water their plants with collected rainwater. For washing purposes, at their house, 3.26% of them use collected rainwater.

3.4 Water Savings through Rainwater Harvesting

Rainwater harvesting ensures savings of water and also reduces pressure from water supply authority. At KUET, there is no direct connection of water supply from KWASA. In the whole campus, at present, water is being extracted from three ponds and twelve shallow tube wells are also being used for extracting water from ground level. Extracted water then goes to treatment plant before getting supplied to both residential and non-residential beneficiaries. This creates massive pressure on WTP as it is only supply source of water in the whole campus. Using rainwater minimize this pressure from WTP.

From figure 4, it can be said that, amongst the respondents, 84.36% of students, 82.11% of faculties and 75.37% of officers and staffs think rainwater harvesting would ensure savings of water. They consider that as WTP is the only source of water at KUET, rainwater harvesting would be the most effective supporting source of water with the existing system. They also thinks that as WTP is treating water before supplying it so it would reduce in a significant manner by single harvested rainwater. Moreover, the rainwater which is getting wasted usually can thus be used for meeting the demand of beneficiaries.

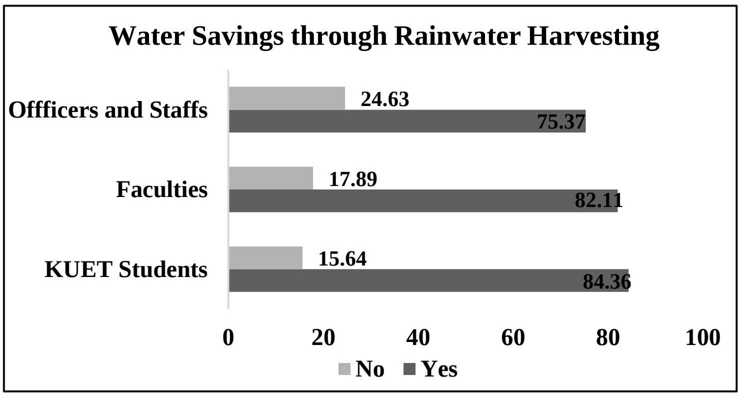

Figure 5: Water Savings through Rainwater Harvesting

3.5 Effectiveness of Rainwater as an Alternative Non-Potable Water Source at KUET

The benefits of rainwater harvesting are enormous (Krishna, 2005). Rainwater ensures free water only with storage and treatment cost and it supplement limited quantities of groundwater and reduce storm water runoff (Aladenola & Adeboye, 2010). Rainwater harvesting is thus effective to cope with both residential and non-residential demands. There are several reasons behind why faculties, students and officer and staffs thinks that rainwater harvesting system would be an effective and sustainable non-potable water source system at KUET. At present, water treatment plant (WTP) is the only source of water supplier at KUET for non-potable purposes. Halls and quarters demands a large quantity of water every day for non-potable purposes such as- bathing, washing clothes, washing utensils, cleaning , toilet flushing etc. Moreover, during working period, departments and schools of KUET also requires water.

From figure 6, it can be mentioned that, 65.16% faculties considers rainwater harvesting system as an effective system and they stated that it would be obviously a good initiative if the university authority adopt rainwater harvesting as soon as possible with existing water supply system.

Moreover, they consider that, as KUET is located in salinity prone region, it should adopt rainwater harvesting system for meeting non-potable requirements. Officers and

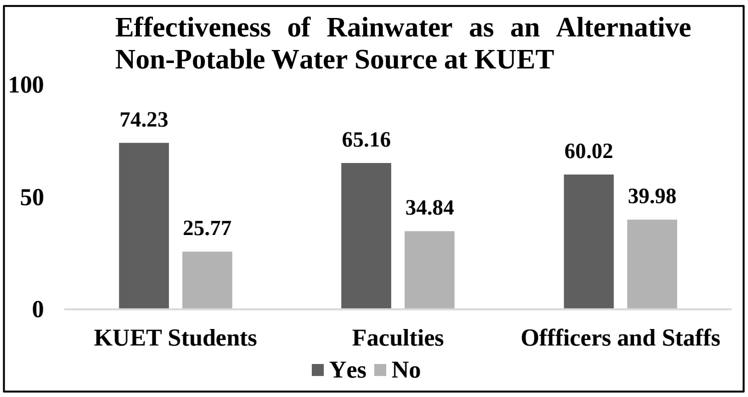

Figure 6: Effectiveness of Rainwater as an Alternative Non-Potable Water Source at KUET

staffs gave their complement in affirmative on rainwater harvesting and also said that accepting rainwater harvesting for fulfilling water demands at KUET would also inspire indigenous people to install rainwater harvesting structure in their existing and new dwelling units. Furthermore, students are also found to be positive on effectiveness of rainwater harvesting and willing to have this system in their university.

3.7 Safety of Rainwater for Non-Potable Water Consumption

Rainwater has the added advantage that it is free from arsenic (Ahmed, Anwar, & Hossain, September, 2013). Generally, serious chemical contamination of stored rainwater is rare (Pathak & Heijnen, 2006). Non-potable purposes such as bathing, washing clothes, washing utensils, cleaning, toilet flushing etc. requires a large amount of water every day.

From figure 7, it can be seen that, among the faculties, 49.32% of them considers harvested rainwater safe for non-potable consumption. Officers and staffs around 38.42% of them thinks rainwater safe for non-potable consumption.

They usually use rainwater for potable consumption with after having little filtration. Therefore, they considers that, harvested rainwater could be used for non-potable consumption without any treatment.12.26% of students also believe that harvested rainwater would be safe for any kind of non-potable consumption as rainwater have limited organic materials which are not harmful to human body.

Hence, harvested rainwater could be easily use for non-potable purposes.

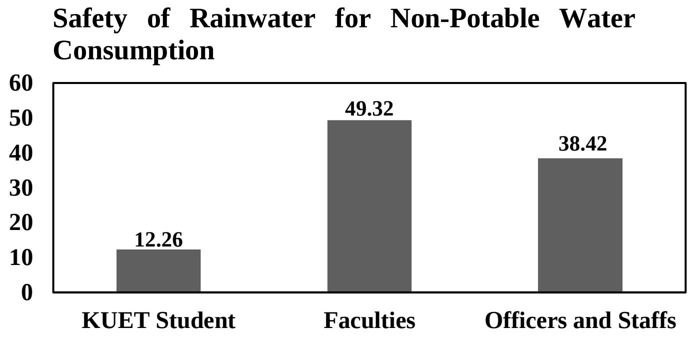

Figure 7: Safety of Rainwater for Non-Potable Water Consumption

3.8 Acceptance of Rain Water Harvesting (RWH) to Meet Non-Potable Water Demand

In Bangladesh where average rainfall varies from 1200 mm in the extreme west to over 5000mm in northeast (W.B, 2000), rainwater harvesting is considered to be the next option (Haq, 2005) to look into. Water scarcity is very common in Bangladesh. RWH offers an ideal solution in urban cities where inadequate ground water supply and surface water resources are either lacking or are insufficient (UN-HABITAT, 2012). Using harvested rainwater thus would not only be able to fulfil demand of water but also would minimize the amount of extraction of water from ground level as well as would also reduce treatment pressure from WTP at KUET. Faculties, officers and staffs and students expressed their positive acceptance of RWH to meet non-potable water demand.

From figure 8, it is seen that, faculties, officers and students showed their acceptance to use harvested rainwater at KUET for any kind of non-potable use. Their affirmative comments also specified that rainwater harvesting should be adopted in KUET so that local people get influence to install this system in their houses to cope with problem of excessive salinity in water.

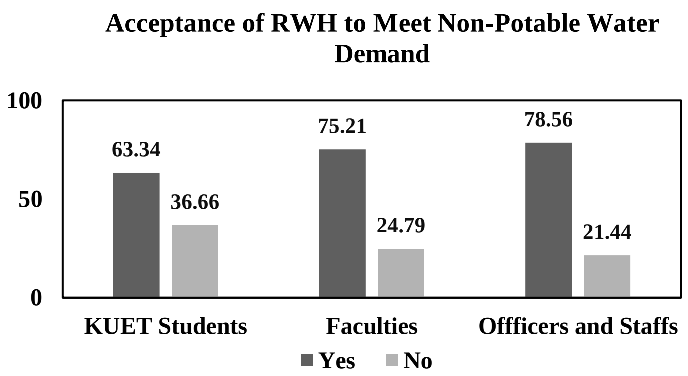

Figure 8: Acceptance of RWH to Meet Non-Potable Water Demand

3.9 Effectiveness of Harvested Rainwater to Meet Particular Non-Potable Water Demand at KUET

Non-potable water requirement generally consists of bathing, washing, cleaning and flushing toilets. As the water treatment plant is the only supplier source of water at KUET, so here rainwater harvesting would be an effective supporting source of along with the existing system. Harvested rainwater can be used for a specific non-potable water demand so that the demand can be fulfilled effectively with the amount of harvested rainwater.

From analysis it was found that, 65.84% of respondents considers that harvested rainwater would be most effective to use in washing purposes specially washing utensils and clothes. They also believes that rainwater would be more effective to clean utensils and clothes than current treated water by water treatment plant.

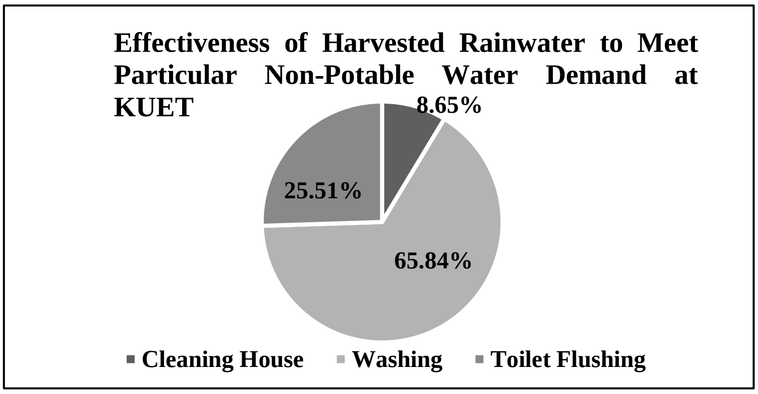

Figure 9: Effectiveness of Harvested Rainwater to Meet Particular Non-Potable Water Demand at KUET

25.51% people thinks that flushing toilets with harvested rainwater would also beneficiary especially to the authority as it would reduce the treatment cost of water treatment plant in a great scale. Few respondents expressed their complement for using harvested rainwater in house cleaning purposes. They also thinks that as rainwater is free from any harmful substances and so it would be safer from treated water.

3.10 Total Initial Investment Expected to be Available to Install Rainwater Harvesting System (RWHS) at KUET

Rainwater harvesting system consists of development of catching system, gutters, conduits, first flushing devices, reservoir, treatment components etc. Installation of RWHS in the KUET campus thus would involve a huge amount of installation cost.

If RWHS is installed at KUET, then benefit of this system would be enjoyed by students as well as faculties, officers and staffs who reside in quarters with their family members. From figure 10, it can be said that, 86.24% of respondents confirmed that they would like to contribute in between 2000~3000 taka at a time to install RWHS at KUET. 3.68% respondents said that they would like to contribute more than 3000 taka at a time as this system would bring numerous benefits

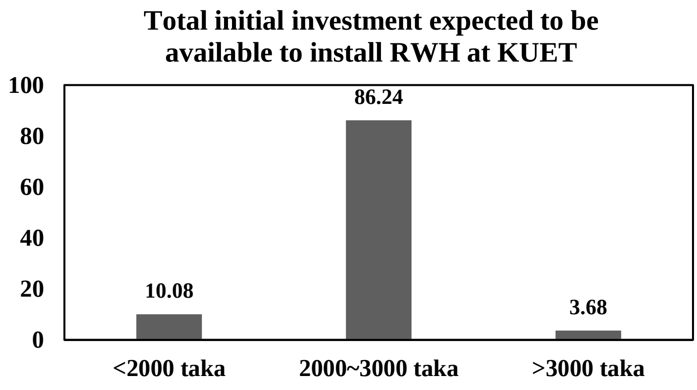

Figure 10: Total Initial Investment Expected to be Available to Install RWHS at KUET

university authority as well as to its beneficiaries. Among the respondents, 10.08% of them told that they would like to give less than 2000 taka at a time to install RWHS at KUET.

3.11 Expectation of Incentives by Government to Install Rainwater Harvesting System (RWHS) at KUET

KUET is a residential accommodation providing university. At present, here are seven halls for students and eighteen quarters for faculties and staffs of KUET. Moreover, there are also three dean houses and a VC house.

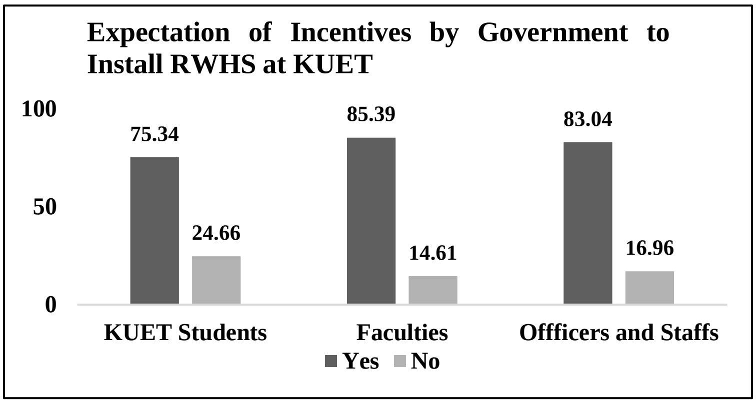

Figure 11: Expectations of Incentives by Government to Install RWHS at KUET

Installation of RWHS involves a huge amount of money. In Bangladesh, at present there are 37 public universities which also provides residential accommodation as well. From figure 11, it can be said, among the faculties 85.39% of them considers government should provide some incentive to install RRWH in residential providing universities. Officers also thinks that government should provide incentive and make it mandatory to install RWHS in every residential accommodation providing universities to cope with water scarcity problem. Students of KUET also thinks that the government should provide incentive to so that every large public educational institution of Bangladesh could maintain a sustainable water consumption practice.

4. CONCLUSIONS

Rainwater harvesting is the way to capture and store rainwater when it falls onto the surface of any structure to use it in future. At KUET, residential beneficiaries such as students resides in halls, faculties and staffs resides in quarters with their family members inside the campus boundary. This draws a large quantity of water to meet their demand each and every day. Currently, as the university does not have any municipal water connection, it have its own provision to extract and supply water in the whole campus area. In this case, rainwater harvesting is the most efficient way to fulfill the non-potable water demand of people. From analysis, it was found that, residential and non-residential beneficiaries of the university was found to be interested to have rainwater harvesting system in the campus. Respondents were also found to have practice of rainwtaer harvesting at their home. They stated that, using rainwater for non-potbale purposes at KUET would not only reduce the dependency from WTP but also ensure an environment friendly water supply source. Besides, respondents were also found to be interested to contribute in order to install RWHS at university. Hence, practicing rainwater harvesting along with the existing water supply system is a viable solution to meet non-potable water demand and to cope with water scarcity problem in any large educational institutions. Additionally, Bangladesh Government should take initiatives to practice rainwater harvesting system in every large educational institutions of the country with strong rules and regulations with logistical supports.

REFERENCES

Ahmed, I., Kadir, M. N., & Ahmed, M. H. (2014). Surface water salinity intrusion assessment of south-west region of- A GIS based approach.*International Journal of Surface and Groundwater Management, I(3)*

Ahmed, M., Anwar, R., & Hossain, M. (September, 2013). OPPORTUNITIES AND UTILIZATION OF RAINWATER HARVESTING IN RESIDENCES OF DHAKA CITY. *International Journal of Civil Engineering (IJCE), II*(4), 67-74.

Aladenola, O., & Adeboye, B. (2010). Assessing the Potential for Rainwater Harvesting. *Springer*, 2129–2137.

Bari, Q., & Hassan, K. (2016). ASSESMENT OF ROOFTOP RAINWATER HARVESTING SYSTEM IN KHULNA CITY AND PROPOSAL FOR MODIFICATION. *3rd International Conference on Civil Engineering for Sustainable Development.* ICCESD.

Chowdhury, M. H. (2017, August 05). New regulations will require Dhaka buildings to harvest and reuse rainwater. Retrieved from https://bdnews24.com/bangladesh/2017/08/05/new-regulations-will-require-dhaka-buildings-to-harvest-and-reuse-rainwater.

Haq, S. (2005). Rainwater Harvesting: Next Option as Source of Water. *Proceeding of Third Annual Paper Meet and International Conference on Civil Engineers.* Dhaka: IEB.

Islam, T., Arif, Y., & Noman, S. (2015). Rainwater Harvesting Potential in Educational Institution. In *Rainwater harvesting in Bangladesh- Potentials, challenges and stakeholders' responses.* WaterAid Bangladesh.

Israel, G. (1992). *Determining Sample Size.* University of Florida.

Jyotiba, G., & Regulwar, D. (2013). "Rainwater Harvesting – A Case Study". *Sustainable Water Resources Development and Management*, pp. 179-183.

Krishna, H. (2005). The success of rainwater harvesting in Texas—a model for other states. *Paper presented at the North American rainwater harvesting conference.* Seattle, WA.

Miaoulis, G., & Michener, R. (1976). *An Introduction to Sampling.* Iowa: Kendall/Hunt Publishing Company.

Pathak, N., & Heijnen, H. (2006). Health & Hygiene Aspects of Rainwater for Drinking. *32nd WEDC International Conference.* Srilanka.

Quadir, D., & Saha, T. (2016). Recent changes in temperature and rainfall trends and variability over Bangladesh. *THE GOBESHONA CONFERENCE FOR RESEARCH ON CLIMATE CHANGE IN BANGLADESH.* WAGENINGEN University and Research . Retrieved from WeatherOnline Ltd. - Meteorological Services.

Rahman, M., & Yousuf, F. (2003). Rainwater harvesting and the reliability concept. Retrieved from http://www.nd.edu/~pmc2000/pmc2000/sessions/papers/p084.pdf

Sultana, F. (2007). *Sustainable Water Supply: Rainwater Harvesting for Multistoried Residential Apartments in Dhaka, Bangladesh.* Texas A&M University.

UN-HABITAT. (2012, April). *Beneficiaries & Capacity Builders: Rainwater Harvesting and Utilisation.* United Nations Human Settlements Programme. Retrieved from Available:http://www.hpscste.gov.in/rwh/BlueDropSeries02 Capacity Building.pdf

W.B. (2000). *Bangladesh: Climate Change and Sustainable Development.* World Bank.

Yamene, T. (1967). *Statistics, An Introductory Analysis.* New York: Harper and Row.

ENVIRONMENTAL MONITORING AT AND AROUND THE MATUAIL LANDFILL SITE OF DHAKA CITY USING REMOTE SENSING

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ABSTRACT

Municipal Solid Waste (MSW), a part of which is being disposed off at Matuail sanitary landfill located within Jatrabari Thana. This study has analysed the environmental impacts at and around this landfill using remote sensing techniques. Special attention was given on the effect of biodegradation process of waste which results gas emissions and leachate contamination of land. Information can be gained from remote sensing data by grasping the nature of electromagnetic radiation in terms of their wavelength and frequency. Data from satellite platforms can be utilized to landfill management and monitoring practices, solve future waste management agenda without being kept in touch of earth's surface using remote sensing. The objective of this research is to develop a means of environmental monitoring at the landfill site and its surroundings through the implementation of various time series remote sensing indices e.g., Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Modified Soil Adjusted Vegetation Index (MSAVI). LST is the skin temperature of the earth which is calculated by SW algorithm. It is used to observe the spatio-temporal pattern of temperature distribution. NDVI, SAVI and MSAVI are the Bio-indicators and they are helpful to analyse the vegetation health condition at and around the landfill area. Vegetation coverage plays a significant role on the LST distribution. The Landsat data were downloaded from United States Geological Survey (USGS) websites for Landsat 4-5 TM and Landsat 8 OLI/TIRS by using the path and row of 137 and 44 respectively. Images at a 5-year interval starting from 1993 to 2018 were used to monitor the impact in this study. From the result of LST, it is observed that the average temperature of the Jatrabari thana has increased from 23.12℃ in 1993 to an optimum temperature of 35.20℃ in 2013, then it went down to 29.09℃ in 2018. Also, the average temperature of the Existing Sanitary Landfill (ESL) has increased from 22.56℃ in 1993 to 31.99℃ in 2018 and from 21.97℃ in 1993 to 31.52℃ in 2018 for Fulfilled Semi-aerobic Landfill (FSAL). The NDVI result for the study period shows that the percentages of 'Bare Soil' and 'Structural Object' has increased drastically from 10% to 41.20% and 13.30% to 31.52% respectively for this 25-year period in Jatrabari thana. On the other hand, the percentages of 'Shrub and Grassland' and 'Moderate Vegetation' have gone down from 54.20% to 25.15% and 12.55% to 0% respectively. SAVI and MSAVI also show the evidence of increasing the amount of bare soil and structural object and decreasing the amount of vegetation. From overall assessment, it can be said that due to the inappropriate waste management at the Matuail landfill, a harmful effect has been done to the surrounding environment. As an outcome, temperature has risen rapidly and amount of vegetation has declined to a significant extent.

Keywords: *Landfill Monitoring; Land Surface Temperature (LST); Normalized Difference Vegetation Index (NDVI); Soil Adjusted Vegetation Index (SAVI); Modified Soil Adjusted Vegetation Index (MSAVI).*

1. INTRODUCTION

Bangladesh is located in the South-East Asia region which has a population over 160 million. Dhaka is the capital of Bangladesh. More than 15 million people live in this city. A study by the Department of Environment (DoE) revealed that Dhaka's problem regarding solid wastes is worse compared to cities in other developing countries. Total wastes produced in Dhaka city is about 4600 tons/day (Abedin & Jahiruddin, 2015). Besides, the amount of waste generation rises during the wet season. It seems like impossible to dispose that amount of waste as the city does not have enough resources. Dhaka City Corporation (DCC) uses two landfill sites specifically; Matuail (40ha) which is a sanitary landfill and Amin Bazar (20ha) is under operation process for sanitary condition. Among total wastes 1150 tons/day to 1450 tons/day wastes are disposed off at Matuail landfill. The rest of the wastes are disposed off at Amin Bazar landfill (Bhuyan, 2010). Matuail landfill site is located around 8 kilometers from the center of the south of Dhaka city which is mainly used for disposal of municipal solid waste by the Dhaka South City Corporation (DSCC). It is located in the DSCC region in between latitude of 23°42.97' to 23°43.35' N and longitude of 90°26.83' to 90°27.2' E (Hossain, Jahan, Parveen, Ahmed & Uddin, 2018). Matuail landfill is located in Jatrabari thana which has an area of 13.19 square kilometers and the total population is about 260772 and the population density is about 19770/km² where average monthly temperature is around 30°C; average monthly rainfall is around 100mm; average monthly wind speed is around 15kmph and average monthly humidity is around 50% from 2009 to 2018 (Bangladesh Meterological Department [BMD], 2018). A location map of Jatrabari thana is given in the figure 1 below.

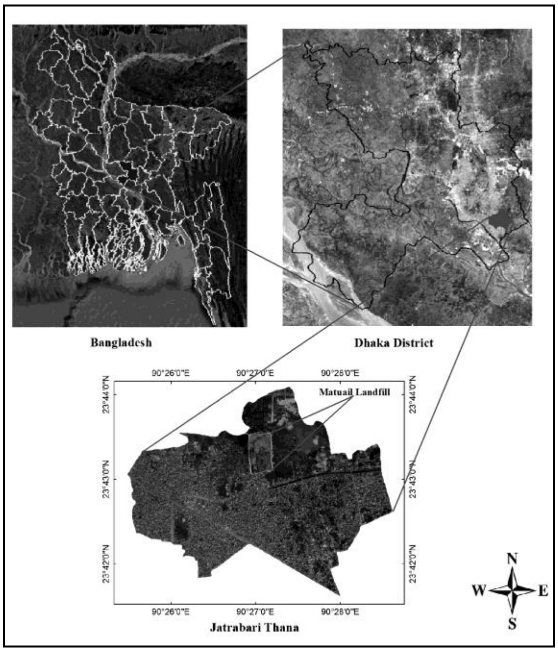

Fig 1: Location Map of Jatrabari Thana

Main waterbody in Jatrabari thana is Balu River which carries floodwater from the Shitalakshya and the Turag during the flood season. The Balu is important mainly for the local drainage and can be accessed by small boats. From Google earth it is assured that there is a huge amount of urban area in the south direction and a small portion of vegetation in the north-east corner and some water bodies are scattered in the whole region of Jatrabari thana area. Main crops are paddy, potato and various kinds of vegetables (Banglapedia, 2019). The overall objective of this research is to monitor the condition of Matuail landfill site and the surrounding area. The major objective of this research is:

1. To calculate and analyze various remote sensing indices e.g., LST, NDVI, SAVI and MSAVI.
2. To observe the temperature distribution pattern and vegetation health condition at the Matuail landfill site and the surrounding region.

3. To assess the present status of waste management at Matuail landfill site of DSCC.

2. METHODOLOGY

The methodology of the study comprises on extracting the LST, NDVI, SAVI and MSAVI of the Jatrabari thana area which covers the Matuail landfill. A systematic development of the methodology of this study is shown in the figure 2 below with the help of a flow diagram.

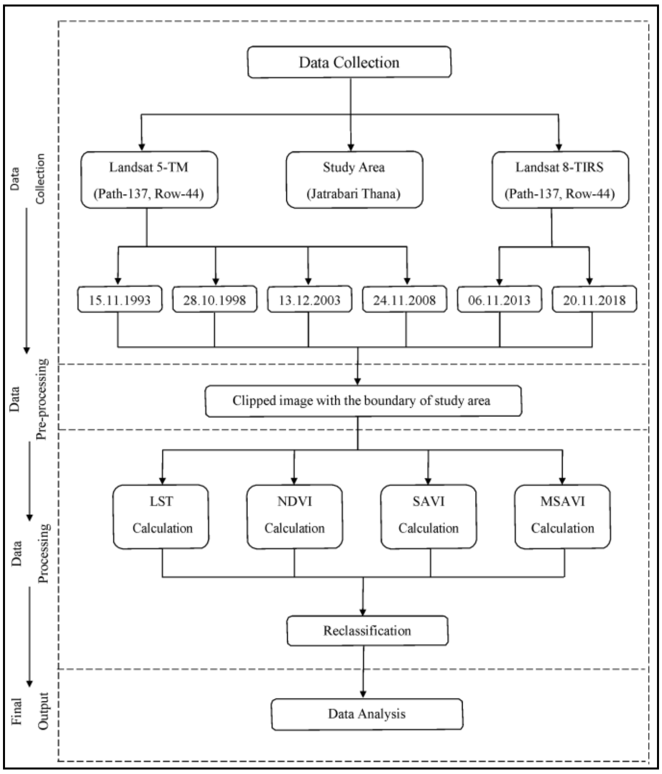

Fig 2: Methodology Flow Chart

2.1 Data Collection

The operational activities of Matuail landfill started in 1993. As the main focus of this study is to acquire the environmental effect of the Matuail landfill from its very beginning, images at a 5-year interval started from 1993 to 2018 are used in this study. The Landsat data were downloaded at free of cost from USGS websites, namely www.glovis.usgs.gov and www.earthexplorer.usgs.gov. The path and row is 137 and 44 respectively. ArcGIS 10.2.2 was used for data analysis. The shape file of Jatrabari thana is collected from Bangladesh Agricultural Research Council (BARC).

2.3 Data Processing

Before data processing, image is clipped with the help of desired shape file of the Jatrabari thana area. The process of estimating LST for two satellites is different. Required data were extracted from respective metadata file and digital number (DN) of thermal band is converted to radiance. Then, LST is estimated by the required equation. For NDVI, Near Infrared Reflectance (NIR) and Red band is needed which represents the band reflectance obtained in the near-infrared and red (visible) wavelengths respectively. Then, SAVI was improved by conjoining a soil reconcilement factor L into the NDVI equation. The L value differs with the quantity of green vegetation. Lastly, MSAVI is a modification of SAVI that further diminish soil brightness dominances, therefore, resulting in higher vegetation susceptibility. In SAVI, L is generally left alone at a constant 0.5, but for MSAVI, the soil reconcilement factor is simply computed by an equation. Images of LST and NDVI are reclassified into categories to understand the variation of values to compare with each other and to analyze the values properly. The temperature classes are (19-22), (22-25), (25-28), (28-31), (31-34), (34-37), (37-40) and (40-44) Degree Celsius, while the categories for NDVI are (-0.5-<0), (0), (>0-0.05), (0.05-0.1), (0.1-0.3), (0.3-0.6) and (0.6-0.8) for water body, no vegetation, bare soil, structural object, shrub and grassland, moderate vegetation and high vegetation respectively.

3. RESULT AND DISCUSSION

3.1 Thermal Comparison

Table 1: Comparison of Highest, Lowest and Average Temperature of Jatrabari Thana

Year	Highest Temp (°C)	Lowest Temp (°C)	Average Temp (°C)
November 15, 1993	26.67	19.28	23.12
October 28, 1998	30.42	22.81	25.89
December 13, 2003	30.82	21.50	25.10
December 10, 2008	29.18	21.06	24.69
November 6, 2013	43.96	30.42	35.20
November 20, 2018	34.84	25.32	29.09

From the overall comparison of temperature of Jatrabari thana shown in the table 1, it is observed that the highest temperature increases rapidly from 26.27°C in 1993 to 43.96°C in 2013 and then it goes down to 34.84°C in 2018 and the lowest temperature rises drastically from 19.28°C in 1993 to 30.42°C in 2013 and then it fells down to 25.32°C in 2018. The average temperature of the Jatrabari thana increases 12.08°C by an interval of 20 years (1993 to 2013). Though the average temperature reduces 6.11°C from 2013 to 2018, but in the contrast of 1993 to 2018, the average temperature increases significantly.

The reclassified images of LST of 1993, 1998, 2003, 2008, 2013 and 2018 are given in the figure 3 to 8 below.

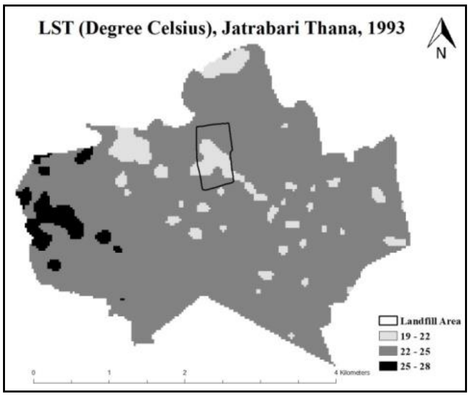

Fig 3: The reclassified LST Image (1993)

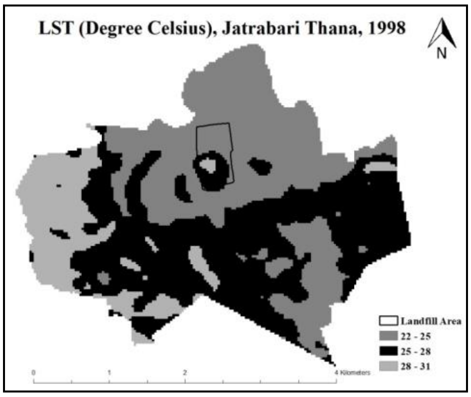

Fig 4: The reclassified LST Image (1998)

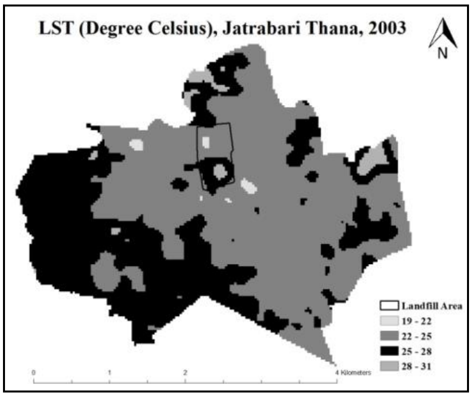

Fig 5: The reclassified LST Image (2003)

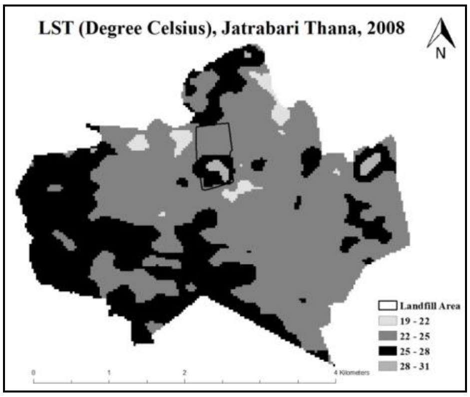

Fig 6: The reclassified LST Image (2008)

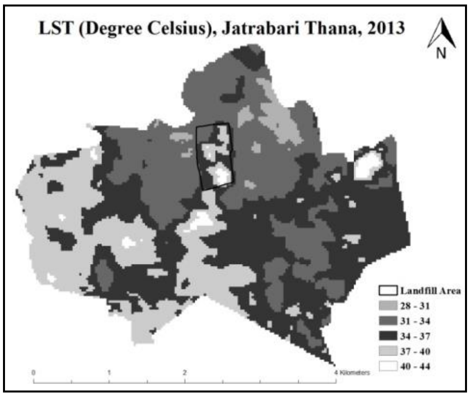

Fig 7: The reclassified LST Image (2013)

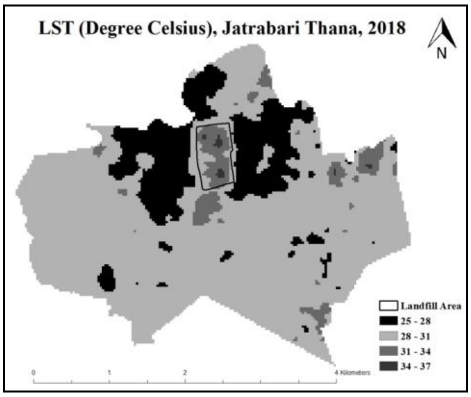

Fig 8: The reclassified LST Image (2018)

Table 2: The LST Pixel Percentage of Each Range over the Whole Area (Based on Pixel Count)

Temp Range (℃)	**Pixel Percentage of Each Range Over The Whole Area**					
	Nov ‘93	**Oct ‘98**	**Dec ‘03**	**Dec ‘08**	**Nov ‘13**	**Nov ‘18**
19-22	7.1	-	0.5	2.3	-	-
22-25	89.3	40.1	57.8	60.5	-	-
25-28	3.6	44.71	39.8	36.4	-	18.3
28-31	-	15.2	1.9	0.8	2.5	76
31-34	-	-	-	-	32	5.5
34-37	-	-	-	-	40.7	0.2
37-40	-	-	-	-	24.4	-
40-44	-	-	-	-	1.4	-

From the table 2, it can be said that 22-25 ℃ temperature range has a covering of 89.3% in 1993. In 2013, 34-37 ℃ has become the major covering temperature range. By the year of 2018, 28-31 ℃ is the major covering temperature range and also some temperature ranges as 19-22 ℃ and 22-25 ℃ disappear in 2018. To find out the temperature variation pattern year by year, two polygons are generated within Matuail landfill area which represents ESL and FSAL. A layout of ESL and FSAL within Matuail landfill is given in the figure 9.

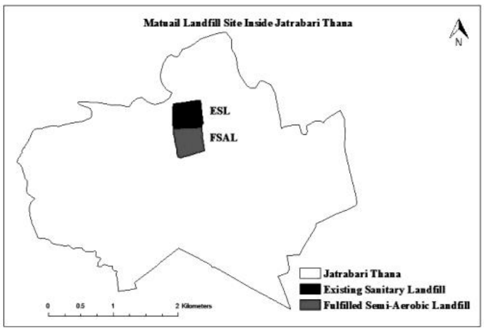

Fig 9: Layout of ESL and FSAL within Matuail Landfill

Table 3: Maximum, Minimum and Average Temperature of ESL and FSAL from 1993 to 2018

Year	Polygon	1993	1998	2003	2008	2013	2018
Maximum	ESL	23.68	26.25	26.27	25.40	40.07	34.69
Temp (℃)	FSAL	23.25	29.59	28.77	29.18	41.36	34.84
Minimum	ESL	21.50	23.25	21.94	22.38	31.20	28.86
Temp (℃)	FSAL	19.28	24.54	24.11	24.55	33.75	28.32
Average	ESL	22.56	23.81	23.53	23.33	35.81	31.99
Temp (℃)	FSAL	21.97	26.83	26.61	26.97	37.11	31.52

The capacity of FSAL was fulfilled by 2006, so the construction of ESL was required and ended in 2005-2006. From the table 3, it can be concluded that temperatures of ESL are comparatively less than temperatures of FSAL for almost every particular year. In 1993, as these places were barren land, temperatures were stable. By the year of 1998, waste composition process of FSAL influences to increase temperature for it and ESL also. Temperatures increase drastically between 2008 and 2013, striking at around 40-44℃ and this can be explained by the stabilization process of wastes. As it takes many years to stabilize the decomposed waste, it emits a huge quantity of heat during this long period. This stabilization process takes nearly 15-20 years sometimes depending on some major criteria. The study clearly revealed that as the landfill activities starts, the temperature at and around Matuail landfill increases rapidly to 40-44 ℃ from 19-22 ℃ range.

3.2 Bio-Indicators

3.2.1 NDVI

The reclassified images of NDVI of 1993, 1998, 2003, 2008, 2013 and 2018 are given in the figure 10 to 15 below.

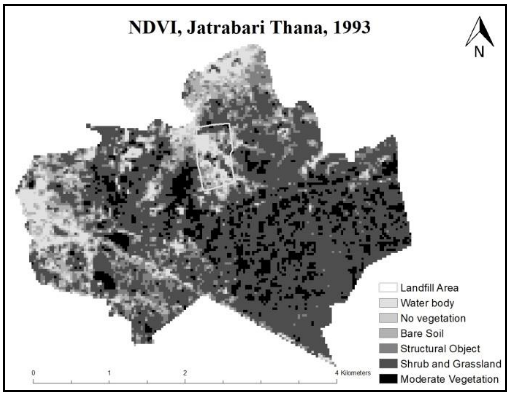

Fig 10: The reclassified NDVI Image (1993)

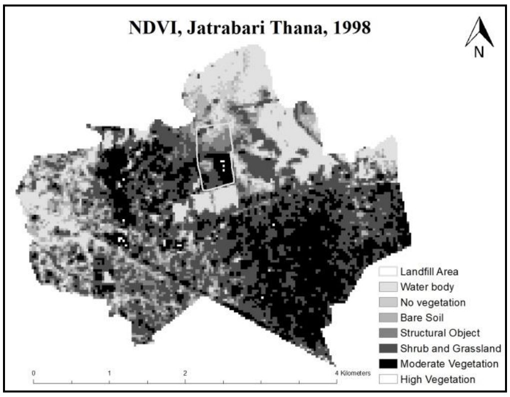

Fig 11: The reclassified NDVI Image (1998)

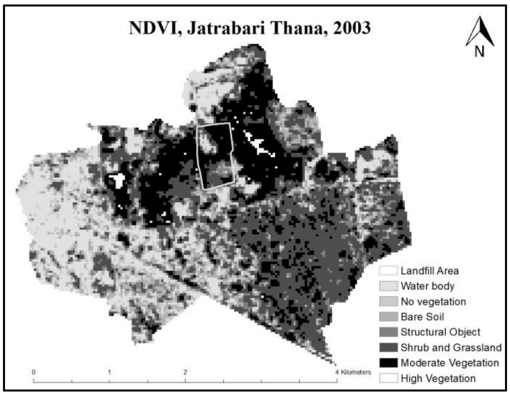

Fig 12: The reclassified NDVI Image (2003)

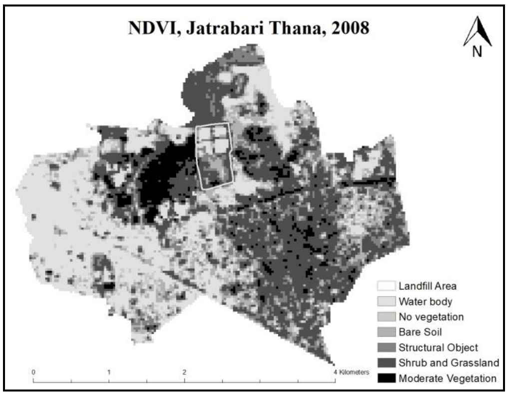

Fig 13: The reclassified NDVI Image (2008)

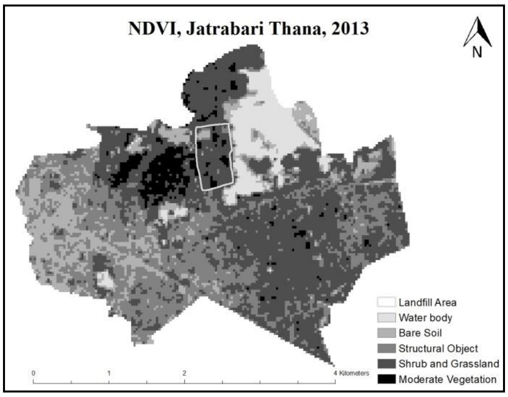

Fig 14: The reclassified NDVI Image (2013)

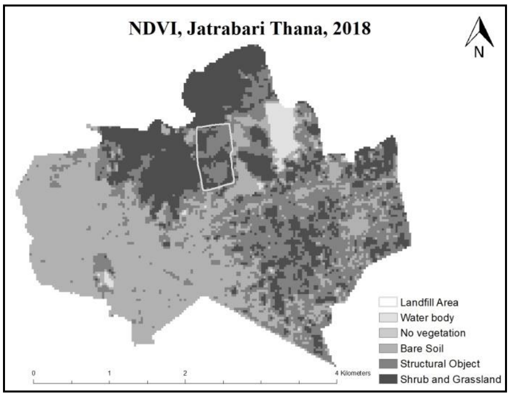

Fig 15: The reclassified NDVI Image (2018)

Table 4: The NDVI Pixel Percentage of Each Range over the Whole Area (Based on Pixel Count)

NDVI Category	**Pixel Percentage of Each Range Over The Whole Area**					
	Nov '93	**Oct '98**	**Dec '03**	**Dec '08**	**Nov '13**	**Nov '18**
Water Body	6.6	14.9	16.9	27.3	7.5	2.1
No vegetation	3.35	4.1	5.5	5.9	-	0.007
Bare Soil	10	10.1	11.5	13.1	14	41.2
Structural Object	13.3	12.1	10.5	13.9	30.6	31.52
Shrub and Grassland	54.2	33.8	34.7	33.45	43.3	25.15
Moderate Vegetation	12.55	24.9	20.3	6.35	4.6	-
High Vegetation	-	0.1	0.6	-	-	-

Higher NDVI value represents healthy vegetation, whereas lower NDVI value represents defective and unhealthy vegetation. From the table 4, it is clearly exposed that within the 25 year period, amounts of bare soil and structural object increase vastly, on the other hand, amounts of vegetation health and water body is diminishing. Improper waste management system is affecting the natural environment of the surroundings. The waterbody percentage is almost 27.3% in 2008, which seems unreal. Also the figure 13 shows water body in some areas which are covered with structural object and roadway in real (assured from Google Earth). Jatrabari thana is a low lying area and also the drainage system of some parts of this area are mostly ineffective. 2007, 2008 and 2009, in these three consecutive years a huge amount of rainfall occurred (BMD, 2018), thus creates huge waterlogging problem in the area. Reclassified images of 2007 and 2009 are given in the figure 16 and 17.

Comparing these images with the reclassified NDVI image of 2008 (figure 13), it can be said that due to waterlogging problem the water body percentages have reached 27.3%.

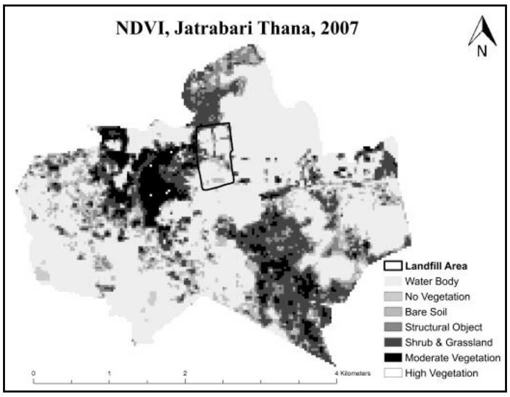

Fig 16: The reclassified NDVI Image (2007)

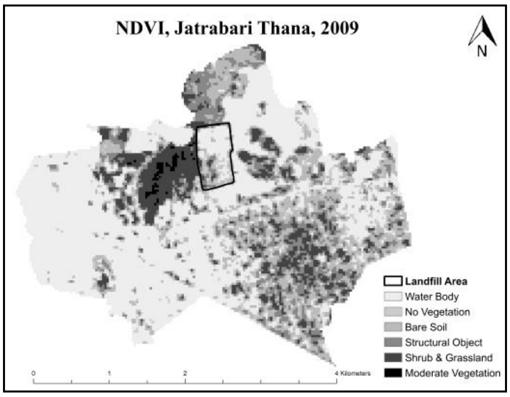

Fig 17: The reclassified NDVI Image (2009)

3.2.2 SAVI

The images of SAVI of 1993, 1998, 2003, 2008, 2013 and 2018 are given in the figure 18 to 23 below.

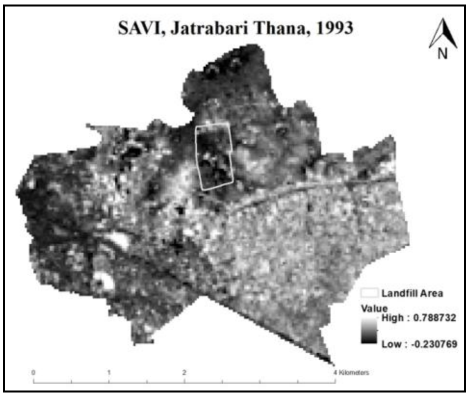

Fig 18: The reclassified SAVI Image (1993)

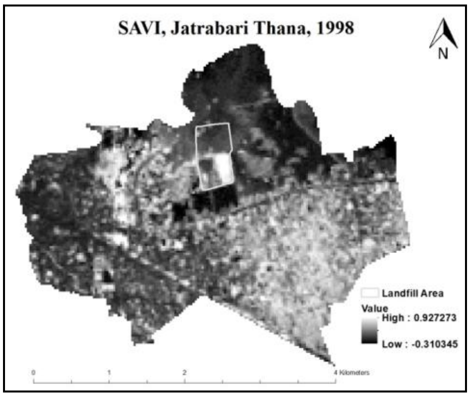

Fig 19: The reclassified SAVI Image (1998)

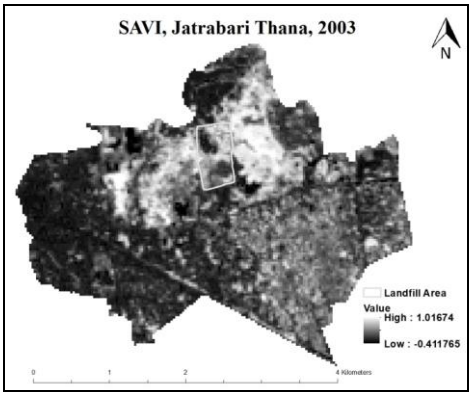

Fig 20: The reclassified MSAVI Image (2003)

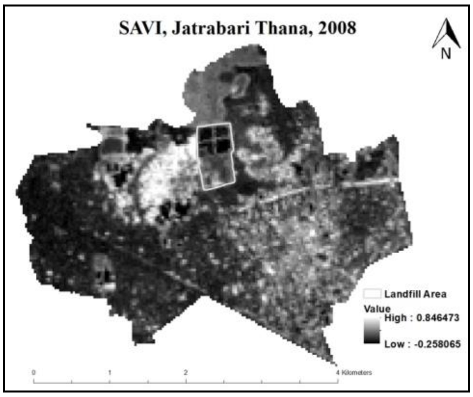

Fig 21: The reclassified MSAVI Image (2008)

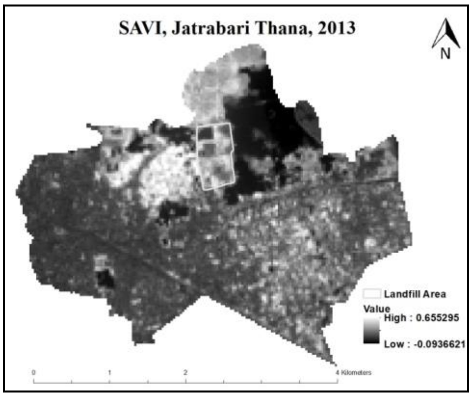

Fig 22: The reclassified MSAVI Image (2013)

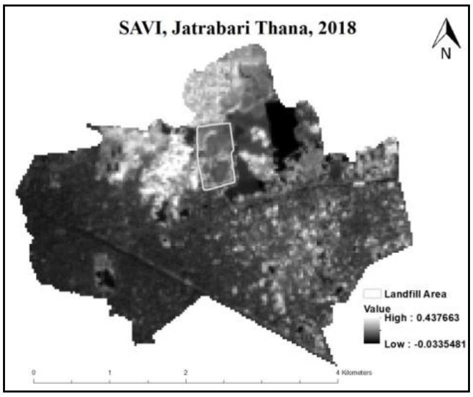

Fig 23: The reclassified MSAVI Image (2018)

SAVI is improved by the alteration of NDVI to be used in infertile areas whereas vegetative cover is little. The highest value increases from 0.78 in 1993 to 1 in 2003. Then it starts to decrease from the optimum value to 0.43 in 2018. Consequently, the lowest value decreases from -0.23 in 1993 to -0.41 in 2003. From the peak point it increases drastically to -0.03 in 2018. As the positive higher value represents healthy vegetation growth and positive lower value represents poor vegetation growth, so it can be said that, the vegetation growth diminishes in a significant way. Here, negative value represents water body. Though only from the minimum and maximum highest and lowest value, it cannot be said clearly how much the vegetation growth increases or decreases for these particular year.

3.2.3 MSAVI

The images of MSAVI of 1993, 1998, 2003, 2008, 2013 and 2018 are given in the figure 24 to 29 below.

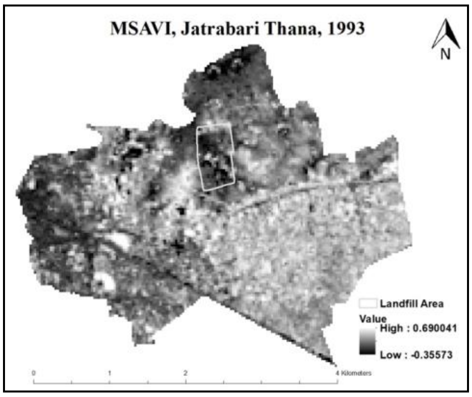

Fig 24: The reclassified MSAVI Image (1993)

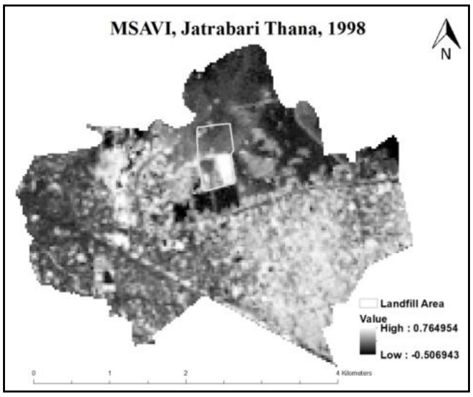

Fig 25: The reclassified MSAVI Image (1998)

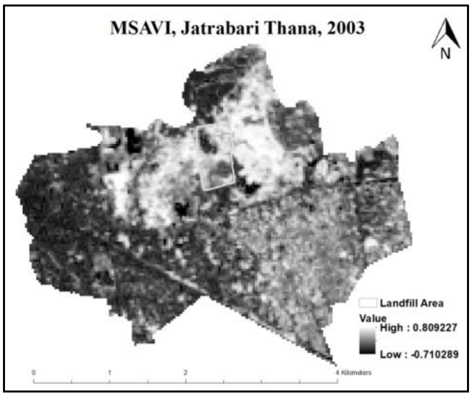

Fig 26: The reclassified MSAVI Image (2003)

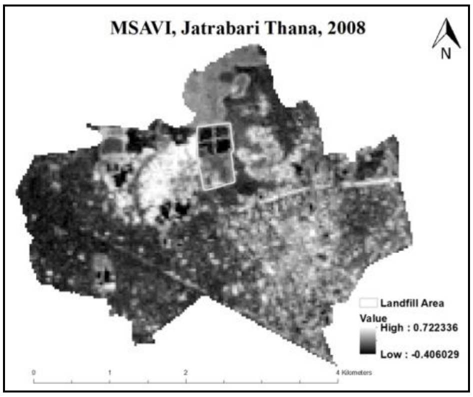

Fig 27: The reclassified MSAVI Image (2008)

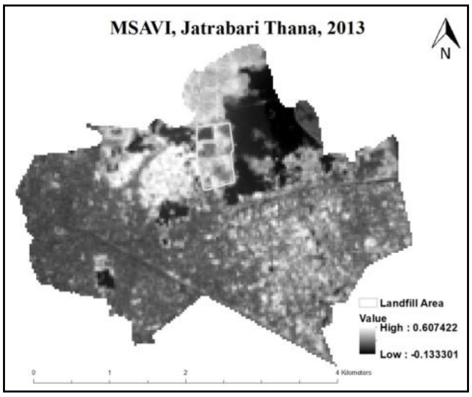

Fig 28: The reclassified MSAVI Image (2013)

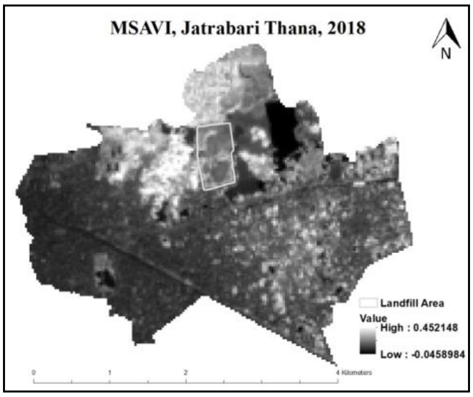

Fig 29: The reclassified MSAVI Image (2018)

MSAVI is the further modification of SAVI. The highest value rises from 0.69 in 1993 to 0.81 in 2003. Then it reducess from the optimum point to 0.45 in 2018. Similarly, the lowest value falls from -0.35 in 1993 to -0.71 in 2003. From the optimum point it ascends drastically to -0.04 in 2018. As like SAVI, the positive higher value represents healthy vegetation growth and positive lower value represents poor vegetation growth, so it can be said that, the vegetation growth has diminished in a significant way. Here also, negative value represents water body and from the minimum and maximum highest and lowest value, it is quite obscure that how much vegetation growth increases or decreases for these particular year.

4. CONCLUSIONS

This research analyses the spatio-temporal pattern of LST and interprets the vegetation health measuring indices such as NDVI, SAVI and MSAVI as indicators of environmental degradation in Matuail landfill and its surrounding region between 1993 and 2018. Though global warming which occurs mainly due to human activities such as the emission of greenhouse gases and so on has an impact on increase in global surface temperatures and there are some industries which also influenced the rise of the temperature in Jatrabari thana, mainly the landfill operations have a great impact on the LST increase of the study area. Because, Poor vegetation growth obtained from NDVI appears at and around the Matuail landfill which indicates the increase of surface temperature as NDVI and LST are vastly correlated. So, this goes without saying that LST increases in the study area significantly mainly due to the landfill gases by rising the average air temperature from the decomposition process of wastes alongside with some other factors as urbanization, deforestation and so on. In addition, the overall activities happened in the landfill severely impacts the output values of NDVI, SAVI and MSAVI. Threateningly, more and more wastes are generating every day and little in the way of recycling and separation of waste will lead to a disastrous condition in the future.

REFERENCES

Abedin, M. A., & Jahiruddin, M. (2015). Waste generation and management in Bangladesh: An overview. *Asian Journal of Medical and Biological Research*, 1(1), 114-120.

Bangladesh Meteorological Department (2018). *Climatic information of Jatrabari thana.* Retrieved from http://datalibrary.bmd.gov.bd/maproom/Climatology/index.html

Banglapedia (2019). *Geographical information of Jatrabari thana.* Retrieved from http://en.banglapedia.org/index.php?title=Jatrabari_Thana

Bhuyan, M. S. S. (2010). *A Study on Quantity and Quality of Leachate of Matuail Sanitary Landfill* (Master's thesis). Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

Hossain, M. F., Jahan, E., Parveen, Z., Ahmed, S. M., & Uddin, M. J. (2018). Solid Waste Disposal and its Impact on Surrounding Environment of Matuail landfill Site, Dhaka, Bangladesh. *American Journal of Environmental Sciences*, 14(5), 234-245.

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ASSESSMENT OF THE BEHAVIOUR OF CONTAMINANTS OF A WASTE DISPOSAL SITE AT KHULNA IN BANGLADESH USING FUGACITY MODEL

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ABSTRACT

Landfill wastes contain various kind of toxic contaminants such as Atrazine, Trichloroethylene, m-Xylene etc. This study was undertaken to assess the behaviour of such contaminants through Level II Fugacity model in different components like landfill gas (LFG), leachate and waste itself due to emission from a selected waste disposal site at old Rajbandh, Khulna, Bangladesh. In this study, an evaluative environment was considered using fictitious but realistic properties like volume, temperature and composition of the waste disposal site at Rajbandh for implementing the Fugacity Model. The model finally shows the concentration, mass distribution, rate of reaction, rate of advection etc. of the selected chemical compounds in different waste media. The concentration of Trichloroethylene in landfill gas (Air), leachate and waste media was found 5.70E-03 mol/m^3, 4.40E-03 mol/m^3 and 4.60E-03 mol/m^3 respectively modelled under Fugacity approach. An uncertainty analysis was also conducted using Monte Carlo simulation (MCS) in order to account the variability and uncertainty of the model inputs as well as to observe its effect on the model outputs. The most likely range (90%) of the concentration of Trichloroethylene, Atrazine and m-Xylene was found 4.53E-03 - 7.29E-03 mol/m^3, 2.90E-02 - 4.14E-02 mol/m^3 and 3.70E+01 - 5.16E+01 mol/m^3 in LFG, waste and LFG media, respectively, through MCS using @RISK 7.6 with 5000 iterations. The concentrations from Fugacity model for these contaminants also found within these ranges which justified the model outcomes. The simulation from MCS also revealed the input parameters which had the most impact on behaviour of the contaminants. It was found that, oxidation reaction rate constant at landfill gas, emission rate of Atrazine in waste media and emission rate of m-Xylene in LFG media were the most important parameter for characterizing the concentration of Trichloroethylene, Atrazine and m-Xylene in LFG, waste and LFG media, respectively. The study results instruct the health risk management of landfill and help future health risk predcition and control. This study highlights the need (i) for accurate emission rate data of the contaminants in different compartments of evaluative environment and (ii) accurate site specific properties (density, aqueous solubility, temperature, vapor pressure, first order reaction rate constants and octanol-water partition coefficients) of the contaminants in different compartment corresponding to the real environment.

Keywords: *Fugacity model, Monte Carlo simulation, Contaminants, Advection, Reaction.*

1. INTRODUCTION

1.1 Background

Landfill is a unit operation system for solid waste disposal and it must be designed to protect the environmental receptors such as human, water, landfill gas (LFG), soil, etc. from contaminants which may be present in the waste stream (Visvanathan C. et al.,1999). Rajbandh landfill is the main waste disposal site for the Khulna city. The city generates approximately 450 tons of municipal solid waste (MSW) every day which increases to approximately 500 tons due to demand and seasonal variation of products. Of the total amount, only 250-270 tons of MSW are dumped into the open dumping ground at Rajbandh, Khulna (Khan M.S. et al., 2015). As these wastes decomposes, various types of toxic LFG and toxic leachate compounds generates such as Atrazine, Trichloroethylene etc. These contaminants enter the atmosphere and pollute the main components of environment such as atmosphere, lithosphere (land) and hydrosphere (water). The generated toxic leachate also percolates through the underlying soil layer. These contaminants contain extensive ranges of possible carcinogens, non-carcinogens and toxicological compounds that signify a potential risk to the public health. So, it has become important to know the possible concentration, mass and percentage of these chemicals in different waste components like landfill gas, leachate and waste (soil) to extract the behaviour profile of these contaminants in the environment. In this study, an attempt is made to find the behaviour of three priority contaminants in landfill waste on the basis of Level II Fugacity model. The behaviour here actually means concentration, mass distribution, fugacity, rate of reaction, rate of advection etc. of selected contaminants which releases from the waste landfill site at old Rajbandh.

1.2 Rationale

Assessment of chemical fate requires some modelling because human mind is incapable of assimilating and processing the various disparate quantities such as vapor pressure, octanol water partition coefficients, reaction rate constants and transfer coefficients which combine to determine the chemical's behaviour (Mackay D. et al., 1985). Fugacity model is a great tool for predicting the behaviour of contaminants which are subjected to steady state partitioning, advection, reaction, intermedia transport etc in an evaluative environment. This model generates consistent behaviour profiles which may be useful for predicting the behaviour of contaminants for which no environmental observations exist.

The Level II Fugacity model adopted here comprises three environmental compartments: LFG, leachate and waste. The model in this study was generated in the form of a MS Excel program. Areas, depths and volumes are user specified from which the volume of each compartment was derived. Other input parameters include advection inflow rate (G), fraction organic carbon and emission rate of the contaminant in each of the compartment. With regards to the chemical input data, molecular weight, density, aqueous solubility (C_s), temperature (T), vapor pressure (P_s), first order reaction rate constant (k) and octanol water partition coefficients (K_{ow}) need to be specified.

Using the input parameters, Henry's Law Constant (H) is determined using the following Equation 1,

$$H = \frac{P_s}{C_s} \tag{1}$$

Where, H is the Henry's Law Constant (Pa^3m/mol), P_s is Vapor pressure (Pa) and C_s is Aqueous solubility (mol/m^3)

Oxidation, hydrolysis, photolysis and biodegradation reaction were considered in each of the compartment for the decay or removal of the contaminant from the evaluative environment. The combined values of first order reaction rate constant were obtained from Equation 2.

$$K = K_O + K_P + K_H + K_B \tag{2}$$

Where, K is the Combined reaction rate constant (h^{-1}) and K_O, K_P, K_H, K_B are the reaction rate constant for oxidation, photolysis, hydrolysis and biodegradation reactions respectively (h^{-1})

The fugacity capacities (Z) of contaminant at different compartment of the evaluative environment are obtained using the formulas presented in Table 1.

Table 1: Definition of fugacity capacities

Compartment	**Fugacity capacity, Z(mol/m³Pa)**	**Source of parameters**
LFG/air (1)	$1/RT$ [a]	R = 8.314 Pa^3/mol K T= Absolute temperature (298 K)
Leachate (2)	$1/H$ or C_S/P_S [b]	H = Henry's Law Constant (Pa^3m/mol) C^S = Aqueous Solubility (mol/m^3) P^s = Vapor Pressure (Pa)
Waste (3)	$K_P\rho/H$ [c]	K_p = Partition Coefficient (L/kg) P = density (kg/L) K_p = 0.411 x K_{ow} Where, x = Fraction of organic carbon K_{ow} = Octanol-water partition coefficient

[a, b, c] (Mackay D. et al., 1985)

The contaminant can be removed from different compartment of the evaluative environment by advection and reaction. To acknowledge advection and reaction, a term called D value arises which is further used for calculating the rate of advection and reaction separately. D values for advection can be found using Equation 3.

$$D_A = GZ \tag{3}$$

Where, D_A denotes D values for advection (mol/Pa h), G is advection inflow rate of the contaminant (m^3/h) and Z is fugacity capacity (mol/m^3 Pa).
D values for reaction can be found using Equation 4.

$$D_R = VKZ \tag{4}$$

Where, D_R denotes D values for reaction (mol/Pa h), V is volume of the compartment (m^3), K is combined reaction rate constant (h^{-1}) and Z is fugacity capacity (mol/m^3 Pa)
Mass balance equation for each compartment yields a general form like Equation 5.

$$E_i = D_A f + D_R f \tag{5}$$

Where, E_i is emission rate of contaminant at compartment *i* (mol/h), D_A is D value for advection (mol/Pa h), D_R is D values for reaction (mol/Pa h) and f is fugacity of the contaminant at compartment *i* (Pa).

Lumping Eq. (5) for the three compartments, a linear matrix can be formed. Solving this matrix, fugacity (Pa) of the contaminant in each of the compartment can be obtained. The concentration, rate of advection and rate of reaction of contaminants can be obtained from Equations 6, 7 and 8, respectively.

$$C = fZ \tag{6}$$
$$E_A = D_A f \tag{7}$$
$$E_R = D_R f \tag{8}$$

Where, C denotes Concentration (mol/m^3), E_A denotes rate of advection (mol/h) and E_R denotes rate of reaction (mol/h). Equations (6), (7) and (8) represents the behaviour of contaminants in LFG, leachate and waste compartment, respectively, of the evaluative landfill envirionment.

1.3 Major Contaminants in landfill waste

In the process of MSW degradation in landfills, leachate and LFG are the two crucial and principal outputs of landfill. These leachate and LFG are the dominant components for the environmental impacts as well as public health effects as they contain harmful toxic chemicals having carcinogenous and non-carcinogenous behaviour. This study focussed on atrazine, trichloroethylene and m-xylene as representative of main types of priority contaminants.

1.4 Study aims

This study sought to build a representative landfill environment derived from fictitious but realistic properties such as composition, volume and temperature as well as apply the Level II Fugacity model. The objectives of this study were to (i) characterize the fate of these contaminants in the evaluative environment based on Fugacity model and (ii) perform Monte Carlo simulation using @RISK 7.6 (Palisade, 2019) to validate the obtained behaviour profiles of these contaminants and find the most sensitive parameters.

2. MATERIALS AND METHODS

The methodology adopted in this study is highlighted and hence discussed in the following articles.

2.1 Evaluative landfill environment

The dumping site of old Rajbandh, Khulna was taken as the evaluative environment which allows for three phases: landfill gas (LFG), water (leachate) and solid waste for processes of gas and water flux through the system being represented. The entire dumping site was considered as a single cell of MSW. This choice was influenced by the availability of data on the site-specific properties. The dimensions and characteristics of the evaluative environment are reported in Table 2. The volumetric composition and physical characteristics of the environment (Table 3) provide a valuable base for this study.

Table 2: Dimension of evaluative environment

Parameter	Value
Cell area	5.42E+04 m^2
Cell depth	4 m[a]
Cell volume	2.17E+05 m^3
Waste density	1.00E+03 kg/m^3[g]
Waste deposition rate	260 ton/day[h]

Table 3: Volumetric composition of environment

Parameter	Volume fraction	Volume
LFG/air	0.10[d]	2.17E+04 m^3
Leachate	0.65[e]	1.27E+05 m^3
Waste	0.25[f]	6.83E+04 m^3

[d, e, f, g, h] (Islam M.R., 2014)
[h] (Khan M.S. et al., 2015)

2.2 Chemical input

Environmental fate of contaminants is intimately connected with their physiochemical properties as well as environmental properties in the specific study areas, so model input parameters need to be updated when analysing different contaminants in different study areas (Mackay D. et al., 1985). There are variabilities and uncertainties associated with chemical input parameters due to lack of local environmental data. For this reason, typical values from (Mackay D. et al., 1985) were used as the chemical input parameters such as emission rates, reaction rate constants, fraction of organic carbon, etc. (Table 4 and 5).

The emission rate for all contaminants in the evaluative environment was considered 1 mol/h and it distributes in different compartments of the evaluative environment according to their nature. Due to lack of local environmental data, no background concentration of the contaminants was considered. In Monte Carlo simulation (MCS) using @RISK 7.6, these chemical input parameters were varied in nature of a lognormal distribution curve with suitable mean and standard deviation values supporting the literatures.

Table 4: Chemical properties and emission rates

Chemical Name	MW (g/mol)	C^s (g/m^3)	P^s (Pa)	$LogK_{ow}$	Emission Rate (mol/h)		
					LFG/air	Leachate	Waste/soil
Trichloroethylene	1.3E+02	1.8E+03	1.1E+03	2.3E+00	9.0E-01	5.0E-02	5.0E-02
Atrazine	2.2E+02	3.3E+01	3.0E-06	2.3E+00	0.0E+00	1.0E-01	9.0E-01
m-Xylene	1.1E+02	1.6E+02	1.1E+03	3.2E+00	9.3E-01	4.3E-02	2.7E-02

Table 5: First order reaction rate constants

Chemicals	Reaction Rate Constant, K (h^{-1})						
	Photolysis	Oxidation		Hydrolysis		Biodegradation	
	LFG/air	LFG/air	Leachate	Waste/soil	Leachate	Leachate	Waste/soil
Trichloroethylene	0.0E+00	7.2E-03	0.0E+00	0.0E+00	9.0E-05	0.0E+00	0.0E+00
Atrazine	3.7E-02	0.0E+00	0.0E+00	1.4E-04	0.0E+00	3.9E-03	8.0E-05
m-Xylene	0.0E+00	0.0E+00	1.4E-07	0.0E+00	0.0E+00	1.0E-03	0.0E+00

2.3 Fugacity modelling

Level II fugacity calculations illustrate the partitioning behaviour of contaminants in the evaluative environment of landfill. Level II model accounts for equilibrium, steady state and flow system i.e. the amount of contaminant entering the environment is mass balanced by the amount lost to flow, reaction or degradation (Shafi S. et al., 2006). The entire phenomenon is briefly illustrated in Figure 1 where contaminant is introduced in the evaluative landfill environment. It partitions among the LFG, leachate and waste compartment and after certain residence time, the contaminant is removed by flow and reaction.

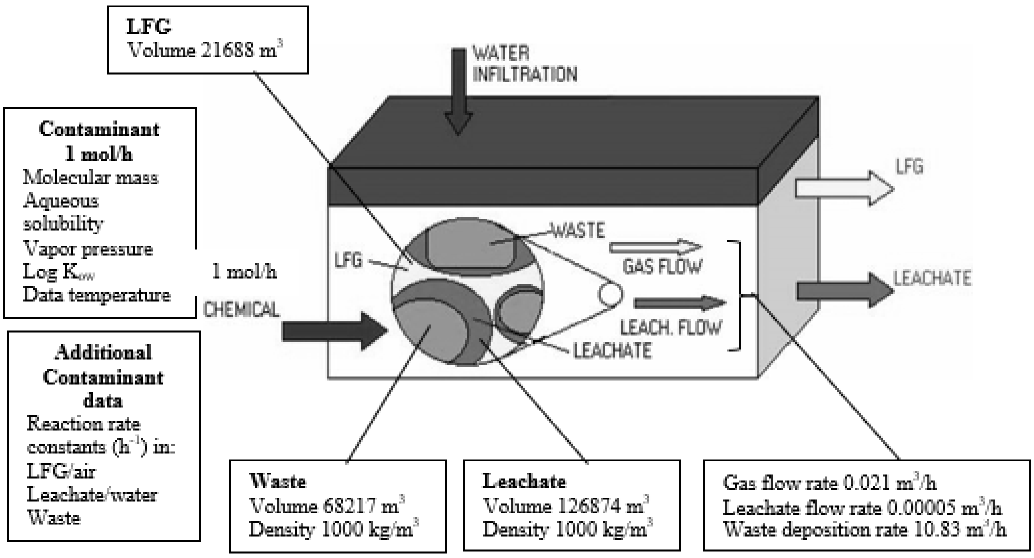


Figure 1: Evaluative environment for Level II Fugacity model

The characteristics of the system are presented in Table 6. Using Equations (1) to (8), the behaviour such as concentration, fugacity, mass distribution, rate of advection, rate of reaction etc. of specific contaminants in LFG, leachate and waste compartment were characterised.

Table 6: Parameters for Level II Fugacity model calculation

Parameter	value	Justification/Reference
Emission rate into environment	1 mol/h	Taken from (Mackay D. et al., 1985)
Landfill gas flow rate	2.10E-02 m^3/h	Adapted to evaluative environment [i]
Leachate flow rate	5.00E-05 m^3/h	Adapted to evaluative environment [j]

[i, j] (Islam M.R., 2014)

2.4 Monte Carlo simulation

As models are only approximation of the contaminant's actual behaviour in real environment, communicating the uncertainties associated with the model is crucial (Kilic S.G. & Aral M.M., 2008). Monte Carlo simulation (MCS) is a great tool for quantifying uncertainties in fugacity model. A typical MCS calculates the model hundreds of times and each time it uses a randomly selected values for the input parameters. When the simulation is complete, it has large number of results from the model, each based on random input values. These results describe the likelihood, or probability of reaching various results in the model (Kumar M.P., 2018). It also justifies the outcomes of the model. In this study, chemical input parameters such as aqueous solubility, vapor pressure, first order reaction rate constants, octanol water partition coefficients and contaminant emission rates in different compartments have been assigned lognormal distribution as it has a positive state space. They were assigned with suitable mean and standard deviation values supporting the literatures. For each contaminant, the highest concentration in respective compartment was chosen as the output parameter of the simulation. A total of 5000 trials were performed using @RISK 7.6 for the Monte Carlo runs with 5000 random variables created for the overall aqueous solubility, vapor pressure, first order reaction rate constants, octanol water partition coefficients and contaminant emission rates. The simulation outcomes were used to check the Level II Fugacity model outcomes and the most sensitive parameters were recognized from tornado charts.

3. RESULTS AND DISCUSSION

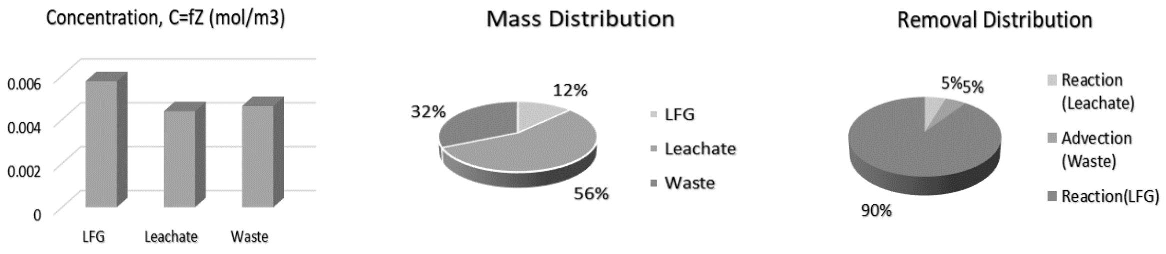
The findings from Level II Fugacity model and Monte Carlo simulation are presented and hence discussed in the following articles.

3.1 Level II Fugacity Modelling

The level II Fugacity model was implemented to characterize the selected contaminants emitted from MSW landfill and the findings are highlighted in the following sections.

3.1.1 Trichloroethylene

The modelled concentration of Trichloroethylene was found 5.70E-03 mol/m^3, 4.40E-03 mol/m^3 and 4.60E-03 mol/m^3 in LFG, leachate and waste compartment, respectively (Figure 2a). High concentration was found in the LFG compartment (Figure 2a) because Trichloroethylene has high volatility and high emission rate in LFG media. Most of the mass was found in leachate compartment (Figure 2b) because of its high volume. The behaviour depicted in Figure 2c showed that about 90% of the total emitted Trichloroethylene was removed by reaction (oxidation) in LFG, 5% by advection in waste and the remaining (5%) was removed by reaction (hydrolysis) in landfill leachate. About 95% of total emitted amount was removed by reaction. So, advection was relatively unimportant compared to reaction as a removal mechanism for Trichloroethylene.

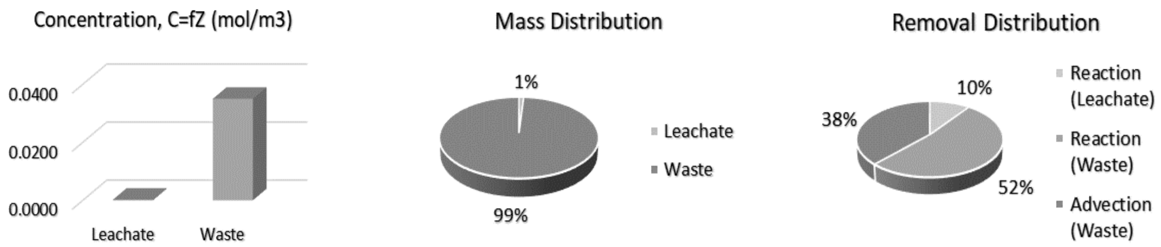


(a) (b) (c)

Figure 2: Behaviour of Trichloroethylene in evaluative environment

3.1.2 Atrazine

The concentration of Atrazine was found approximately 2.00E-04 mol/m^3 and 3.50E-02 mol/m^3 in leachate and waste compartment, respectively (Figure 3a). No mass and concentrations of atrazine was found in LFG compartment as there was no emission of it in LFG and no intermedia transfer was considered. About 98.93% of total mass was found in leachate and remaining 1.07% was in waste (Figure 3b). The illustration in Figure 3c showed that about 52% Atrazine was removed by reaction (photolysis and hydrolysis) in waste, 38% by advection in waste and the remaining by reaction (biodegradation) in leachate. Reaction (photolysis, hydrolysis and biodegradation) was the main removal mechanism for Atrazine as about 62% of the total emitted amount was removed by reaction.

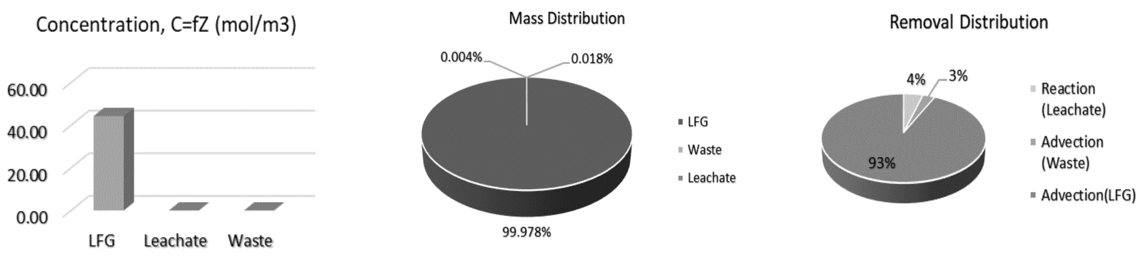


(a) (b) (c)

Figure 3: Behaviour of Atrazine in evaluative environment

3.1.3 m-Xylene

The concentration of m-Xylene was found 44.29 mol/m^3, 3.30E-04 mol/m^3 and 2.50E-03 mol/m^3 in LFG, leachate and waste compartment, respectively (Figure 4a). High concentration and most of the mass (Figure 4b) was found in the LFG compartment because of its high emission rate in LFG media, high volatility and relatively low aqueous solubility. Figure 4c showed that about 93% of the total emitted m-Xylene was removed by advection in LFG, about 4.3% by reaction in leachate and the remaining 2.7% by advection in waste. So, advection was the main removal mechanism for m-Xylene. Though m-Xylene has very low concentration in leachate, it was the only compartment where reaction (oxidation and biodegradation) could occur for this contaminant. This is why a little portion (4.3%) of the total emitted m-Xylene was removed by reaction in leachate.



(a) (b) (c)

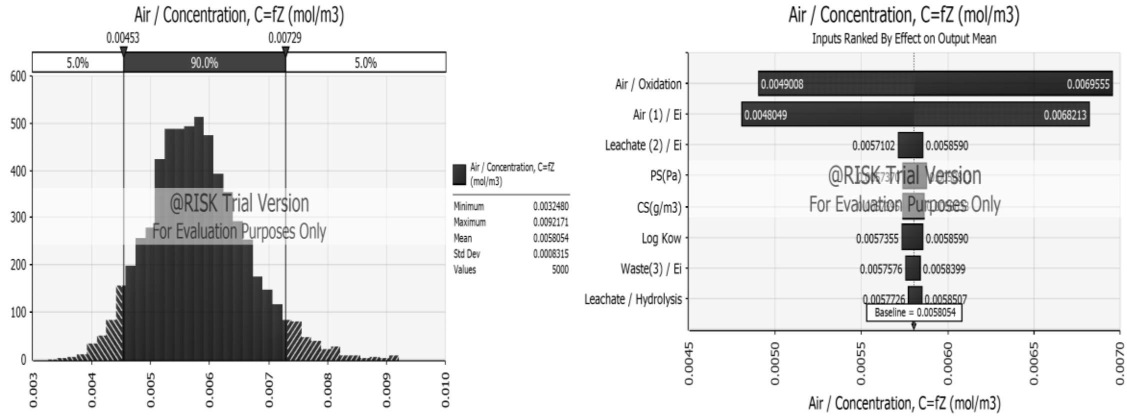
Figure 4: Behaviour of m-Xylene in evaluative environment

3.2 Monte Carlo simulation

To fit a lognormal distribution of the input parameters, this highest concentration was compiled using @RISK 7.6. The MCS was run for 5000 trials with 5000 random variables for the input parameters of Fugacity model. The most sensitive parameter in Monte Carlo runs was found by varying each of the input parameter within the assigned lognormal distribution curve and keeping the other parameters at their static values.

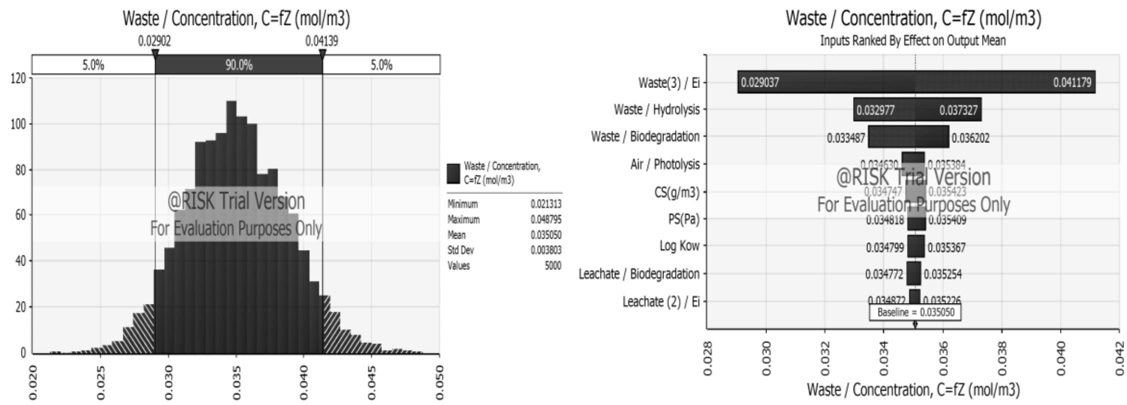
3.2.1 Trichloroethylene

Highest concentration of Trichloroethylene was found in LFG compartment with a value of 5.70E-03 mol/m^3. In Figure 5a, the height of the bars (y axis) represents the relative frequency of this concentration and the spread of the bars represents (x axis) the varying amount of this concentration. From Figure 5a, it is seen that the concentration of Trichloroethylene in LFG media ranges from 3.00E-03 mol/m^3 to 4.53E-03 mol/m^3 and 7.29E-03 mol/m^3 to 1.00E-02 mol/m^3 for the 5th and 95th percentile, respectively. The concentration of 4.53E-03 mol/m^3 responds to 5th percentile and 7.29E-03 mol/m^3 responds to 95th percentile. So approximately, 90% (i.e. 0.95-0.05 = 0.90) of the concentration is likely to be exist between 4.53E-03 mol/m^3 to 7.29E-03 mol/m^3 with a mean value of 5.80E-03 mol/m^3. The modelled concentration was also found within this range. It was also found that oxidation reaction rate constant and emission rate in LFG compartment was the most sensitive parameter for variation of this concentration in Monte Carlo runs (Figure 5b). The concentration increases if the oxidation reaction rate constant in LFG compartment decreases and vice versa (Figure 5b). It also increases if the emission rate of Trichloroethylene in LFG media increases and vice versa.



(a) (b)

Figure 5: Monte Carlo simulation run for Trichloroethylene



(a) (b)

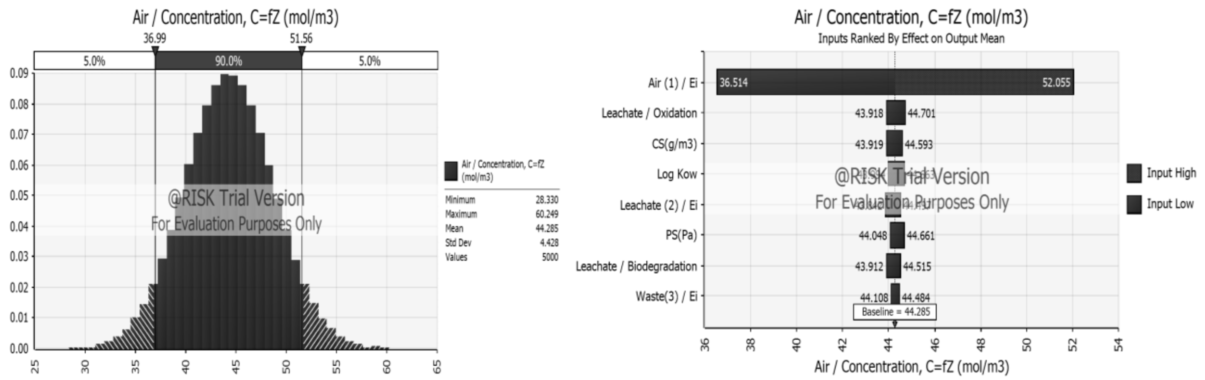
Figure 6: Monte Carlo simulation run for Atrazine

3.2.2 Atrazine

Atrazine had highest concentration in waste compartment with a value of 3.50E-02 mol/m^3. In Figure 6a, the height of the bars (y axis) represents the relative frequency of this concentration and the spread of the bars represents (x axis) the varying amount of this concentration. From Figure 6a, it is seen that the concentration of Atrazine in waste media ranges from 2.00E-02 mol/m^3 to 2.90E-02 mol/m^3 and 4.14E-02 mol/m^3 to 5.00E-02 mol/m^3 for the 5th and 95th percentile, respectively. The concentration of 2.90E-02 mol/m^3 responds to 5th percentile and 4.14E-02 mol/m^3 responds to 95th percentile. So approximately, 90% (i.e. 0.95-0.05 = 0.90) of the concentration is likely to be exist between 2.90E-02 mol/m^3 to 4.14E-02 mol/m^3 with a mean value of 3.51E-02 mol/m^3. The modelled concentration was also found within this range. The most sensitive parameter for the variation of this concentration in Monte Carlo runs was emission rate in waste media (Figure 6b). The concentration increases if the emission rate of Atrazine in waste media increases and vice versa.

3.2.3 m-Xylene

m-Xylene had highest concentration in LFG compartment with a value of 44.29 mol/m^3. In Figure 7a, the height of the bars (y axis) represents the relative frequency of this concentration and the spread of the bars represents (x axis) the varying amount of this concentration. From Figure 7a, it is seen that the concentration of m-Xylene in LFG media ranges from 25 mol/m^3 to 36.99 mol/m^3 and 51.56 mol/m^3 to 65 mol/m^3 for the 5th and 95th percentile respectively. 36.99 mol/m^3 responds to 5th percentile and 51.56 mol/m^3 responds to 95th percentile. So approximately, 90% (i.e. 0.95-0.05 = 0.90) of the concentration is likely to be exist between 36.99 mol/m^3 to 51.56 mol/m^3 with a mean value of 44.285 mol/m^3. The modelled concentration was also found within this range. Most sensitive parameter for the variation of this concentration in Monte Carlo runs was emission rate in LFG media (Figure 7b). The concentration increases if the emission rate of m-Xylene in LFG media increases and vice versa.



(a) (b)

Figure 7: Monte Carlo simulation run for m-Xylene

3.3 Study limitations

Lack of site-specific data regarding input parameters was one of the major limitations of this study. It was important in terms of emission rates, but also for the volumetric composition of the LFG, leachate and waste that are required to create the evaluative environment. Due to lack of local environmental data, representative mean values of input parameters from (Mackay D. et al., 1985) were considered including emission rate, aqueous solubility, vapor pressure, octanol-water partition coefficient and so on. In addition, for simplicity, LFG and leachate was treated as having the same input parameters of air and water, respectively, though they would express their own complex characteristics in the real environment as they generate and migrate through the waste. A further limitation is evaluating the model at standard temperature of 25°C though landfill will undergo diurnal, seasonal and microbiologically induced temperature changes through various stages of its lifetime (Shafi S. et al., 2006). Temperature is influential for factors like aqueous solubility, vapor pressure and octanol-water partition coefficient. But Fugacity model cannot address this problem without running multiple simulations. A further and significant limitation was choosing the Level II Fugacity approach rather than Level III and IV approach. Level II Fugacity approach doesn't address the intermedia transport of the contaminants between the compartment of the evaluative environment. Due to lack of intermedia transport coefficient data, Level II approach was chosen and it was not capable of representing the actual complex behaviours that contaminants were undergoing in the landfill environment.

4. CONCLUSIONS

Implementing Level II Fugacity model on complex landfill environment like old Rajbandh have shown how contaminants like Trichloroethylene, Atrazine and m-Xylene partitions among the landfill media in a simplified way. Trichloroethylene and m-Xylene had the highest concentration in landfill gas, while, Atrazine had the highest concentration in waste. The model also showed how these contaminants could be lost or removed from the landfill environment without considering intermedia transportation of the contaminants. Atrazine and Trichloroethylene was mostly removed by reaction, while, advection was the main removal mechanism for m-Xylene. Monte Carlo simulation was introduced here to reduce the variability and uncertainty associated with the input parameters addressed in the model. As standard data set regarding the model outcomes for the selected landfill site was sparse, Monte Carlo simulation justified the model outcomes primarily. There is an explicit need for precise site-specific chemical input parameters and emission rates to increase the efficiency of this model. More accurate outcomes would have been found if intermedia transportation of contaminants were taken into account. Landfill pose health hazard to the local communities and workers. To address health hazard, it is a must to know the behaviour of potential harmful contaminants. Notwithstanding several limitations, this study had illustrated the application of Fugacity model on determining the potential behaviour of contaminants generated from landfill.

REFERENCES

Visvanathan, C., Pokhrel, D., Cheimchaisri, W., Hettiaratchi, J.P.A., & Wu, J.S.. (1999). Methanotrophic activities in tropical landfill cover soils: effects of temperature, moisture content and methane concentration. Waste Management & Research, 313-323.

Mackay, D., Paterson, S., Cheung, B., & Neely, W.B. (1985). Evaluating the environmental behavior of chemicals with a level III fugacity model. Chemosphere, 14, 335-374.

Islam, M.R. (2014). Evaluation of Contamination Potential and Treatment Techniques of Leachate Generated from Landfill Lysimeter. Khulna University of Engineering &Technology, Department of Civil Engineering. Khulna: PhD Thesis Report.

Mahanta, P.K. (2018). Assessment of the Potential Human Health Risk of a Waste Disposal Site in Khulna. Khulna: MSc. Thesis Report.

Khan, M.S., Hossain, S., & Jahan, I. (2015). RS and GIS Based Site Suitability Analysis for Solid Waste Disposal: A Multi Criteria Analysis of Khulna City Area. Waste Safe. Khulna.

Palisade. (2019, October 14). RISKDownload. Retrieved from go.palisade.com.

Kilic, S.G., & Aral, M.M. (2008). Probabilistic fugacity analysis of Lake Pontchartrain pollution after Hurricane Katrina. Journal of Environmental Management, 448–457.

Shafi, S., Sweetman, A., Houg, R.L., Smith, R., Rosevear, A., & Pollard, S.J.T. (2006). Evaluating fugacity models for trace components in landfill gas. Environmental Pollution, 1013-1023.

PROSPECTS OF HYBRID UP-FLOW ANAEROBIC SLUDGE BLANKET REACTOR IN TREATING TEXTILE WASTEWATER IN BANGLADESH

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ABSTRACT

In this study, the performance of a lab-scale hybrid up-flow anaerobic sludge blanket (HUASB) reactor treating textile wastewater was evaluated. Biocell filter media was incorporated in the UASB reactor for the attached growth of microorganisms. The wastewater was collected from Mahmud Denims Ltd which had high COD, BOD and color concentration. The reactor was operated under three different conditions: i) textile wastewater mixed up with glucose as food, ii) textile wastewater seeded with sewage sludge and glucose and iii) textile wastewater only. In all cases, two days of incubation period was provided for bacterial growth. In the first case, Klebsiella was the primary bacterium growing in the reactor and the removal efficiency of COD and color was 25% and 56.4% respectively. In the second case, Klebsiella and Escherichia coli were the major bacteria and removal efficiency of COD and color was found to be 38% and 65% respectively. In the last case, Pseudomonas bacterium was dominant in the reactor and removal efficiency of COD, BOD and color was 84%, 93%, and 96~97% respectively. Wastewater treatment without glucose favored the growth of Pseudomonas which has been found to be effective in degrading organics present in textile wastewater. For all cases, the reactor's performance decreased after the third or fourth cycle of treatment. However, the removal of sludge after the third cycle maintained a high degradation efficiency of organics. The performance of the lab-scale HUASB reactor was compared with that of some conventional UASB reactors currently being operated in Bangladesh. Our lab-scale reactor showed better performance than the UASB units of these effluent treatment plants in removing COD, BOD, and color in spite of having significantly lower retention time. So, with proper bacterial growth and maintenance, the HUASB reactor can be a considerable upgrade from conventional UASB and a suitable alternative to conventional processes for the treatment of textile wastewater.

Keywords: *Hybrid UASB, Textile wastewater treatment, Anaerobic process, COD removal, Color removal.*

1. INTRODUCTION

The textile industry contributes a significant portion of the total exports of Bangladesh. Share of Ready-made-garments (RMG) in national export is 85.43% (Bangladesh Bureau of Statistics [BBS],2017). However, the textile industry consumes large quantities of water and produces large volumes of wastewater. It is estimated that textile industries in Bangladesh generated around 217 million m3 of wastewater in 2016 and if the textile industries continue using conventional dyeing practices then wastewater production for the year 2021 will be 349 million m3 (Hossain, Sarker, & Khan, 2018). Wastewater from printing and dyeing units is often rich in color, contains residues of reactive dyes and these dyes are mostly aromatic and heterocyclic organic compounds (Wang, Xue, Huang & Liu, 2011). These structures are complicated and stable which poses a greater difficulty for degradation using conventional wastewater treatment processes (Joshi, Bansal, & Purwar, 2004).

In the past several decades, many techniques have emerged to find an economical and efficient way to treat the textile dyeing wastewater, including physicochemical, biochemical, biological and combined treatment processes. Industries adopting chemical treatment processes are facing the problem of excessive sludge generation which is unmanageable in most developing countries (Samer, 2015). Also, chemically treated water with low regulation may pose an additional health hazard (e.g. formation of trihalomethanes) (Akpor, 2011). Aerobic treatment processes show lower efficiency under increased organic loading, have a high operational cost associated with blower operation and generates a large amount of sludge. These problems have led industry owners to adopt anaerobic wastewater treatment processes which could potentially overcome some of these problems. The Up-flow Anaerobic Sludge Blanket (UASB) Reactor has been successfully implemented to treat wastewater in our neighboring country, India for more than 20 years and its performance was found to be satisfactory (Khalil, Mittal, Raghav, & Rajeev, 2006). Presently over 200 full-scale UASB plants are in operation all over the world for the treatment of both domestic and industrial wastewaters.

UASB reactor is a methanogenic (methane-producing) digester. It works even when the wastewater contains chemical oxygen demand (COD) and biochemical oxygen demand (BOD) value so high that the aerobic treatment becomes ineffective. The UASB reactor reduces COD and BOD concentration to such a level that it can be treated further using aerobic processes. The main advantage of this technology is low capital cost, low energy requirements, low operational and maintenance cost(Miah, 2013). No chemical is needed except for controlling pH. Moreover, the biogas produced bythe UASB reactor can be used to recover energy(Daud et al., 2018). But in this technology, a start-up period of 3-4 months is needed for granule formation in a delicately controlled environment (Hulshoff Pol, De Castro Lopes, Lettinga & Lens, 2004). Besides, COD removal efficiency is about 50%, necessitating further treatments (Amaral, Kato, Florêncio & Gavazza, 2014). If the environment for bacterial growth is disturbed, the reactor fails and an additional maturation period for granules is needed for restarting the reactor. In order to eliminate all these shortcomings, a modification has been proposed to the conventional UASB which is through the introduction of a media for attached growth and the modified setup is termed as hybrid UASB (HUASB). This adjustment has been found to reduce the start-up time, enhance COD and color removal efficiency and to lower down retention time (Priya, Meenambal, Balasubramanian & Perumal, 2015). As this technology works better in a hot climate, it is deemed to be highly suitable for countries like India and Bangladesh. This technology is yet to be implemented in large industrial effluent treatment plants in Bangladesh.

The objective of this study is to evaluate the performance of the HUASB reactor treating textile wastewater in Bangladesh. A lab-scale reactor was operated and bacterial growth, sludge production, COD, BOD, and color removal efficiencies were monitored under different operating conditions.

2. METHODOLOGY

2.1 Wastewater Collection

Textile wastewater from Mahmud Denims Limited, Shafipur, Kaliakoir, Gazipur was used in our experiments. The factory comprises of spinning, weaving, dyeing, and jeans section. The production capacity of thisfactoryis about 1,50,000 Yards/day while consuming about 2500 m^3 water/day. Water used in different processes is mainly groundwater. The wastewater was fed with cow dung at a ratio of 1:3 v/v in the feeding tank. Wastewater was collected in 25L plastic containers from the equalization tank of the industry's ETP. The raw wastewater characteristics are shown in Table 1.

Table 1: Characteristics of raw wastewater

Parameter	Value
pH	7.4
Electrical Conductivity (mS/cm)	6.59
Color (Pt-Co Unit)	8700~8900
Dissolved Oxygen (mg/L)	0.06
Phosphate (mg/L)	72
Total Dissolved Solids (mg/L)	1578
Total Suspended Solids (mg/L)	8513
COD (mg/L)	2310~2416

2.2 Experimental Setup

A lab-scale reactor with a capacity of 12.3 liters was fabricated using a transparent acrylic fiber cylinder with a diameter of 3.5 inches and a height of 6.5 feet with a wall thickness of 0.5 inches. The reactor is divided into three zones- Digestion zone, Transition zone, and Settling zone. A Schematic diagram is shown in figure 1.

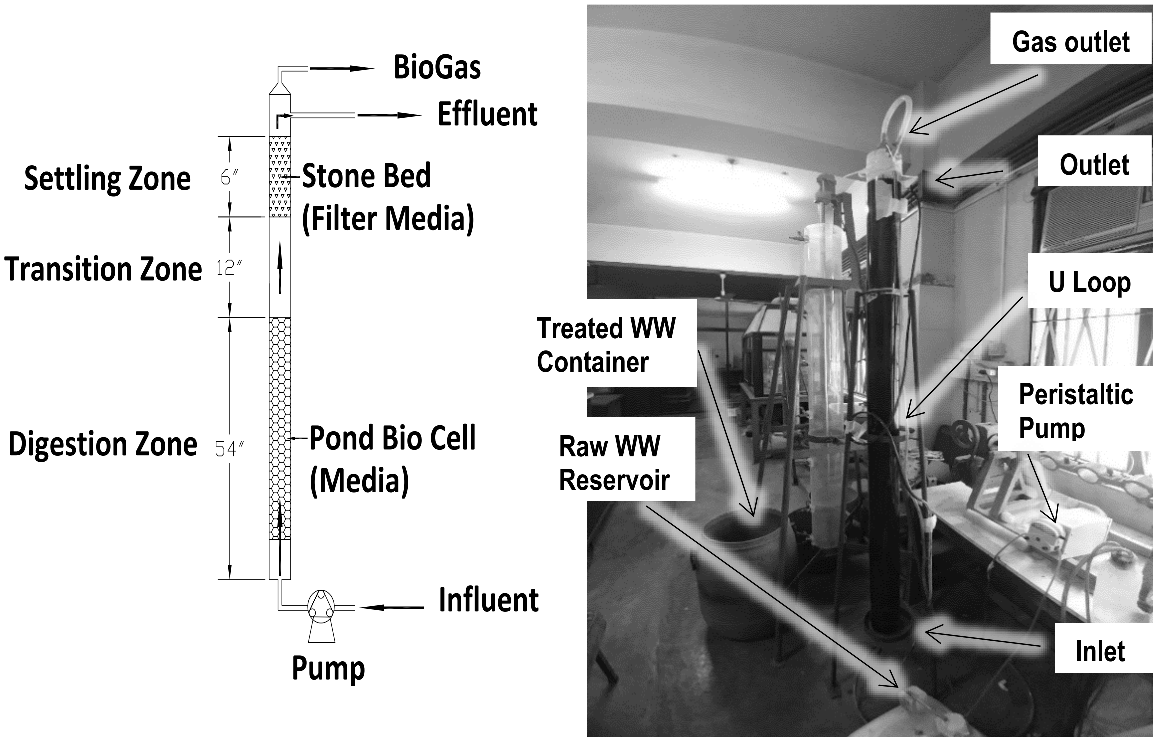


Figure 1: Schematic diagram (left) and image (right) of the experimental setup

The digestion zone was at the lower part of the reactor, 4.5 feet long and filled with pond bio cells (packing media, polypropylene rings of 20 mm diameter) in between 2 fixed screens (0.2-inch diameter screen size). The screens are placed at a distanceof 48 inches to contain the pond bio cells. These bio cells facilitate the growth of microorganisms. 6 inches of space was provided at the bottom of the rector for sludge accumulation. Above the digestion zone, there was a 1-foot blank space as a transition zone. The next 6-inch height was the settling zone filled with fine gravel (passing 3/8 inches sieve and retaining on #4 sieve) held between two similar screens functioning as a filter media. Gravel bed and the packing media reduce the working volume of the reactor to 8.8L. Outlet pipe was connected to the effluent tank through rubber tubing with a U loop. The U loop provided a water seal and prevented the intrusion of atmospheric air into the reactor in order to retain anaerobic conditions in the reactor. A peristaltic pump was used to pump wastewater into the reactor.

2.3 Operational Method

Raw textile wastewater was treated with varying hydraulic retention times (HRT) under different start-up conditions. Five trials were given to treat wastewater using the laboratory setup. Anaerobic seed culture collected from the feeding tank of the ETP plant of Mahmud Denims Limited was used for the inoculation in the HUASB reactor. For the first trial, glucose was mixed with textile wastewater as a source of food for microorganisms. For the second and third trials, glucose and sewage sludge were added during start-up. For the fourth and fifth trials, only textile wastewater was fed in the reactor. An HRT of 2 days was maintained during the reactor set-up period. Wastewater was cycled once a day with intended retention time. 5-6 cycles of wastewater treatment were completed in each trial. Since the reactor's hydraulic characteristics were closer to the plug flow, samples at the inlet were compared with samples taken from the outlet one HRT later. Different parameters such as BOD, COD, color, Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Oxidation-reduction Potential (ORP), etc. were tested for each condition using standard procedures. DO concentration less than 0.1 mg/L and ORP value less than -300 mV ensured anaerobic condition in the reactor. Bacterial growth was identified whenever there was a significant change in results. The reactor was operated at mesophilic temperature (27±5° C). During winter the temperature was controlled by incorporating a room heater beside the reactor. The pH of the incoming wastewater into the reactor was maintained at 8 for optimal bacterial growth. Effluent pH varied between 5.6~7.5 which indicated that decomposition was taking place in the rector. For the first three trials, the reactor was operated for 5 to 6 cycles without desludging. For the fourth trial, sludge was fully removed after the fourth cycle. Whereas for the fifth trial, sludge was partially removed after the third cycle. For the detection of bacteria, water and sludge samples were taken from the reactor and sent to the pathology lab of Impulse Hospital, Dhaka, Bangladesh.

3. RESULTS AND DISCUSSION

3.1 Bacterial Species

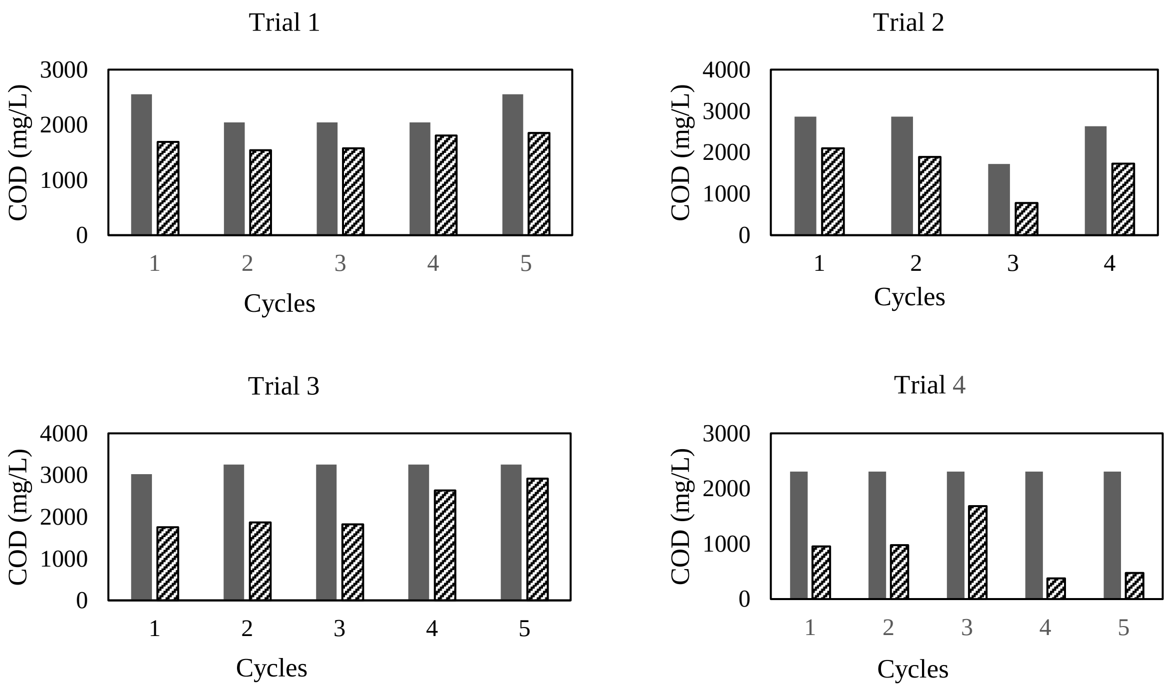
Three types of bacteria were found in the reactor. In the first trial when glucose was added with wastewater, *Klebsiella* was the dominant bacteria. But the addition of sewage sludge in trials 2 and 3 introduced *Escherichia coli* along with *Klebsiella*. Exclusion of both glucose and sewage water in trials 4 and 5 initiated the growth of *Pseudomonas*. All these bacteria are gram-negative, facultative and anaerobic. As the parameters of the environment were kept constant inside the reactor except for food, the dominance of a particular species in the reactor was dependent on the type of food added to the system. The addition of glucose favored the growth of *Klebsiella* and since *E. coli* was present in sewage wastewater, the trials having both glucose and sewage added have both *Klebsiella* and *E. coli*. But when no glucose or sewage sludge was added, *Pseudomonas* was the dominant species in the reactor.*Pseudomonas* has been shown previously to grow in similar environments due to its greater capability in digesting complex hydrocarbons i.e. polycyclic aromatic hydrocarbon (PAH) (Karimi, Habibi & Esvand, 2015).Influent characteristics and corresponding dominant microbes are shown in table 2.

Table 2: Description of the trials and the Dominant Microbes in each trial

Influent	*Klebsiella*	*E. coli*	*Pseudomonas*
Textile wastewater + Glucose, HRT 6 hours (Trial 1)	✓		
Textile Wastewater + Sewage Sludge + Glucose, HRT 8 hours (Trial 2)	✓	✓	
Textile Wastewater + Sewage Sludge + Glucose, HRT 24 hours (Trial 3)	✓	✓	
Textile Wastewater, no additional food, HRT 7 hours (Trial 4)			✓
Textile Wastewater, no additional food, HRT 4 hours (Trial 5)			✓

3.2 COD and Color Removal

In these experiments, the influent wastewater had high COD value (2046 mg/L ~ 3252 mg/L). Influent and effluent COD and COD removal efficiency for different trials are shown in figure 2 and figure 3 respectively. For the first trial, COD removal efficiency gradually decreased from 33.8% to 11.6% from cycle 1 to 4 with the efficiency slightly increasing in the fifth cycle. The average COD removal efficiency is 25%. An HRT of 6 hours was maintained for all cycles and *Klebsiella* was identified in the reactor in this trial. In the second trial, HRT was 8 hours and bacteria in the reactor were mainly *Klebsiella* and *E. coli*. COD removal efficiency gradually increases from 26.7% to 54.5% from cycle 1 to 3 and decreased to 34.3% in the fourth cycle. The average COD removal efficiency was 38% which was slightly higher than the first trial. Increasing HRT from 8 hours to 24 hours in the third trial did not improve the removal efficiency of the reactor. COD removal efficiency remained close to 43% for the first three cycles. However, it drastically decreases to 19% and 10.3% in the fourth and fifth cycles.



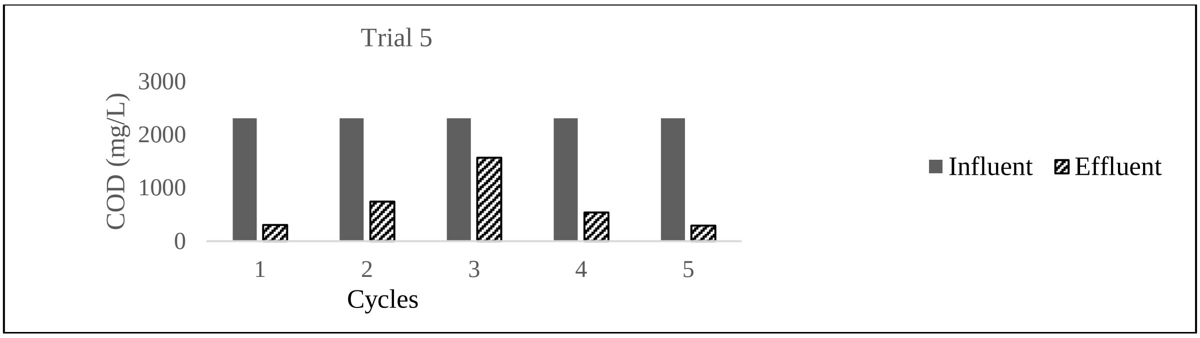


Figure 2: Performance of the reactor in removing COD over different cycles of run for different trials where each trial represents different operating conditions

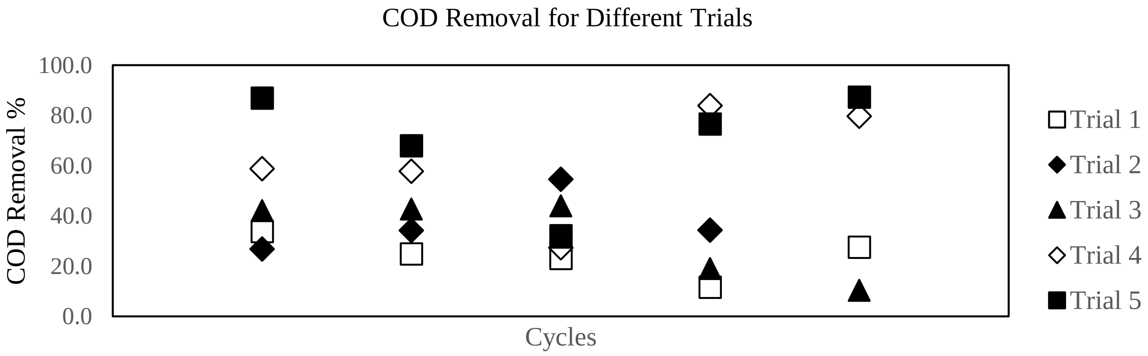


Figure 3: COD removal efficiency for different trials

Textile wastewater had a high color value (8700~8900 Pt-Co Unit). For the first three trials, color removal efficiencies were 56.4%, 65% and 20.6% which were not satisfactory. So, the color value of the effluent was not measured for every cycle. The color removal efficiency increased significantly from the fourth trial. Influent and effluent color and color removal efficiency for the last two trials are shown in figure 4 and figure 5 respectively.

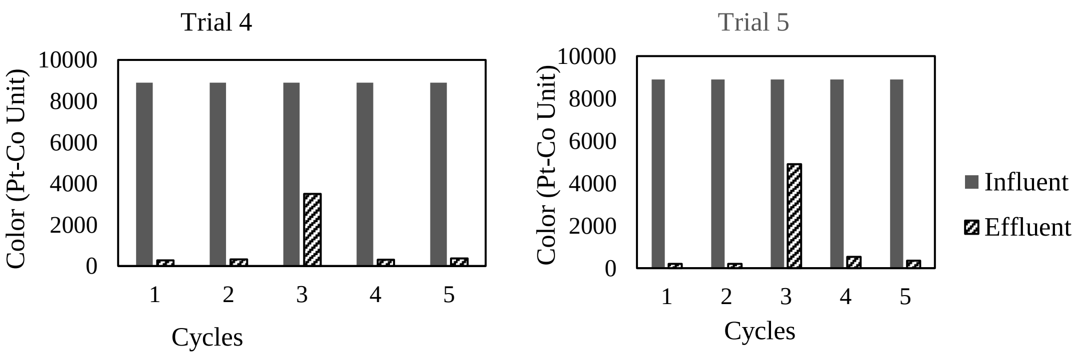


Figure 4: Performance of the reactor in removing color over different cycles of run for different trials where each trial represents different operating conditions

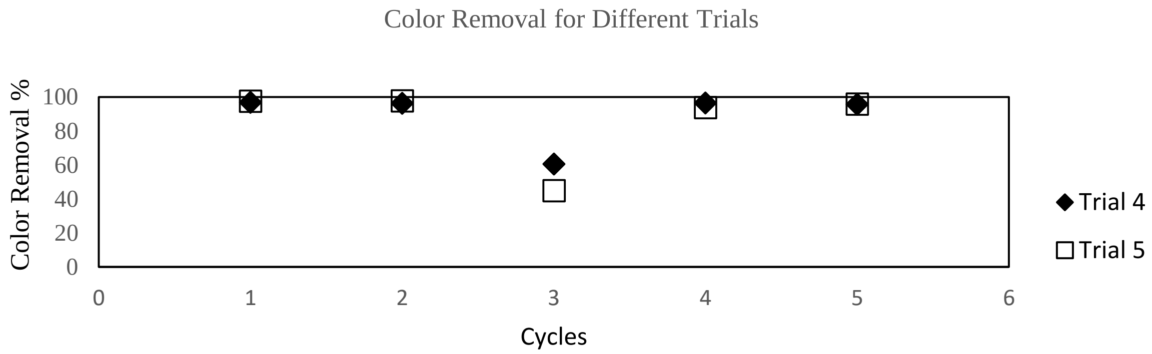


Figure 5: Color removal efficiency for different trials

For the first three trials, COD removal efficiency started to decrease from the fourth cycle (figure 3). In these trials, the generated sludge remained in the reactor which could be affecting the effectiveness of the reactor. So, in the fourth and the fifth trials, sludge was removed after the third cycle of wastewater treatment. In these trials, *Pseudomonas* was dominant in the reactor. Though HRT was comparatively lower compared to the previous trials (~7 hours), high COD and color removal were observed. COD removal for the first two cycles remained around 58% which decreased to 27.3% in the third cycle. Color removal for the first two cycles remained around 96% which decreased to 60.7% in the third cycle. Removing the sludge after the third cycle resulted in 83.8% and 79.6% COD removal and 96.5% and 95.8% color removal for cycles 4 and 5 respectively. Further decreasing HRT from 7 hours to 4 hours in the fifth trial did not affect the performance of the reactor significantly. In trial 5, initially, 86.9% COD removal and 97.6% color removal was observed in cycle 1. Similar to trial 4, removal efficiency decreased in the third cycle (32.1% for COD and 44.9% for color). After removing the sludge, the efficiency of the reactor increased to 76.6% and 87.3% for COD removal and 93.9% and 96% for color removal in cycles 4 and 5 respectively. It can be inferred that the accumulation of sludge had a negative impact on the performance of the reactor. For our setup, removing sludge after every three cycles increased the performance of the reactor.

It has been mentioned earlier that, different bacterial species were found in the reactor depending on the type of food present. The presence of these species can also be correlated with the removal efficiency obtained in the different trials (Figure 6). It can be seen that while *Klebsiella* and *E. coli* were the dominant species in the reactor (trials 1 – 3), the COD removal efficiency did not exceed 54.5%. Though sludge removal improves the efficiency of the reactor and sludge was not removed in trials 1 to 3, it can be envisaged that even with sludge removal we would not expect the removal efficiency to go beyond what we observed in the initial cycles of these trials. On the other hand, in trials 4 and 5, *Pseudomonas* was dominant and due to its efficiency in degrading complex hydrocarbons, we observed higher COD and color removal compared to the previous trials.

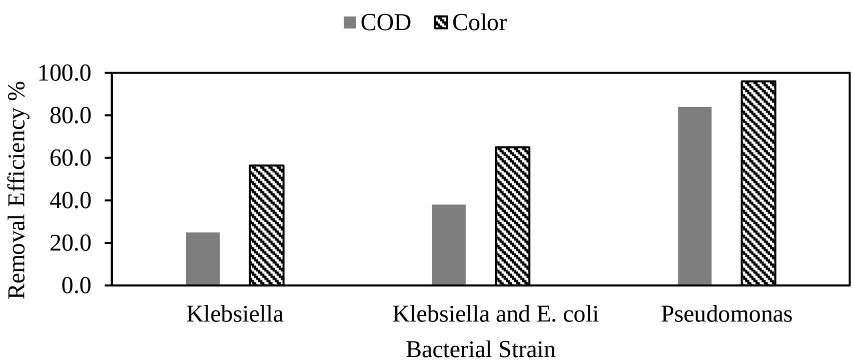


Figure 6: COD and color removal efficiency for different bacterial growths

3.3 BOD Removal

As COD was the main parameter for evaluating the performance of the reactor, BOD was not monitored until significant removal of COD was achieved. Only after achieving more than 80% COD removal, BOD removal was measured. BOD value decreased from 730 mg/L to 52 mg/L and 54 mg/L in the fourth and the fifth trial respectively (removal efficiency 93%, not shown in figure) which are well below the national discharge standard for BOD of textile industry effluent (150 mg/L) according to ECR 1997.

3.4 Comparison with Full-scale UASB ETPs operational in Bangladesh

The performance of the lab-scale HUASB is compared to three other UASB based Full-scale ETPs currently operational in Bangladesh (Table 3). These ETPs have Downflow Hanging Sponge (DHS) unit and aeration processes in addition to UASB unit and high retention time (40 hours HRT for UASB unit). Though the final effluent quality conforms to the discharge limits described in the Environment Conservation Rules (ECR) 1997, the efficiency of the UASB unit in particular in the removal of COD, BOD and color is poor. ETP1 showed the best performance among the operational UASB units where a maximum removal of 66%, 53%, and 50% for COD, BOD, and color respectively was obtained. ETP2 and ETP3 had comparatively stronger wastewater with COD value in the feeding tank of 1075 and 2310 mg/L respectively. However, the removal efficiencies of these two ETPs are considerably lower compared to ETP1. For example, for ETP3, the wastewater from feeding tank is passed through two UASB reactors, each of which had an HRT of 20 hours and in spite of having longer retention time than what we used in our experiments, COD, BOD and color removals are 2.8%, 18%, and 3% respectively. Such low removal efficiencies are very unlikely for a UASB unit. Most probably, the accumulation of sludge is the reason behind the poor performance of the reactor. The UASB unit has been operational for more than a year. But according to the maintenance engineer, the sludge was never removed from the UASB unit which could have reduced the effectiveness of the process. In contrast, the DHS unit of that particular ETP performed better with a removal efficiency of 50%, 61%, and 20.9% for COD, BOD, and color respectively. Our lab-scale HUASB reactor showed better performance than the UASB units of these ETPs. Moreover, in spite of having significantly lower retention time and no additional treatment operation (e.g. aeration), the lab-scale HUASB delivered an end product that was comparable to that of the three ETPs. This indicates that if a Hybrid UASB can be installed in these ETPs, their efficiencies can be increased with concomitant savings in operational costs.

Table 3: Comparison among operational efficiencies of different operational UASB based ETPs in Bangladesh and Lab-scale HUASB (Removal percentages with respect to the concentration in the equalization tank are shown in parentheses)

ETP	Parameter	Equalization Tank	After UASB	After DHS	Outlet
ETP 1(Rashid & Shahid, 2017) **UASB+DHS +Aeration**	Color (Pt-Co Unit)	1264	432(66%)	120(90%)	110(91%)
	COD (mg/L)	428	198(53%)	179(58%)	57(87%)
	BOD (mg/L)	200	99(50%)	69(65%)	22(69%)
ETP 2 **UASB+DHS +Aeration**	Color (Pt-Co Unit)	1320	1100(17%)	1400 (-6%)	660(50%)
	COD (mg/L)	1075	923(14%)	658(39%)	158(85%)
	BOD (mg/L)	496	262(47%)	160(68%)	20(96%)
ETP 3 **UASB+DHS+ Aeration**	Color (Pt-Co Unit)	8900	8600(3%)	6800(24%)	23(99%)
	COD (mg/L)	2310	2246(3%)	1124(51%)	76(97%)
	BOD (mg/L)	733	600(18%)	233(68%)	22(97%)

ETP	Parameter	Equalization Tank	After UASB	After DHS	Outlet
This Study (Lab-scale HUASB)	Color (Pt-Co Unit)	8900	344(96%)	-	-
	COD (mg/L)	2310	293(87%)	-	-
	BOD (mg/L)	733	52(93%)	-	-

4. CONCLUSIONS

UASB reactor generally requires post-treatment for satisfactory effluent quality. It takes almost three to four months for the growth of bacteria granules in UASB when no inert materials are added (Hulshoff Pol et al., 2004). But in hybrid UASB, bacterial biofilm is generated quickly because of the attached growth. For our lab-scale reactor, only two days were needed for the incubation of bacteria. Effectiveness of different bacteria grown in the reactor was evaluated and *Pseudomonas* was found out to be very effective which takes polycyclic aromatic hydrocarbon (PAH) as the main food. After the growth of this bacterium in the reactor, removal efficiency of COD, BOD and color increased significantly. After sludge was taken out, the reactor performance increased. Without further treatment, effluent quality from HUASB, particularly BOD and COD, has been found to conform to the limits for discharging in public sewerage system or irrigated land as prescribed in the national standards. So, with effective bacterial growth and maintenance, the HUASB reactor can be a huge step up from conventional UASB and a suitable alternative for the treatment of textile wastewater.

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REFERENCES

Akpor, O. B. (2011). Wastewater Effluent Discharge : Effects and Treatment Processes. *3rd International Conference on Chemical, Biological and Environmental Engineering*, *20*, 85–91. Retrieved from http://ipcbee.com/vol20/16-ICBEE2011E20001.pdf

Amaral, F. M., Kato, M. T., Florêncio, L., & Gavazza, S. (2014). Color, organic matter and sulfate removal from textile effluents by anaerobic and aerobic processes. *Bioresource Technology*, *163*, 364–369. https://doi.org/10.1016/j.biortech.2014.04.026

Bangladesh Statistics 2017 Bangladesh Bureau of Statistics (BBS) Statistics and Informatics Division (SID) Ministry of Planning. (n.d.). Retrieved from www.bbs.gov.bd.

Daud, M. K., Rizvi, H., Akram, M. F., Ali, S., Rizwan, M., Nafees, M., & Jin, Z. S. (2018). Review of upflow anaerobic sludge blanket reactor technology: Effect of different parameters and developments for domestic wastewater treatment. *Journal of Chemistry*, *2018*. https://doi.org/10.1155/2018/1596319

Hossain, L., Sarker, S. K., & Khan, M. S. (2018). Evaluation of present and future wastewater impacts of textile dyeing industries in Bangladesh. *Environmental Development*, *26*, 23–33. https://doi.org/10.1016/j.envdev.2018.03.005

Hulshoff Pol, L. W., De Castro Lopes, S. I., Lettinga, G., & Lens, P. N. L. (2004). Anaerobic sludge granulation. *Water Research*, *38*(6), 1376–1389. https://doi.org/10.1016/j.watres.2003.12.002

Joshi, M., Bansal, R., & Purwar, R. (2004). Color Rremoval from textile effluents. *Indian Journal of Fibre & Textile Research*, *29*, 239–259.

Karimi, B., Habibi, M., & Esvand, M. (2015). Biodegradation of naphthalene using Pseudomonas aeruginosa by up flow anoxic-aerobic continuous flow combined bioreactor. *Journal of Environmental Health Science and Engineering*, *13*(1), 26. https://doi.org/10.1186/s40201-015-0175-1

Khalil, N., Mittal, A. K., Raghav, A. K., & Rajeev, S. (2006). UASB technology for sewage treatment in india: 20 years experience. *Environmental Engineering and Management Journal*, *5*(5), 1059–1069.

Miah, M. S. (2013). Cost-effective treatment technology on textile industrial wastewater in Bangladesh. *Journal of Chemical Engineering*, *27*(1), 32–36. https://doi.org/10.3329/jce.v27i1.15855

Priya, M., Meenambal, T., Balasubramanian, N., & Perumal, B. (2015). Comparative study of treatment of sago wastewater using HUASB reactor in the presence and absence of effective microorganisms. *Procedia Earth and Planetary Science*, *11*, 483–490. https://doi.org/10.1016/j.proeps.2015.06.048

Rashid, I., & Shahid, S. B. (2017). *Evaluation of Up-flow Anaerobic Sludge Blanket (UASB) Treatment Process in Treating Textile Wastewater (*Bachelor's thesis). Bangladesh University of Engineering and Technology, Bangladesh.

Samer, M. (2015). Biological and Chemical Wastewater Treatment Processes. In *Wastewater Treatment Engineering*(pp.1-50). London, UK: InTechOpen https://doi.org/10.5772/61250

Wang, Z., Xue, M., Huang, K., & Liu, Z. (2011). Textile Dyeing Wastewater Treatment. InProf. Peter Hauser (Ed.),*Advances in Treating Textile Effluent*(pp. 91-116). Rijeka, Croatia:InTech Europe. https://doi.org/10.5772/22670

ANALYSIS OF HEAVY METAL CONCENTRATION IN SOILS OF A WASTE DISPOSAL SITE IN KHULNA USING ARTIFICIAL INTELLIGENCE TECHNIQUE

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ABSTRACT

Analysis of heavy metal concentration in soils is very essential for their unfavourable environmental and wellbeing impacts due to have a moderately high density and toxic behavior. The assortment of soil samples is labored and time consuming as well as the finding of heavy metal concentrations in the laboratory was costly. In these endeavours, artificial intelligence techniques (AI) such as adaptive Neuro-fuzzy inference system (ANFIS), support vector machine (SVM) and artificial neural networks (ANN) were executed for the analysis of heavy metal concentrations in soils of a certain waste disposal site at old Rajbandh, Khulna. The point of this investigation was to fix the functions, algorithms, optimization methods, for AI techniques based on their best performance and then select a good technique for the analysis of heavy metal concentrations in soils. In this investigation, soil samples were gathered from eighty-five areas at a profundity 0-30 cm from the existing ground surface of the selected disposal site. In the laboratory, the concentrations of heavy metals of Pb, Cu, Ni, Zn, Co, Cd, As, Sc, Hg, Mn, Cr, Ti, Sb, Sr, V and Ba in soils were measured.

The result reveals the model with SCP, gaussmf, linear and hybrid was the best-fitted model of ANFIS for the prediction of heavy metal concentrations in soils. In addition, in SVM analysis, the model SVM-RBF with 15 folds was selected for the prediction of heavy metal concentrations in soils. In ANN, the model LT (Levenberg-Marquardt and Tansig functions) with neuron structure 2-10-1 was selected. The accuracy of the predicted results was checked based on the acceptable limits of prediction parameters like R value, RMSE, MAPE, GRI and percentage recovery. Among all heavy metals analysis in ANFIS, the maximum R-value 0.999 was found with the minimum RMSE 0.12 for Sc indicating the best correlation in prediction of Sc in soils. The others value of prediction parameters (MAPE= 36.00, GRI=1.50, percentage recovery=123.43%) for Sc were found within the acceptable limits. In addition, in SVM analysis, maximum R-value 0.73 with RMSE 2.03 was found for Cu; while, maximum R-value 0.88 with the minimum RMSE 1.01 for As was found in ANN. The outcomes showed that ANFIS model was a solid procedure than that of other counterparts of SVM and ANN to analyse the heavy metal concentrations in soils with the acceptable degree of robustness and accuracy. Therefore, the performance of AI techniques may be stated by the sequence of ANFIS > SVM > ANN. Here it can be noted that one can easily be computed the concentration of a particular heavy metal in soils by inserting GPS values (latitude and longitude) only in the developed rule viewer of ANFIS. Therefore, this newly developed model will further be helpful for other researchers in this line to analysis heavy metal concentration in soils of selected waste disposal sites.

Keywords: *Waste disposal site, Soil, Heavy metals, Soft computing systems, Khulna*.

1. INTRODUCTION

Heavy metals are metallic components that have moderately high density and poisonous behavior even at low concentration (Alloway et al., 1990). In waste disposal site, municipal solid waste (MSW) decays and creates three components of solid (degraded waste); liquid (leachate that is penetrating into the fundamental layer) and landfill gas (Sanjida and Rafizul, 2018). Open dumping discharge enormous amount of destructive as well as toxic synthetic compounds like heavy metals to the neighbouring water bodies as well as basic soil layer, and so on. The greater part of the environmental and human health issues originate from the emanation of heavy metals from the proliferated leachate, contaminated soil, landfill gas (LFG), non-methanic volatile organic compounds as well as menacing air contaminants in waste disposal site (Talib et al., 2008). In Khulna city, the greater part of the MSWs were gathered from door to door without any sorting and dumped in an open disposal site at Rajbandh. The emanations of poisonous heavy metal element from MSW, leachate and soil will be vulnerable to the environmental constituents and the nearby inhabitants. The assessment of heavy metal distribution in soils is significant to save the environment. Moreover, for various soil assessment techniques, heavy metal concentrations are needed. However, the collection of soil samples is labored, time consuming and determination of heavy metal concentration in soils from laboratory is expensive. The prediction of heavy metal concentration using artificial intelligence techniques (AI) may be the answer for take care of this issue. In the literature, the AI techniques such as adaptive neuro-fuzzy inference system (ANFIS), support vector machine (SVM), artificial neural networks (ANN), fuzzy logic (FL), knowledge-based systems (KBSs), genetic algorithms (GAs), biogeography-based optimization (BBO) etc. are available. These AI techniques have many functions, algorithms, optimization methods, which can be used. The aim of this study is to fix functions, algorithms and optimization methods for all AI techniques based on their best performance and select a best AI technique for the analysis of heavy metal concentrations in soils. In this study, for the analysis of heavy metal concentrations in soils, the AI techniques such as ANFIS, SVM and ANN was performed.

A study stated that over the last few years or so, various AI techniques for analysis of heavy metals concentrations in soils and other quality parameters; environmental modelling; water quality monitoring and assessment; estimation as well as forecasting in climatic sciences (Soyupak et al., 2003). In this study, AI techniques such as ANFIS, SVM and ANN were implemented to analysis heavy metal concentrations in soils of a selected waste disposal site at old Rajbandh, Khulna. In ANFIS, the validation of models was performed by interchanging different input and output membership functions as well as optimization methods to select the best model of ANFIS. In addition, for SVM analysis various models with different kernel functions were formed to select best-fitted model of SVM. The cross-validation with different folds was also performed to control overfitting of the data. Furthermore, for selecting the best-fitted model of ANN; different neuron structures, different training functions as well as various transfer functions was implemented. The results of ANFIS, SVM and ANN model were also compared with the satisfactory values of correlation coefficient (R), root mean square error (RMSE), mean absolute percentage error (MAPE), geometric reliability index (GRI) and percent recovery. Therefore, the newly developed model of AI techniques will further be helpful for other researchers in this line to analysis heavy metal concentration in soils of selected waste disposal sites.

2. METHODOLOGY

The concentrations of relevant heavy metal in soils were measured and monitored through standard test methods and the AI techniques such as ANFIS, SVM and ANN were performed to predict the heavy metal concentrations, which were highlighted in the following articles.

2.1 Soil Sampling

In this investigation of model fixation, overall sixty soil samples were gathered from the separate locations of a selected open disposal site at old Rajbandh, Khulna, Bangladesh. Every one of the samples were gathered at a profundity of 30 cm from the existing ground surface. The latitude and longitude of all the soil-sampling positions was recorded using GPS apparatus, which were later brought into a geographic information system (ArcGIS 10.1) shown in Figure 1.

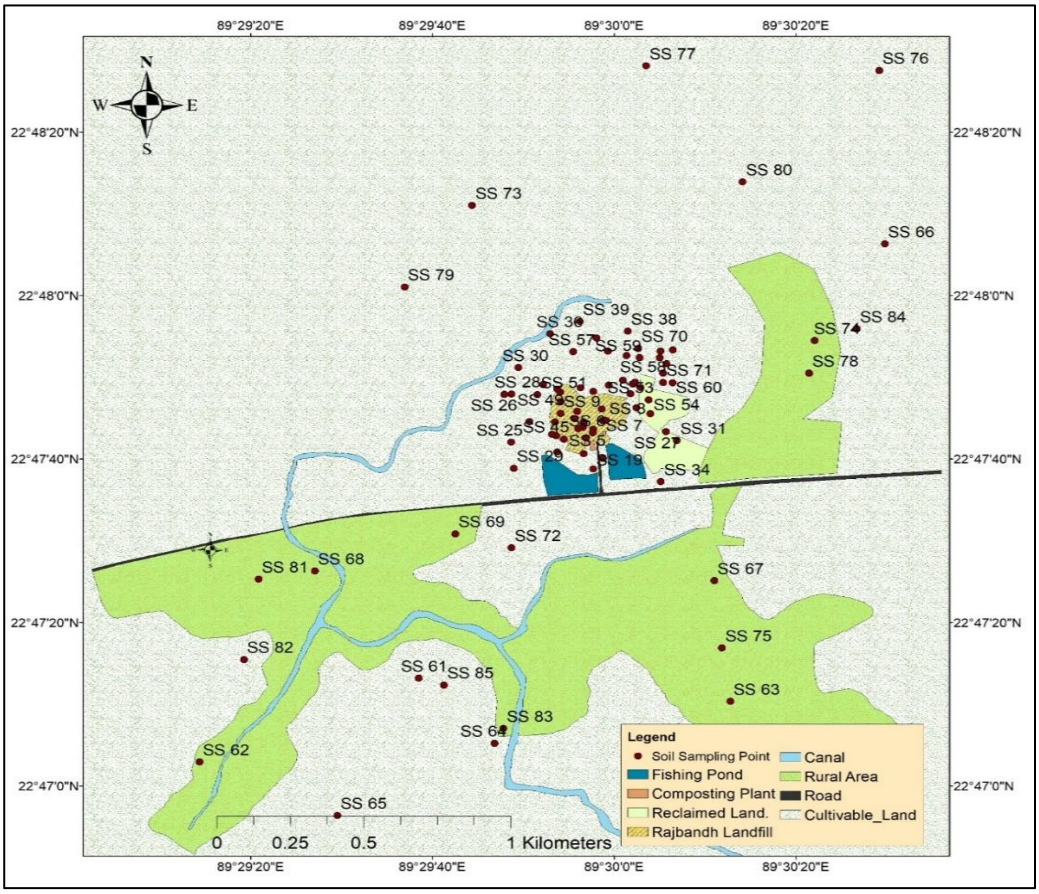

Figure 1: Location map showing soil sampling points of the selected waste disposal site at old Rajbandh, Khulna

2.2 Laboratory Investigations

In laboratory investigation, at first 10 gm of every soil pattern was taken into a 100 ml conical flask. The flask had already been washed with deionized water organized by adding 6 ml HNO3/HClO4 acid in ratio 2:1 and left overnight. Subsequently, HCl solution changed into brought in ratio 1:1 to the digested sample and re-digested once more for another 30 minutes. The digested sample washed into one hundred ml volumetric flask and obtained mixture changed into cooled right down to room temperature. After acting the digestion, the concentration of the heavy metals of Pb, Cu, Ni, Zn, Co, Cd, As, Sc, Hg, Mn, Cr, Ti, Sb, Sr, V and Ba in mg/kg were determined by the use of atomic absorption spectrophotometer (AAS) method and the quantity of each heavy metal deduced from the calibration graph.

2.3 Modelling of AI Techniques

In this study, artificial intelligence (AI) techniques such as adaptive neuro-fuzzy inference system (ANFIS), support vector machine (SVM) and artificial neural network (ANN) were performed through MATLAB to analysis heavy metal concentrations in soils of waste disposal site. The latitude and longitude of soil sampling points of the selected waste disposal site were used as inputs, while, heavy metal concentrations were considered as outputs in AI techniques. In this study, total 85 sampling point’s data were considered among which training data 83% (70) and testing data 17% (15) were assigned in AI techniques. The adopted AI techniques are hence discussed in the following articles.

2.3.1 Adaptive Neuro-Fuzzy Inference System

In ANFIS, the steps for the prediction heavy metal concentrations reveals as:

- ✓ First open Neuro-Fuzzy Designer app and load the training data from workspace.

- ✓ Generate the FIS to train the model of different selected functions and algorithms.
- ✓ Get the FIS output for training with training error.
- ✓ Load the data of testing and get the FIS output of testing.
- ✓ Export ANFIS model structure, rules viewer and surface viewer.
- ✓ Predict the concentration of heavy metals in soils.

2.3.2 Support Vector Machine

In SVM, the steps for the prediction heavy metal concentrations reveals as:

- ✓ First open regression learner app and import the data.
- ✓ Select particular kernel functions and validation methods.
- ✓ Train the model and export the results.
- ✓ Predict the concentration of heavy metals in soils.
- ✓ Use personal coding for representing the outcomes.

2.3.3 Artificial Neural Network

In ANN, the steps for the prediction heavy metal concentrations reveals as:

- ✓ First, open neural network or data manager window and import the data.
- ✓ Create neural network model by selecting various training and transfer functions.
- ✓ Train ANN model and simulate the test data.
- ✓ Export of All Outputs
- ✓ Predict the concentration of heavy metals in soils.

2.4 Assessment of Model Performance

The predicted concentration of heavy metals were determined from ANFIS, SVM and ANN. Getting predicted results, the predicted concentrations were assessed with the following prediction parameters.

2.4.1 Correlation Coefficient

A correlation coefficient (R) is the statistical measure of the linear relationship between a dependent variable and an independent variable. In completely related variables, the worth will increase or decreases in cycle. In negatively related variables, the worth of 1 will increase and therefore the value of the opposite decreases. The "R" represents it that displays within the following Equation (1).

$$R = \frac{n(\sum y.y_p)\ (\sum y)(\sum y_p)}{\sqrt{[n\sum y^2\ (\sum y)^2][n\sum y_p^2\ (\sum y_p)^2]}} \tag{1}$$

Where y = observed value, y_p = predicted value, n = number of observations.

A research conducted by Smith (1986) advised that the worth of R lies between zero to one. It's additionally advised some pointers for deciding the performance of the model. If $|R| \geq 0.8$: a strong correlation exists, $0.2 < |R| < 0.8$: correlation exists and $|R| \leq 0.2$: a weak correlation exists. as soon as the worth of |R| is larger than 0.9, then a very strong correlation exists between the variables.

2.4.2 Root Mean Square Error

The root mean square error (RMSE) is one in every of the foremost oftentimes used measures of the goodness of fit of generalized regression models. It's drawn by the following Equation (2).

$$RMSE = \sqrt{\frac{\sum_1^n (y-y_p)^2}{n}} \tag{2}$$

According to Schweizer (2010), lower values of RMSE indicate a higher match with the expected results and zero suggests that no error. RMSE may be a workable factor of however accurately the model predicts the response, and it's the foremost necessary criterion for appropriate match of results if the main purpose of the model is predicting any value.

2.4.3 Mean Absolute Percentage Error

The mean absolute percent error (MAPE) measures the scale of the error in percentage terms. it's calculated as the average of the unsigned proportion errors, as shown in the following Equation (3).

$$MAPE = \frac{1}{n}\sum \frac{|y - y_p|}{|y|} \times 100\,\% \tag{3}$$

In a comprehensive analysis of county-level projections, the MAPE was on the average higher by regarding 30–40% than strong measures of central tendency for many strategies and projection horizons (Rayer, 2007).

2.4.4 Geometric Reliability Index

A version of the geometric reliability index (GRI) was outlined by way of the inverse of the coefficient of variation. The reliability index is that the shortest distance from the origin of reduced variables. Using geometry, the reliability index will be dignified by the subsequent Equation (4).

$$GRI = \frac{1 + \sqrt{\frac{1}{n}\sum_{t=1}^{n}(\frac{\hat{y}_t - y_t}{\hat{y}_t + y_t})^2}}{1 - \sqrt{\frac{1}{n}\sum_{t=1}^{n}(\frac{\hat{y}_t - y_t}{\hat{y}_t + y_t})^2}} \tag{4}$$

Where $\boldsymbol{y_t}$ = observed value, $\boldsymbol{\hat{y}_t}$ = predicted value, n = number of observations.

According to Leggett and Williams (1981), GRI could be a statistical procedure to work out the reliability of a model. The index could be a range GRI ≥ 1 represents the perfectness and dependability of model.

2.4.5 Percent Recovery

The percent recovery suggests that what percentage of measured worth is recovered by the expected value. It's depicted by the subsequent Equation (5).

$$Persent\ Recovery = \frac{y_p}{y} \times 100 \tag{5}$$

According to Walfish (2006), recoveries within the ranges of 20-200% for internal standard are thought as 'acceptable'. Food and Drug Administration (FDA), Investopedia declares that recovery shouldn't have to be compelled to be 100% however ought to be consistent. FDA approved variability limit for Lower Limit of Qualification (LLOQ) is +/- 20%. Therefore, the best frame of recovery is 80-120% that represents the robustness of the model.

3. RESULTS AND DISCUSSION

3.1 Validation of Models in ANFIS

In this study, to validate the models of ANFIS, twenty models symbolized A to T were formed considering sub-clustering partitioning (SCP); different input membership function (MF) like gaussmf, trimf, trapmf, psigmf, gbellmf; output MF like linear and constant; optimization method such as hybrid or back-propagation (BP) as well as number of epochs. A developed ANFIS rules viewer determined the predicted concentration of particular heavy metal in soils. The performance of different models (A to T) of ANFIS were examined based on the satisfactory limits of the prediction parameters such as R and RMSE. The results of twenty models (A to T) in ANFIS at different functions for Co with the values of R and RMSE provided in Table 1. For model A (SCP, gaussmf, linear and hybrid) the value of |R| was found to be 0.80 indicating the strong correlation between input and output variables in ANFIS analysis. In this study, the models B, E, F, G, I, J, K, M, N, Q, R, and S provided the R-value within a range of 0.2 < |R| < 0.8 indicating correlations between input and output variables. However, R-values for rest models (C, D, H, L, O, P and T) were found below 0.2 with weak correlations. The model H (SCP, trimf, constant and BP) shows comparatively the lower R-value (0.03) with higher RMSE value (6.71) than that of other models. In addition, two models such as C and D shows R and RMSE values of -0.28 and -0.13 as well as 2.53 and 4.98, respectively, these two models indicated the performance of weak downhill correlations between input and output variables. Besides, the model A shows the maximum value of R 0.80 and minimum value of RMSE 1.52. Based on results of R and RMSE, model A with SCP, gaussmf, linear and hybrid can be considered as fitted model of ANFIS for the prediction of all studied heavy metal concentrations in soils of waste disposal site.

Table 1: Validation of different models in ANFIS for Co

Model name	**GENFIS**	**Input membership function**	**Output membership function**	**Optimization method**	**Epochs**	**Co**	
						R	**RMSE**
A	Sub Clustering	gaussmf	linear	Hybrid	100	**0.80**	**1.52**
B	Sub Clustering	gaussmf	Constant	Hybrid	100	0.64	1.92
C	Sub Clustering	gaussmf	linear	Back Propagation	100	-0.28	2.53
D	Sub Clustering	gaussmf	Constant	Back Propagation	100	-0.13	4.98
E	Sub Clustering	trimf	linear	Hybrid	100	0.79	1.53
F	Sub Clustering	trimf	Constant	Hybrid	100	0.62	1.97
G	Sub Clustering	trimf	linear	Back Propagation	100	0.39	2.66
H	Sub Clustering	trimf	Constant	Back Propagation	100	0.03	6.71
I	Sub Clustering	trapmf	linear	Hybrid	100	0.67	1.87
J	Sub Clustering	trapmf	Constant	Hybrid	100	0.50	2.16
K	Sub Clustering	trapmf	linear	Back Propagation	100	0.32	2.40
L	Sub Clustering	trapmf	Constant	Back Propagation	100	0.04	5.30
M	Sub Clustering	psigmf	linear	Hybrid	100	0.62	1.96
N	Sub Clustering	psigmf	Constant	Hybrid	100	0.61	1.98
O	Sub Clustering	psigmf	linear	Back Propagation	100	0.17	2.45
P	Sub Clustering	psigmf	Constant	Back Propagation	100	0.19	4.98
Q	Sub Clustering	gbellmf	linear	Hybrid	100	0.66	1.88
R	Sub Clustering	gbellmf	Constant	Hybrid	100	0.53	2.13
S	Sub Clustering	gbellmf	linear	Back Propagation	100	0.47	2.35
T	Sub Clustering	gbellmf	Constant	Back Propagation	100	0.13	4.98

3.2 Validation of Models in SVM

In this study, total sixteen models (A to D with 5, 10, 15 and 20 fold numbers) for SVM analysis were formed with different kernel functions like linear-SVM (SVM-L), quadratic-SVM (SVM-Q), cubic-SVM (SVM-C) and gaussian or radial basis function-SVM (SVM-RBF) for fold numbers 5, 10, 15 and 20. The selected model was then compared in terms of the best values of R and RMSE to assess the performance of each model. In this analysis, Arsenic (As) was considered in compare to the results of heavy metals for selecting the best model of SVM.

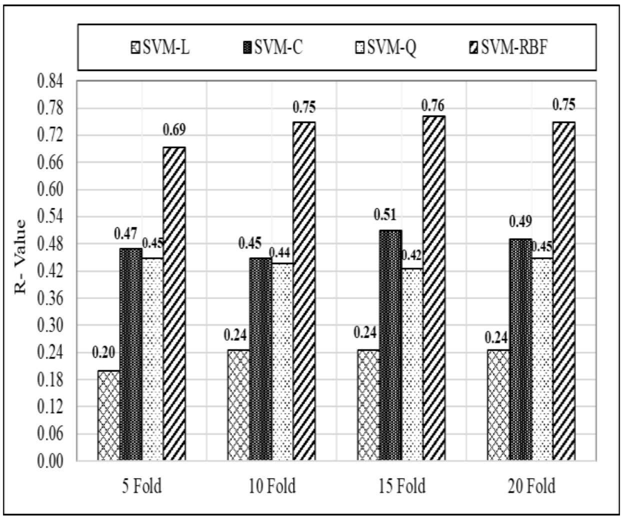

Figure 2: Variation of R with different fold numbers and kernel functions of SVM for As

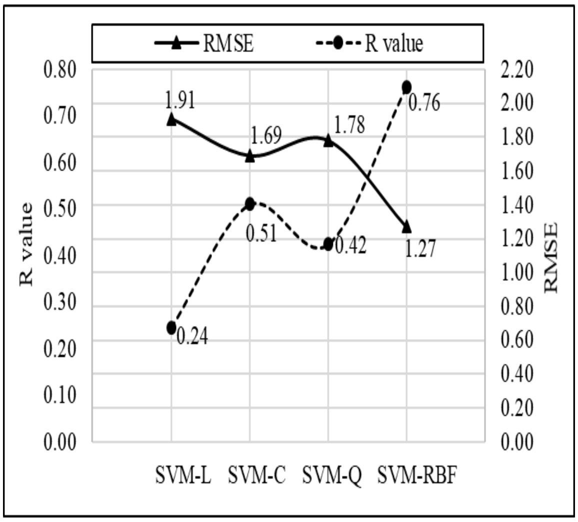

Figure 3: Variation of R and RMSE with kernel functions of SVM of As in soil

The variation of R for As were clearly expressed in Figure 2 for different kernel function and fold number. The SVM-RBF shows the higher value of R than that of other kernel functions of SVM-L, SVM-Q and SVM-C in SVM for fold numbers 5, 10, 15 and 20 (Figure 2). Among the entire folds considered in this analysis, the fold number 15 shows the maximum R-value (0.76) with minimum RMSE (1.27). Figure 3 entirely shows that fold number 15 provides the maximum R-value (0.76) with minimum RMSE (1.27) for model D-15 (SVM-RBF with 15 folds). Based on aforementioned R and RMSE, model D-15 (SVM-RBF with 15 folds) in SVM was selected for the modelling of heavy metal in soils of selected waste disposal site.

3.3 Validation of Models in ANN

In this study, different models of ANN were performed by changing the number of neurons as well as various training and transfer functions of ANN through MATLAB. In ANN analysis, four neuron structures were formed with different neuron numbers of 5, 10, 15 and 20 successively. In this analysis, the selection of neuron structure was performed based on the best values of R and RMSE. The neuron structure 2-10-1 shows the best performance for As with maximum R value (0.88) and minimum RMSE (1.01) than that for the other neuron structures (like 2-5-1, 2-15-1 and 2-20-1). After fixing the neuron structure (2-10-1), different models were formed by interchanging different training functions like levenberg-marquardt (TRAINLM), one-step secant (TRAINOSS) and scaled conjugate gradient (TRAINSCG) as well as transfer functions like tangent sigmoid transfer function (TANSIG), linear transfer function (PURELIN) and log-sigmoid transfer function (LOGSIG). Among all model, LT shows the higher value of R (0.88) than that of other models with minimum RMSE (1.01). On the contrary, model SP shows the lower value of R (0.31) than the other models with maximum RMSE (1.87). Therefore, the model LT (levenberg-marquardt and TANSIG) with neuron structure 2-10-1 was selected for the prediction of heavy metal concentrations in soils of waste disposal site.

3.4 Performance of AI Techniques

The predicted concentration of heavy metal in soils of unknown soil sampling points were determined with various AI techniques such as ANFIS, SVM and ANN. The variation of measured and predicted value of Hg and Sc in soil were depicted in Table 2. From Table 2, it was observed that predicted concentrations are very closer to the measured concentration of Hg and Sc for ANFIS than that of SVM and ANN. The acceptance of predicted results was assessed by some prediction parameters like R, RMSE, MAPE, GRI and recovery percentage. Figures 4 to 8 describe the variation of prediction parameters for all studied heavy metal with acceptable ranges stimulate in literatures. In Figure 4, ANFIS model shows the higher value of R (training) for all studied heavy metals than other models of

AI techniques. The values of R for most of the heavy metals were found in the ranges of 0.81 to 0.999. According to Smith (1986), it indicated the robustness of ANFIS model. Moreover, ANN shows comparatively the better performance than that of SVM.

Table 2: Predicted results of Hg and Sc for various AI techniques

Soils sampling points	Measured	Predicted Hg from AI techniques			Measured	Predicted Sc from AI techniques		
		ANFIS	SVM	ANN		ANFIS	SVM	ANN
5	7.22	6.56	8.58	7.91	16.83	16.99	10.43	15.55
10	4.76	5.49	4.80	5.07	14.76	16.16	10.64	15.01
20	5.03	4.88	1.08	0.80	11.77	10.83	9.86	5.93
25	3.77	3.16	3.64	4.27	10.77	10.73	11.57	12.02
30	1.98	1.58	1.97	0.92	9.58	10.96	9.71	5.33
35	3.45	1.74	3.19	4.81	8.65	8.88	8.12	6.46
45	1.92	2.56	5.22	5.44	9.94	12.39	10.96	13.54
50	1.11	2.38	3.72	4.32	8.07	10.27	9.20	9.94
55	1.26	2.02	3.15	4.00	5.72	8.07	8.04	5.83
60	0.77	1.43	3.08	2.00	3.02	4.85	8.52	7.69
65	2.12	3.43	4.07	3.52	10.02	9.71	11.72	11.13
70	1.07	2.76	3.46	3.85	8.41	5.98	11.85	10.72
75	1.68	2.86	3.13	3.49	6.14	7.23	11.93	10.68
80	0.77	1.75	3.13	3.49	3.39	5.16	11.93	10.68
85	2.95	3.70	2.16	0.78	10.19	9.71	9.69	9.64

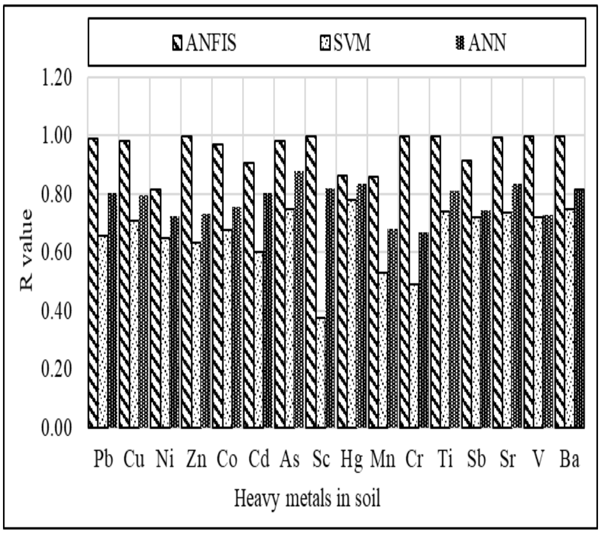

Figure 4: Variation of R with AI techniques

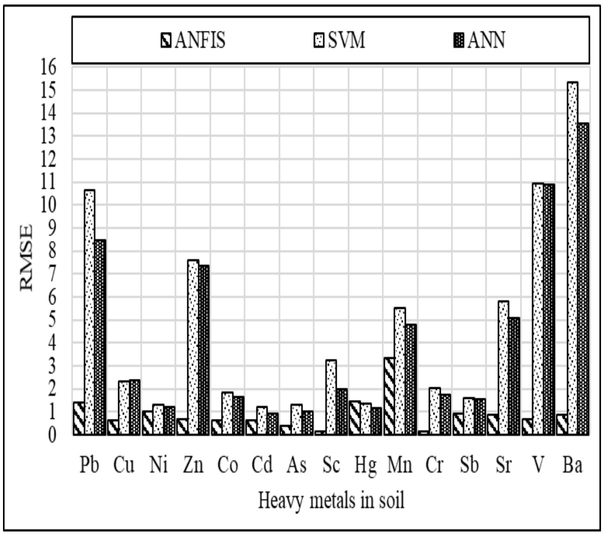

Figure 5: Variation of RMSE with AI techniques

In addition, ANFIS model shows the minimum value of RMSE in training for all studied heavy metals than that of other models of AI techniques (Figure 5). On the other hand, SVM shows the maximum RMSE indicating worse performance than ANN does. Therefore, the performance of R and RMSE in training can be expressed as ANFIS > ANN > SVM

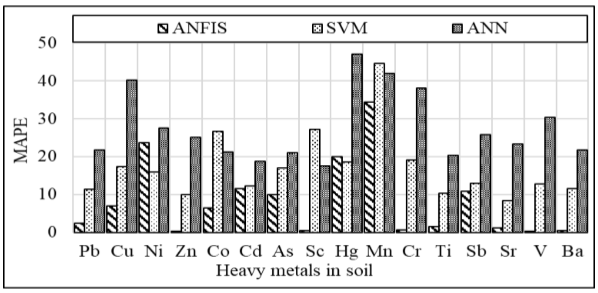

Figure 6: Variation of MAPE with AI techniques

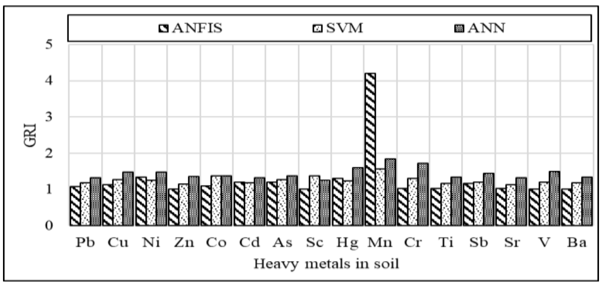

Figure 7: Variation of GRI with AI techniques

In Figure 6, most of all heavy metals show MAPE value in the ranges of 30-40% in ANFIS model for training than other models of AI techniques. On the other hand, ANN shows the maximum MAPE, which indicating worse performance than SVM. In addition, the GRI value for most of all heavy metals were found very close to 1 in ANFIS model than that of other models of AI techniques for training (Figure 7). On the contrary, ANN shows more scattered values of GRI than that of SVM model. Therefore, the performance of MAPE and GRI in training can be expressed as ANFIS > SVM > ANN.

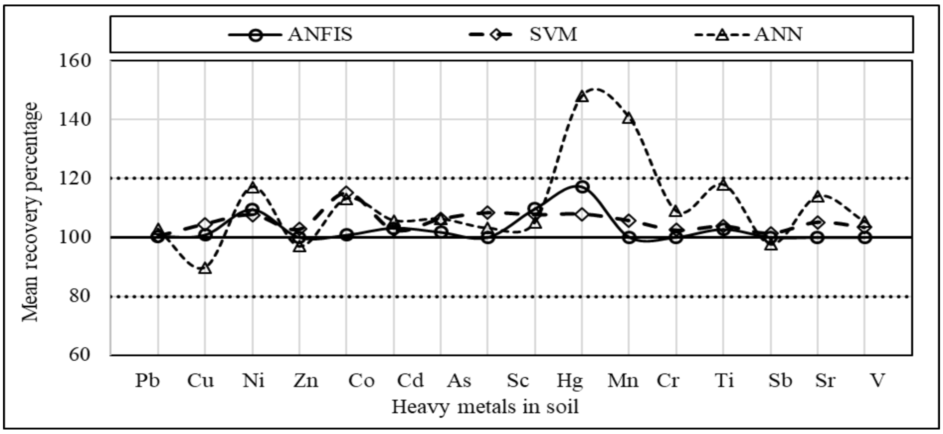

Figure 8: Variation of level for recovery percentage with various AI techniques

In Figure 8, the mean percentage recovery for most of all heavy metals were found very closer to the fit level (100%) in ANFIS model than that of other models of AI techniques for training. In SVM, percentage recovery were found in the ranges of 80-120% and most of them were near to fit level (100%). On the contrary, ANN shows more scattered values of percentage recovery from fit level than SVM. Therefore, the performance in training can be expressed as ANFIS > SVM > ANN.

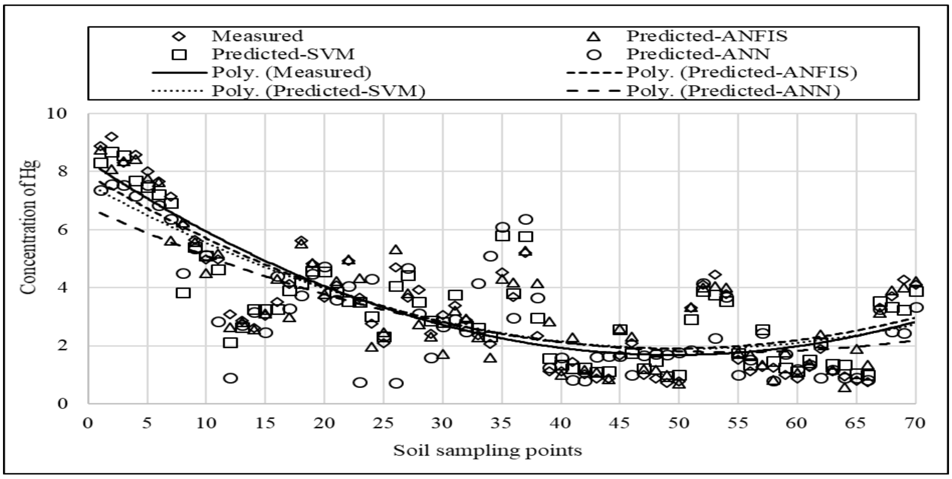

Figure 9: Variation of predicted results of Hg for different AI techniques in training

The predicted concentration of Pb (Figure 9) in ANFIS model was very closed to the measured concentration than other AI techniques, whereas, ANN shown less close measured concentration than that of other AI techniques. The results of various AI techniques from present study and literature were summarised in Table 3. In the present study, ANFIS shows the best performance for all criteria of goodness like R, RMSE, MAPE, GRI and percentage recovery. In addition, SVM shows comparatively the better results for most of the prediction parameters than ANN. Based on results published by Emamgholizadeh et al. (2014), the order of AI techniques was found as ANFIS > ANN. In addition, the results also stated by Rooki et al. (2011) and proved SVM > ANN. Therefore, finally the sequence of ANFIS > SVM > ANN was selected for best prediction of heavy metal concentrations in soils.

4. CONCLUSIONS

ANFIS model was a reliable technique than that of other counterparts of SVM and ANN to analyse the heavy metal concentrations in soil with the acceptable degree of robustness and accuracy. The combinations of best functions and algorithms were chosen for ANFIS with GENFIS: SCP, Input MF: Gaussmf, Output MF: Linear, Optimization Method: Hybrid and no. of epoch: 100; for SVM with kernel function: SVM-RBF and fold number: 15 and for ANN with training function (Levenberg-Marquardt), transfer function (Tansig) and no. of neurons 10. These selected AI techniques with fixed functions and algorithms may be used of other researchers without further analysis of AI techniques to predict heavy metal concentrations in soils of a selected waste disposal site.

Table 3: Summary of results of various AI techniques

Prediction parameters		**Present study**	**Literature**	**Final remarks**
R value	Training	ANFIS > ANN > SVM	ANFIS > ANN	ANFIS > SVM > ANN
			SVM > ANN	
	Testing	ANFIS > SVM ≥ ANN	ANFIS > ANN	
			SVM > ANN	
RMSE	Training	ANFIS > ANN > SVM	ANFIS > ANN SVM > ANN	
	Testing	ANFIS > SVM > ANN	ANFIS > ANN SVM > ANN	
MAPE	Training	ANFIS > SVM > ANN	-----	
	Testing	ANFIS > ANN > SVM	-----	
Mean percentage recovery	Training	ANFIS > SVM > ANN	-----	
	Testing	ANFIS > ANN > SVM	-----	
GRI	Training	ANFIS > SVM > ANN	-----	
	Testing	ANFIS > SVM > ANN	-----	
Performance of predicted results in training		ANFIS > SVM > ANN	-----	
Performance of predicted results in testing		ANFIS > SVM > ANN	-----	

REFERENCES

Alloway, B. J., Jackson, A. P., and Morgan, H. 1990, "The accumulation of cadmium by vegetables grown on soils contaminated from a variety of sources". Sci. of the total Env. Vol. 91, pp. 223-236.

Leggett, R. W., and Williams, L. R. 1981, "A reliability index for models". Ecological Modelling, Vol. 13(4), pp. 303-312.

Rayer, S. 2007, "Population forecast accuracy: does the choice of summary measure of error matter?" Population Research and Policy Review, Vol. 26(2), pp. 163.

Rooki, R., Ardejani, F. D., Aryafar, A., and Asadi, A. B. 2011, “Prediction of heavy metals in acid mine drainage using artificial neural network from the Shur River of the Sarcheshmeh porphyry copper mine, Southeast Iran". Environmental earth sciences, Vol. 64(5), pp. 1303-1316.

Sanjida, K., and Rafizul, I. M. 2018, "Multivariate statistics and spatial distribution of heavy metals in soils of waste disposal site in south western region of Bangladesh". Paper presented at the 33rd Int. Conference on Solid Waste Technology and Management, Annapolis, USA, (ISSN: 1091-8043)

Schweizer, K. 2010, "Some guidelines concerning the modelling of traits and abilities in test construction".

Soyupak, S., Karaer, F., Gürbüz, H., Kivrak, E., Sentürk, E., and Yazici, A. 2003, "A neural network-based approach for calculating dissolved oxygen profiles in reservoirs". Neural Computing and Applications, Vol. 12(3-4), pp. 166-172.

Walfish, S. 2006, "Analytical methods: a statistical perspective on the ICH Q2A and Q2B guidelines for validation of analytical methods". Bio Pharm International, Vol. 19(12), pp. 1-6.

AN EXPLORATORY STUDY OF WATER QUALITY DUE TO WATER LOGGING AND DRAINAGE CONGESTION IN THE BHABODAH AREA

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ABSTRACT

Water logging and drainage congestion are crucial problems in the whole southwest region in Bangladesh over the years. Heavy rains and inadequate drainage of overland run-off increase the rate of percolation and in turn helps in raising water table and may cause water logging problems in Bhabodah and its adjacent area. In this context, the current study aims at delineation of the highly affected domestic level water supply & sanitation situation with their possible solution. Water and wastewater samples had been collected from one of the most severely flood disrupted areas named 'Panchakari' village in both dry and water-logged condition. The shallow tube well water was found to be contaminated with high concentration of Fe 4 mg/L, Mn 3.9 mg/L, Color 396 Pt-Co Unit, and Turbidity 162 NTU. In waterlogged condition, microbial contamination (TC & FC) was also detected in tubewell water. However, Teka River water had high concentration of salinity as Cl^- 858 mg/L, EC 3343 µS/cm and TDS 2061 mg/L. Health risk assessment, using WHO Semi Quantitative Approach, had been determined low to medium level of health hazards in water logged condition of the study area. Nevertheless, wastewater samples exhibit high concentration of BOD 355 mg/L, COD 607 mg/L, TDS 2641 mg/L, TSS 2469 mg/L, Cl^- 1806 mg/L, TC 89 Nos./100 mL and FC 36 Nos./100 mL which pose high risk for the environment. As toilet or septic tank was situated near the tube well (<30m) and remained untreated when disposed into nearby water bodies, sewage pollution had occured. This research recommended some strategical options for the improvement of both water supply and sanitation conditions in the study area. For ensuring safe drinking water, rain water harvesting with storage facility of $150m^3$ could be adopted for a cluster of 50 households. Furthermore, flood resilient tubewells having raised-base-platform would be used to protect the entrance of contaminants during flood time. For the betterment of sanitation situation, mound-built latrine with excavated depth 3.3m circular or 2.6m rectangular pit could be provided for 10 users in waterlogged site. However, other necessary approaches should be implemented by the Government, Non-Governmental Organizations (NGOs) and stakeholders to minimize the existing vulnerable conditions due to waterlogging and drainage congestion in Bhabodah area.

Keywords: *Bhabodah, Water logging, Drainage congestion, Water supply, Sanitation.*

1. INTRODUCTION

Bangladesh is generally considered to be one of the most vulnerable regions in the world to climate change induced sea level rise (Ahmed, 2005). Water logging has been affecting about one million people in Bangladesh during the past two decades leading to large scale damages to crop, employment, livelihoods, and national economy (Rahman, 1995; Ahmed, 1998). It involves deterioration of drainage condition in coastal active tidal rivers of south-west Bangladesh which are main rain water drainage network for coastal polders and low lying beels. The Coastal Embankment Project (CEP) of early 1960s and the commissioning of Farakka Barrage in 1975 had a negative impact upon the geo morphological characteristics of south west part of Bangladesh which accelerated the process of sedimentation in the riverbeds and sluice gates became inoperable (Sarker, 2004; DHV-WARPO, 2000). In the early 70s, the presence of polders restricts the natural tidal flows from upstream and prevents sedimentation on the low-lying lands. As a result, polder areas were suffering from water logging and drainage congestion for quite long periods and that in turn caused large scale environmental, social and economic degradation (IWM, 2010).

Drainage problem of Bhabodah in Jashore district became very severe due to siltation and river encroachment in the main river systems (IWM, 2017). This area is crisscrossed by 7 main rivers and 27 beels. The rate of sedimentation in the Hari-Telegati River from February to April is about 1.2 million tons due to reduced source of flow; these sediments are deposited at river bed. As a result, water drainage capacity decreases gradually for increasing height of river bed with respect to nearby beels. Rain water cannot drain out anywhere naturally by beels and khals and get trapped in beels submerging homesteads, farmlands, roads and educational institutions. It was not possible to conduct TRM at beel Kapalia in 2012. From then, TRM could not be implemented in Bhabodah & its adjacent area. After 2013, rivers are silted up losing its navigability and became waterlogged. About 73,400 hectres of land went under water in 2016-2017. About 70 villages in 5 unions of Abhaynagar Upazila, 100 villages in 16 unions of Manirampur Upazila, 140 villages in 9 unions of Keshabpur Upazila and 69 villages in 5 unions of Jessore Sadar Upazila were severely affected due to drainage congestion. An estimated affected household of 2, 14, 729 nos. and about 8,89,818 populations had been affected during prolonged drainage congestions in 2016 (IWM, 2017). Prolonged water-logging has caused significant displacement presenting humanitarian challenges in safe water supply, sanitation facilities & shelter security. Drinking water is scarce and people use contaminated flood water for washing utensils, clothes, etc. causing various skin and water-borne diseases. Due to lack of sanitation facilities in many areas close to rivers, abundance of Escherichia coli is extremely high and use of river water is cause of gastro-intestinal diseases (IWM, 2017). They cannot use pit latrine because of submerging in flood water and temporary latrines are constructed by the govt. authority. In this context, an in-depth study is imperative to delineate the highly affected domestic level water supply & sanitation situation with their possible solution.

2. METHODOLOGY

The research related field work was conducted at Bhabodah area of Jashore district located in the south-west region of Bangladesh within Khulna division shown in figure 1 & 2. To investigate domestic water supply and sanitation situation, 8 water samples in dry and water logged condition and 3 wastewater samples in waterlogged condition were collected from mostly affected community in Bhabodah, named ‘Panchakari’. Collection, transportation and storage of water samples will be done following laboratory standard methods. And then some improvement options for water and sanitation system were proposed. Various physical, chemical, and biological water quality parameters were tested in ‘Environmental Engineering Laboratory’ at KUET.

For laboratory analyses, standard methods were followed. pH, color, turbidity was determined by electrometric method using pH meter, spectrophotometer and digital turbidimeter, respectively.

Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD) were performed by membrane electrode method and closed reflux titrimetric method.

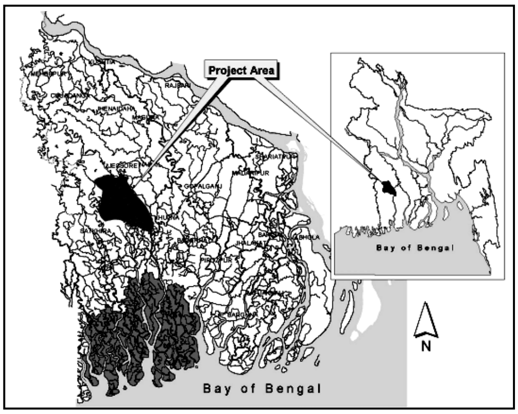

Fig.1: Study area

Fig.2: Selected affected area adjacent to Bhabodah

Biochemical Oxygen (BOD) was carried out using BOD bottles and stored in incubator for 5 days. Total Dissolved Solids (TDS) and Total Suspended Solid (TSS) were determined by gravimetric method. Iron (Fe), Manganese (Mn), Nitrate (NO_3^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}) were determined by spectrophotometer using ferrover; Sodium powder citrate & sodium periodate; nitrover-5; sulfaver-4 and Potassium per sulphate Powder pillow, respectively. Chloride (Cl^-) and hardness tests were performed by titration method. Silver nitrate ($AgNO_3$) and K_2CrO_4 indicator were used for Cl^-. pH buffer solution, Erichrome Black T dye and EDTA were used for hardness test. Total Coliform (TC) & Faecal Coliform (FC) were determined using X-MG Agar and Membrane Filter with 24 hours incubation. Semi-quantitative risk assessment for water and wastewater were followed by WHO and risk score was calculated using the following methodology:

Table.1: Risk matrix for water

		Consequence or Severity				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost Certain (5)	5	10	15	20	25
	Likely (4)	4	8	12	16	20
	Possible (3)	3	6	9	12	15
	Unlikely (2)	2	4	6	8	10
	Rare (1)	1	2	3	4	5
Risk Score		≤5	15-5		>15	
Risk Severity		Low	Medium		High	

Table.2: Risk matrix for sanitation

			SEVERITY (S)				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	4	8	16
LIKELIHOOD (L)	Very unlikely	1	1	2	4	8	16
	Unlikely	2	2	4	8	16	32
	Possible	3	3	6	12	24	48
	Likely	4	4	8	16	32	64
	Almost Certain	5	5	10	20	40	80
Risk Score R= (L)x(S)			<6	7-12		13-32	>32
Risk level			Low Risk	Medium Risk		High Risk	Very High Risk

$$Risk\ Score,\ R = Likelihood\ (L) \times Severity\ (S) \tag{1}$$

As an improvement option for water quality, rain water harvesting system is proposed following the mass-curve method.

$$Monthly\ demand\ (m^3) = (P * q * 30)/1000 \tag{2}$$

[P=Total estimated population and q=Per capita daily water consumption in lpcd]

$$Monthly\ Yield\ (m^3/month),\ Q= (C * I * A)/1000 \tag{3}$$

[C=Runoff coefficient= 0.7; I=Average monthly rainfall intensity (mm) and A=Catchment area (m^2)]

As an improvement option for sanitation, pit latrine is calculated by using all the equations.

$$Effective\ volume\ of\ the\ pit\ (m^3),\ V= 1.33*C*P*N \tag{4}$$

[C=Solids accumulation rate=0.06 m^3/person/year for dry pit; P=No. of latrine users and N=Design life in years]
Depth of the pit= V/A [For circular pit, $A = (\pi D^2)/4$; for rectangular

3. RESULTS AND DISCUSSION

3.1 Field Observation

Field investigation was made to know previous and present conditions of the study area. Water rose about 2-2.5 ft above ground during floods in last years. Most of the people of Panchakari village usually take shelter in Panchakari Primary School for about 6 months or more during floods. Tubewells and pit toilets get inundated and become unusable. About 2-3 nos. of temporary latrines and shallow tubewells had been constructed by the Govt. Authority. People use pond water for cooking and shallow tubewells for drinking purpose. In 2018, for river dredging and not for raining so much, water level rose only upto 2.9 mMSL while in previous years a maximum of 4.0 mMSL.

Fig.3: Water logged condition in 2016

Fig.4: Water logged condition in 2018

3.2 Water Quality in Dry and Water-logged Conditions

The results are presented by taking consecutive three months average data for both dry & waterlogged condition & are shown in table 3 & 4.

Table 3: Comparison between test results & Bangladesh water quality standards for water supply in dry season

Sample / Para-meter	Unit	STW_1	River	Pond	STW_2	*DTW_1	*STW_3	*STW_4	*DTW_2	Bd. Std.
pH	-	7.01	7.54	7.67	7.3	7.68	7.27	7.39	7.41	6.5-8.5
Color	Pt-Co	396	191	282	196	0	53	37	28	15
Turbidity	NTU	98	46	40	33	2	3	3	4	10
EC	µS/cm	1487	2175	513	689	756	1522	1408	1235	
As	mg/L	0.005	0	0	0.01	0	0	0	0	0.05
TDS	mg/L	1126	1661	307	473	582	1163	1060	943	1000
Cl^-	mg/L	720	858	105	83	203	516	394	448	150-600
Hardness	mg/L as $CaCO_3^{2-}$	257	605	131	346	132	565	306	342	200-500
Fe	mg/L	4	0	0	0.4	0.1	0.5	0.3	0.1	0.3-1
Mn	mg/L	3.9	0	0	1.5	0.1	0.3	0.2	0.1	0.1
NO_3^-	mg/L	1	0.4	0.1	0.4	0.4	0.7	0.5	0.7	10
SO_4^{2-}	mg/L	0	22	16	0	0	0	3	10	400
TC	Nos/100 mL	0	40	84	0	0	0	0	0	0
FC	Nos/100 mL	0	16	38	0	0	0	0	0	0

[Note: STW- Shallow Tube Well, DTW- Deep Tube Well, River- Teka river, *Drinking purpose]

Higher value of color, turbidity and TDS make aesthetic problem for maximum samples. River water showed the highest value of EC both in dry (3342.7µS/cm) and waterlogged condition (2175µS/cm) for saline water intrusion when opening Bhabodah sluice gate. Significant increase in EC in waterlogged condition indicates the entrance of polluting discharges into water. However, DoE std. of EC value is 350µS/cm and Bd. Std. for irrigation and fisheries is 750 & 1000 µS/cm respectively. So pond water can be used for irrigation and fisheries. Again, samples exhibit slight variations from std. limit of Fe, Mn & Cl^-. Higher value of TC/FC may cause adverse health hazards for both human & animals and results in spreading of water-borne diseases among residents of the community if especially pond & river water is used without treatment. No TC/FC was found in ground water samples in dry season and is safe to use. But in waterlogged condition, microbial contamination (TC/FC) was detected for the presence of wastewater and many of the pathogenic organisms from nearby pit toilets which are unsuitable for use. So special attention need to be given to protect water from being contaminated.

Table 4: Comparison between test results and Bangladesh water quality standards for water supply in waterlogged condition

Sample / Para-meter	Unit	STW$_1$	River	Pond	STW$_2$	*DTW$_1$	*STW$_3$	*STW$_4$	*DTW$_2$	Bd. Std.
pH	-	7.28	7.58	7.69	7.32	7.55	7.12	7.37	7.45	6.5-8.5
Color	Pt-Co	370	268	252	153	7	20	22	9	15
Turbidity	NTU	162	144	57	31	3	10	6	5	10
EC	µS/cm	1550	3343	681	901	899	1815	1443	1258	-
As	mg/L	0.005	0	0	0.01	0	0	0	0	0.05
TDS	mg/L	915	1232	382	587	569	932	981	711	1000
Cl^-	mg/L	483	729	114	132	245	484	360	362	150-600
Hardness	mg/L as $CaCO_3^{2-}$	455	781	273	548	621	859	517	719	200-500
Fe	mg/L	3.4	0.1	0	0.9	0.3	0.2	0.3	0.3	0.3-1
Mn	mg/L	2.5	0.2	0.2	0.3	0.3	0.4	0.3	0.4	0.1
NO_3^-	mg/L	4	0.1	0.6	0.1	0.6	1.8	0.6	0.8	10
SO_4^{2-}	mg/L	0	59	1	0	0	2	1	5	400
TC	Nos/100 mL	7	48	70	11	3	5	8	6	0
FC	Nos/100 mL	1	24	39	3	1	3	5	1	0

[Note: STW- Shallow Tube Well, DTW- Deep Tube Well, River- Teka river, *Drinking purpose]

3.3 Semi Quantitative Risk Assessment for water

By using risk assessment matrix in table 1 & equation (1), risk level is analysed for all the samples and is represented as in figure 5 & 6. STW$_1$ shows highest risk level (Medium) for Fe in both seasons. Again, in fig.6, risk level of all the samples except river & pond water in waterlogged condition rise significantly for the presence of waste water from nearby pit toilet and different garbage. And in both seasons, it is very likely to contaminate river and pond water on regular basis with pathogens that could result in spreading of water-borne diseases among residents of the community. It is also observed that risk level of tube well water samples rise from low to medium. So people should be conscious for using pond & river water, especially for all the drinking water sources during water logged condition.

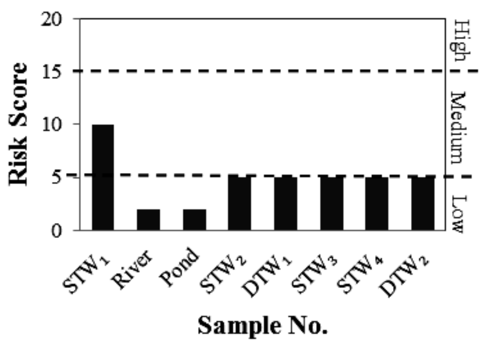

Fig.5: Risk assessment graph for Fe

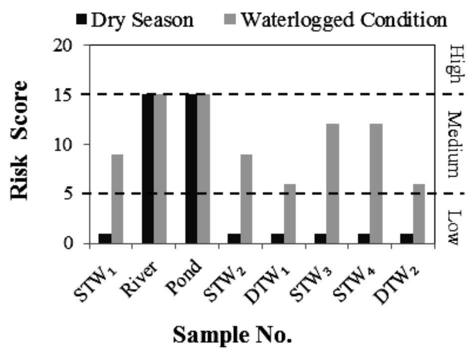

Fig.6: Risk assessment graph for TC/FC

3.4 Exploration of Sanitation Situation

The results are presented by taking consecutive 3 months average data shown in table 5. It can be seen that EC, TDS & TSS values are so high which indicate the presence of organic, inorganic particles and water pollutants. So direct flow of these samples may damage aquatic life and contaminates water bodies. Higher values of BOD & COD indicate water pollution, toxicity of effluents and existence of huge quantity of biologically resistant organic substances that poses high risk for environment. High chloride content (>600mg/L) discharged from S-1 & S-3 into inland water distribution system indicate sewage pollution. High amount of TC/FC containing in the samples contaminates tube well water used for drinking purpose as toilet or septic tank is situated near the tube well (<30m).

Table 5: Comparison among the waste water samples in waterlogged condition

Sample No. / Parameter	Unit	S-1	S-2	S-3	Std. for sewage discharge into inland water
pH	-	7.9	7.67	8.11	5.5-9
Color	Pt-Co	1619	2467	503	
Turbidity	NTU	1534	1802	216	
DO	mg/L	1.1	1.2	1.7	4.5-8*
BOD	mg/L	197	355	133	40*
COD	mg/L	588	607	367	250
EC	µS/cm	1762	1222	4657	
TDS	mg/L	1567	556	2641	1500
TSS	mg/L	2469	1801	347	100
Cl^-	mg/L	671	345	1806	600
Hardness	mg/L as $CaCO_3^{2-}$	932	686	949	
NO_3^-	mg/L	3	9	5	250*
SO_4^{2-}	mg/L	2	3	101	400
PO_4^{3-}	mg/L	4	8	5	35*
TC	Nos./100mL	31	89	48	
FC	Nos./100mL	22	36	27	

[S-1 is collected from waterlogged septic tank water beside Peoples' living & shallow tubewell; S-2 is collected from pond beside pit latrine used for washing and S-3 is from river beside pit latrine used for washing & household purpose; *according to ECR'97 & others are according to BIS 2296: 1982]

3.5 Semi Quantitative Risk Assessment for Waste Water

By using risk assessment matrix (WHO) in table 2, risk level is analysed for all the samples and represented as following graphs.

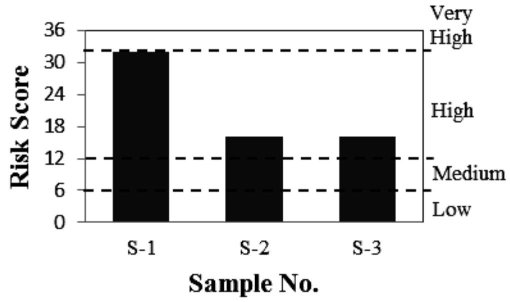

Fig.7: Risk assessment graph for TC, FC, DO, BOD, COD & TSS

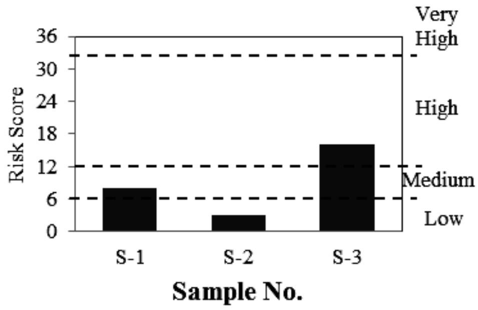

Fig.8: Risk assessment graph for TDS & Cl^-

In fig.7, all the samples lie in the range of high risk. S-1 shows maximum risk score (32). Due to lack of DO and for the presence of excessive amount of TC, FC, BOD, COD & TSS during or after water logged condition, it has possibility to leach waste water from pit to the nearby shallow tube well and contaminate water that can be injurious to health for the users. For excessive amount of TDS & Cl^-, there is possibility to cause sewage pollution in nearby Teka river by S-3 effluents and can be harmful to human health if use without treatment.

3.6 Improving Option of Water quality

3.6.1 Rain Water Harvesting

It is the technique of collection, conveyance & storage of rain water into reservoirs/tanks that consists of elements as roof catchment, gutters, down pipes, first flush devices, filter chamber, storage tank/reservoir & hand pump or other supply system. Schematic diagram of rain water harvesting is shown in fig. 9.

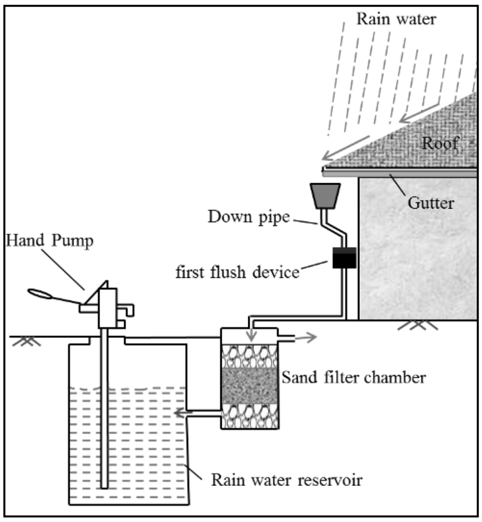

Fig.9: Rain water harvesting

Considering 50 household as a cluster, total study area can be divided into 10 clusters. If per cluster has 250 person and 10 lpcd water is used for drinking & cooking, then monthly demand will be 75 m³ (using equation 2). Assuming total roof area is 2500 m². So by equation 3, monthly yield can be calculated and by using these calculations, graphs can be drawn as following fig. 10 & 11.

From the calculation, water demand & rainwater supply curve are drawn in fig. 10. In fig. 11, cumulative Monthly Supply is 2826.25 m³ & cumulative Monthly demand is 900m³. From the data found in graphs, required storage volume in rain water harvesting system can be calculated in table 6.

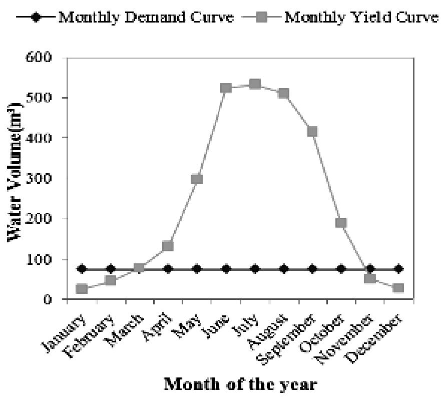

Fig.10: Water demand vs. potential supply curve

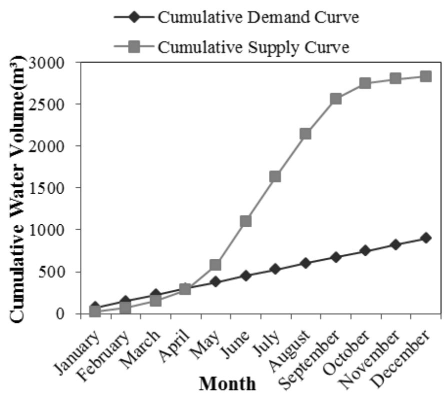

Fig.11: Cumulative demand vs. supply curve

Table 6: Mass Curve Analysis for Required Storage Volume

Month	Monthly Rainfall (mm)	Monthly Supply (m³)	Monthly Demand (m³)	Monthly Stored (m³)	Required Storage Volume (m³)

January	14.8	25.9	75	-49.1	
February	26.1	45.7	75	-29.325	
March	44.6	78.05	75	0	
April	75.4	131.9	75	0	
May	169.9	297.3	75	0	
June	298.7	522.7	75	0	150
July	304.1	532.2	75	0	
August	291.8	510.6	75	0	
September	236.9	414.6	75	0	
October	107.9	188.8	75	0	
November	29	50.8	75	-24.25	
December	15.8	27.6	75	-47.35	

3.6.2 Measures taken for Tubewell

Fig.12: Leakage on tube well

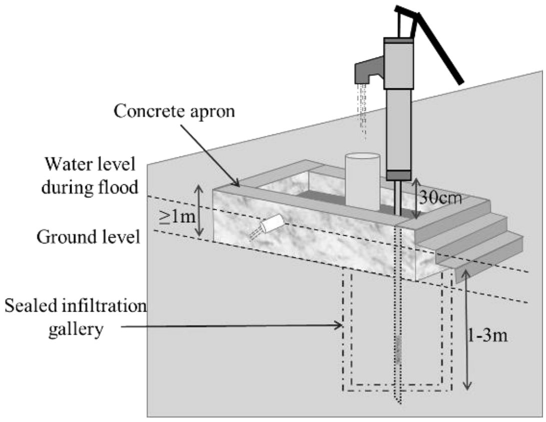

Fig.13: Flood resilience protected well

Fig.12 shows leaks in tubewell from which contaminated water enters into tube well during water logging and make water harmful to the users. So, the leakage should be repaired. A flood resilient protected well can be constructed for preventing flood water contacting with the tube well. In fig 13, schematic diagram of that well is shown. For constructing the well, a concrete apron (≥1m high from ground level) is needed to direct flood water away from the well. A sanitary seal (1-3m) can be provided with clay, grout & concrete to prevent infiltration of contaminants.

3.7 Improving Option of Sanitation System

3.7.1 Mound-built Latrine

In fig.14, the schematic diagram of mound-built latrine is shown. Bottom of the pit should be at least 2 m above ground water table. Minimum horizontal distance should be 30 m between a pit and water source to limit microbial contamination. For 10 nos. of users & 5 years design life, effective volume of the pit 4 m^3 [Using equation 4]. If size of circular pit is 1.25m, depth of the pit will be 3.25m. For rectangular pit of 1.25m, required depth will be 2.56m.

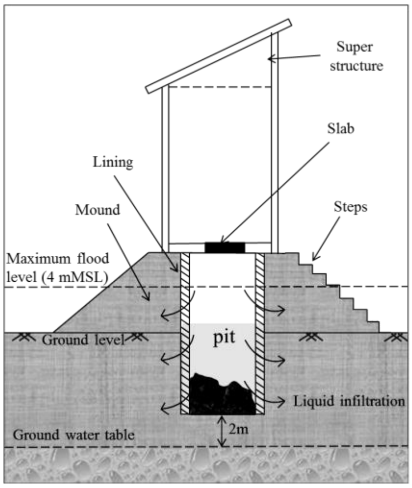

Fig.14: Mound-built latrine

3.7.2 Floating Latrine

Floating latrine is temporary basis used latrine during flood. 6 nos. of plastic drums are used. 3 are used for keeping toilet afloat. 2 are used for installing filtration system having filter material. One is used for installation of pan (3 holes for faecal matter, urine & cleansing water). Collected cleansing water is flown through filter media and finally discharged into water.

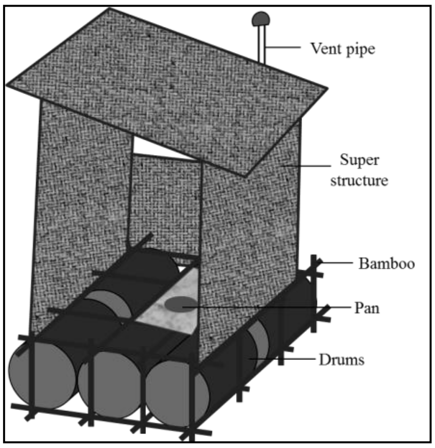

Fig.15: Floating latrine

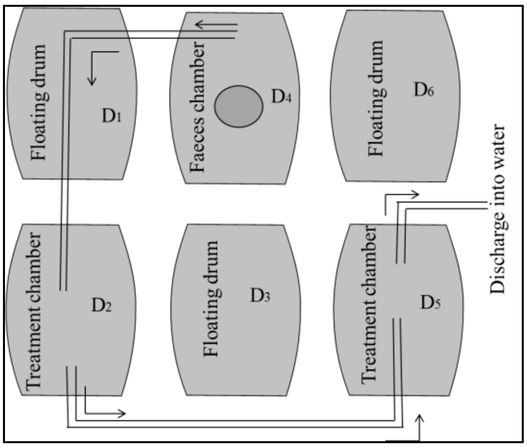

Fig.16: Detailed Schematic diagram of floating latrine

Floating latrine is temporary basis used latrine during flood. 6 nos. of plastic drums are used. 3 are used for keeping toilet afloat. 2 are used for installing filtration system having filter material. One is used for installation of pan (3 holes for faecal matter, urine & cleansing water). Collected cleansing water is flown through filter media and finally discharged into water. Detail schematic diagram of floating latrine is shown in fig.15 & 16.

4. CONCLUSIONS

Water quality and sanitation system of the study area were affected in many ways for waterlogging and drainage congestion. In tubewells, no TC/FC was found in dry season but microbial contamination (TC/FC) was found in waterlogged condition which pose medium level of threat according to WHO sami-quantitative risk approach. Overall, DTW_1 is the most suitable drinking water source in dry season and DTW_2 also seems good except high color concentration (28 Pt-Co). But in waterlogged condition, both DTWs water samples show high concentration of hardness, Mn, TC &

FC beyond the std. limit. STW_2 can be used for washing and domestic purpose although it contains high values of color (196 Pt-Co), turbidity (33.1 NTU) and Mn (1.5 mg/L) in dry season. Whereas other STWs, Teka River and Pond water samples were found to be more polluted and show medium to high risk. For improving the drinking water option in the study area, rain water harvesting system could be adopted with $150m^3$ storage reservoir for every 50 houses cluster. Moreover, the tubewells base-platform could be raised for preventing entrance of contaminants during flood. On the other hand, higher concentration of BOD_5 (355 mg/L), COD (607 mg/L), TDS (2641 mg/L), TSS (2469 mg/L), Cl^- (1806 mg/L), TC (89 Nos./100 mL) and FC (36 Nos./100 mL) of wastewater samples indicate toxicity of effluents and posed high risk to environment and ecosystem. For the betterment of this situation, mound-built latrine is proposed to construct having an excavated depth of 3.3m circular or 2.6m rectangular pit for each 10 users of the area. Moreover, it can be concluded that necessary steps should be taken by the Government and Non-Governmental Organization to minimize the current scenario of vulnerable water and sanitary conditions due to waterlogging and drainage congestion adjacent to Bhabodah area.

REFERENCES

Ahmed AU, Alam M and Rahman AA. (1998). Adaptation to Climate Change in Bangladesh: Future Outlook. In: *Vulnerability and Adaptation to Climate Change for Bangladesh*, S. Huq, Z. Karim, M. Asaduzzaman and F. Mahtab, Eds., Dordrecht: Kluwer Academic Publishers, pp. 125-143.

Ahmed AU. (2005). Adaptation Options for Managing Water Related Extreme Events Under Climate Change Regime: Bangladesh Perspectives. In: *Climate Change and water Resources in South Asia*, MMQ Mirza and QK Ahmad, Eds., Leiden: Balkema Press, pp. 255-278.

BIS 2296: (1982). Available from: http://scclmines.com/env/Linkfile2.htm (cited November 13, 2019).

DHV-WARPO. (2000). Gorai River Restoration Project: Draft Feasibility Report (Main Volume), DHV Consortium and Water Resource Planning Organization (WARPO), Dhaka.

IWM (2010). Feasibility Study and Detailed Engineering Design for Long Term Solution of Drainage Problems in the Bhabodah Area Final Report Main Report, [p: 1-2].

IWM (2017). Feasibility Study and Detailed Engineering Design for Long Term Solution of Drainage Problems in the Bhabodah Area (2nd Phase) Final Report Main Report, [p: 1, 3, 178 &199].

Rahman A. (1995). *Beel Dakatia: The Environmental Consequences of a Development Disaster*. Dhaka: Dhaka University Press.

Sarker MH. (2004). Impact of Upstream Human Interventions on the Morphology of the Ganges-Gorai System. In: *The Ganges Water Diversion: Environmental Effects and Implications*, M.M.Q. Mirza, Ed., Dordreeht: Kluwer Academic Publishers, pp. 49-80.

DEVELOPMENT OF A GRAPHICAL USER INTERFACE (GUI) FOR RAINWATER HARVESTING SYSTEM

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ABSTRACT

Rainwater harvesting (RWH) system has a good potential to supply drinking and cooking water in water-scarce coastal areas in Bangladesh. However, improper design of the storage reservoir, the key element of a RWH system, can result in a failure of the system. The size of a storage tank depends not only on water demand but also on supply (precipitation amount and variability). Therefore, a dynamic reliability based tank sizing tool is imperative for the successful implementation of RWH. This paper aims at developing a graphical user interface (GUI) to ease sizing of storage tank of RWH system. A behavioral model is applied in a MATLAB environment based on a dynamic demand-supply approach to calculate the reliability of the system associated with storage tank sizes. Both time and volumetric reliability are incorporated in the model to provide with the number of days demand is fully met, and also the percent of total demand met by the system respectively. Precipitation data (1953 -2010) from the Bangladesh Meteorological Department (BMD) is used as one of the inputs to the model. In addition, household size, per capita water demand, roof area, roof material are important parameters of the model. The model shows that a 15-m^3 storage reservoir can provide 99% reliability for a typical household having a roof area of 360 ft^2 and a daily demand of 100 liters if precipitation variability in Khulna, a coastal district, is considered. However, maximum 53% reliability can be achieved from the system for the same roof configuration if daily household demand doubles (200 liters). Similar findings for two other adjacet districts (Mongla and Jessore) suggest that model results can be generalized to entire southwest coastal region in Bangladesh.

Keywords: *Coastal, GUI, Rainwater, Harvesting, Reliability.*

1. INTRODUCTION

The right to safe water is recognized as a foundation of all other human rights. According to UNICEF (UNICEF, 2018), more than 97% of the population in Bangladesh have access to improved water sources in 2013 indicating significant. However, still only 34.5% population has access to safe drinking water and 19.4 million people are still drinking arsenic contaminated water. Especially people in coastal zone are suffering from acute water scarcity, as there are relatively fewer surface water bodies there, which are frequently flooded with saline water (Hoque, 2009; Islam, Afrin, Redwan, & Rahman, 2015; Khan, Xun, Ahsan, & Vineis, 2011). So, an alternative method must be sought for. One such method is harvesting rainwater. Rainfall in the coastal areas and roof catchments are suitable for rainwater harvesting (RWH) making it a good source to supply drinking and cooking water in the coastal areas of Bangladesh (Islam, Chou, Kabir, & Liaw, 2010; Islam, Akber, Rahman, Islam, & Kabir, 2019).

Many studies have investigated different components of RWH. Some studies have assessed the financial feasibility of it (Akter & Ahmed, 2015; Bashar, Karim, & Imteaz, 2018), while others applied different modelling approach to calculate how reliable the system is (Islam, Afrin, & Rahman, 2015a; Islam, Chou, & Kabir, 2011; Islam, Afrin, & Rahman, 2015, 2016). The feasibility of RWH system for purposes other than domestic uses (e.g. irrigation and water sensitive urban design) have been explored in some studies (Ghimire & Johnston, 2019; Wahab, Mamtaz, & Islam, 2016). However, lack of interactive rainwater tank sizing curves in coastal zones in Bangladesh prohibit people getting full benefit from RWH system.

This study aims at developing graphical user interface (GUI) of RWH system to make rainwater tank size choosing easy. It takes precipitation variability of three coastal districts into account while developing the tank sizing curves to make the GUI robust as Bangladesh shows distinct seasonal pattern in precipitation (Islam, Afrin, Ahmed, & Ali, 2014, 2015; Islam, Afrin, Redwan, et al., 2015). This paper presents tank sizing curves for RWH system considering both volumetric and time reliability concept.

2. METHODOLOGY

2.1 Study Area

This paper focuses on three coastal districts in Bangladesh: Khulna, Jessore and Mongla as people there have been suffering from water scarcity for a long time. The fresh surface water and ground water sources in those coastal areas are contaminated with saline water (Islam, Afrin, & Rahman, 2014, 2015; Islam, Afrin, Redwan, et al., 2015)

2.2 Data Collection

I collected precipitation data of three study sites from Bangladesh Meteorological Department (BMD). It was daily rainfall data ranging from 1950 to 2010. The study sites have residential, commercial, educational and other community buildings having roof area ranging from 45 ft^2 to 5000 ft^2 (Islam, Afrin, & Rahman, 2015; Islam et al., 2015, 2016). For the sensitivity analysis and inter-site comparison, I used a roof area of 360 ft^2.

2.3 Behavioral Model Development

I applied behavioral model in MATLAB environment for the reliability analysis. The behavioral model is a powerful and reliable tool for assessing performance of rainwater harvesting system (Islam, Afrin, & Rahman, 2015; Islam et al., 2015, 2016). This model is based on mass balance equation. The mass balance equation depends on demand and supply. I used rational formula to get supply matrix. The supply and demand equations can be mathematically illustrated as:

$$Supply = C * I * A \tag{1}$$

$$Household\ Demand = per\ capita\ water\ demand * family\ size \tag{2}$$

Where,
I = rainfall intensity
C = coefficient of runoff
A = catchment area

Roof characteristics were assumed same for all the three study sites, and 0.85 was used as the coefficient of runoff. It was also assumed that historical rainfall data accurately reflects the rainfall pattern of the study sites. I used two fundamental algorithms- yield after spillage (YAS) and yield before spillage (YBS) developed by (Jenkins, 2007) to reflect the actual behaviour of a rainwater tank. The YAS algorithm is shown in Equation 3 and 4:

$$\mathrm{Yt} = \min\begin{cases} D_t \\ V_{t-1} \end{cases} \tag{3}$$

$$\mathrm{Vt} = \min\begin{cases} V_{t-1} + Q_t - Y_t \\ S - Y_t \end{cases} \tag{4}$$

Where
D_t = Demand at time t
V_{t-1} = Volume of water in tank at time t-1
Q_t = Inflow to tank at time t
Y_t = Yield at time t

In YBS algorithm, water is extracted before tank overflow. The YBS algorithm is shown in Equation 5 and 6.

$$\mathrm{Yt} = \min\begin{cases} \mathrm{Dt} \\ \mathrm{Vt} - 1 + \mathrm{Qt} \end{cases} \tag{5}$$

$$\mathrm{Vt} = \min\begin{cases} \mathrm{Vt} - 1 + \mathrm{Qt} - \mathrm{Yt} \\ \mathrm{S} \end{cases} \tag{6}$$

2.4 Graphical user interface (GUI) development

I applied ‘Graphical User Interface Development Environment (guide)’ in MATLAB to develop the GUI for the RWH system. I developed it in a way that it can take the inputs from the users that are necessary for tank sizing curve generation. The basic inputs for the GUI are roof area, water demand and family size. It has a provision to select any of the three study sites considered in this study.

3. ILLUSTRATIONS

3.1 Volumetric reliability

Figure 1 shows the volumetric reliability (R_v) RWH system for different storage tank sizes in three study sites for three different household water demand scenarios. In Khulna, RWH can have 99.7% volumetric reliability for 50 and 100 liter per day demand scenario (Figure 1-a). However, 100 liter per day demand requires higher storage tank size to get it. Interestingly, R_v shows a nearly linear increase with tank size before reaches to its maximum value for the 100 liter per day demand. When demand is high (200 liter per day), R_v does not increase much with storage tank size and has a maximum value of 52%. Rv shows similar trend with storage tank sizes for the three-demand scenario in Mongla and Jessore (Figure 1-b, c). However, under the high demand scenario (200 liter per day), RWH achieves higher R_v in Mongla and Jessore than that in Khulna. A previous study (Islam, Afrin, Redwan, et al., 2015) conducted in Mongla reported similar R_v for the typical roof areas suggesting the validity of the model in this study.

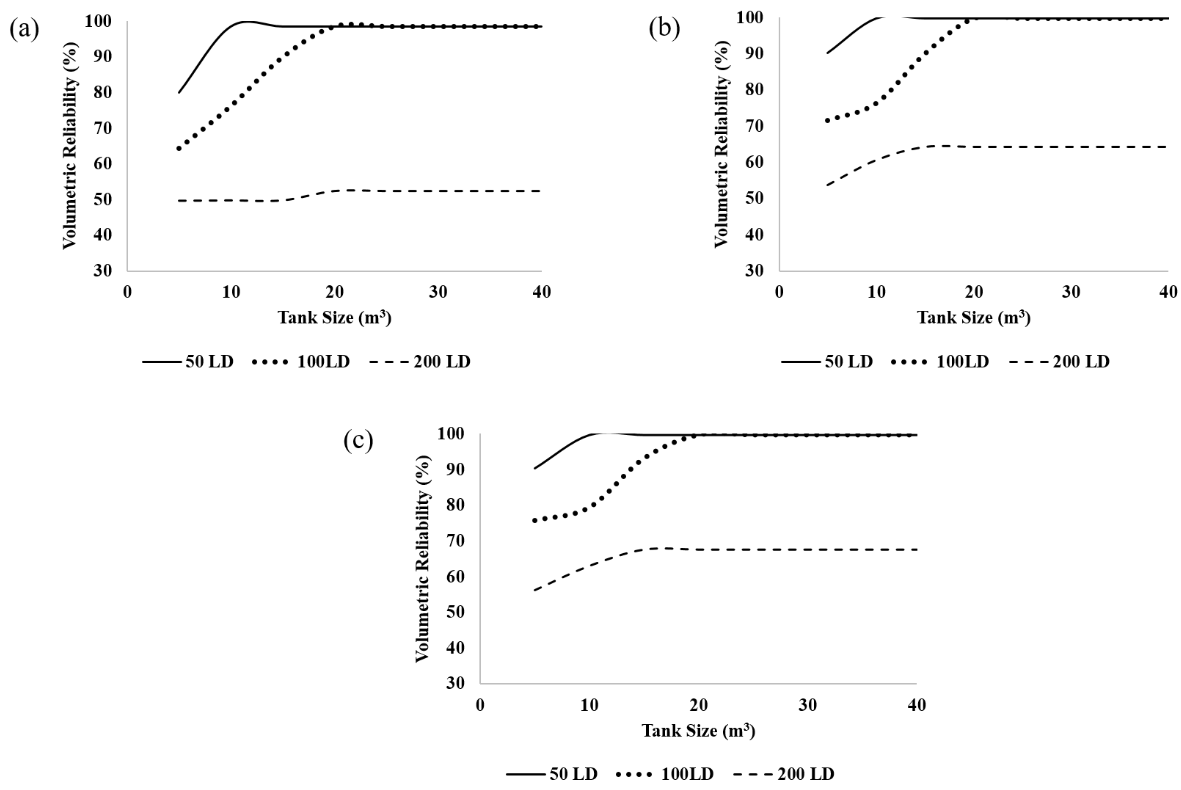

Figure 1: Volumetric reliability curves for (a) Khulna, (b) Mongla and (c) Jessore

3.2 Time reliability

Figure 2 shows the time reliability (R_t) curves of RWH system in three study sites for three different household water demand scenarios. Like Rv, Rt reaches to its maximum earlier for 10 liter per day demand (10 m^3) relative to other two higher demand scenario in all three study sites. In general, RWH shows promise in terms of R_t for the 50 and 100 liter per day scenario in all three sites. Among the three sites, R_t is the highest in Khulna for any tank size indicating that RWH in Khulna can endure higher percentage of days when demand is fully met compared to Mongla and Jessore.

3.3 Graphical user interface (GUI)

As mentioned earlier, the main objective of this study is to develop an interactive GUI to ease deciding about the appropriate tank size. Figure 3 shows the GUI developed for sizing storage tank. The inputs are roof area, household water demand and family size. It also has a provision to take input about the location. Right now, user can choose any of the three locations. The output is a reliability curve for different tank sizes that will help choose the suitable storage tank size given the roof and water demand characteristics of the household.

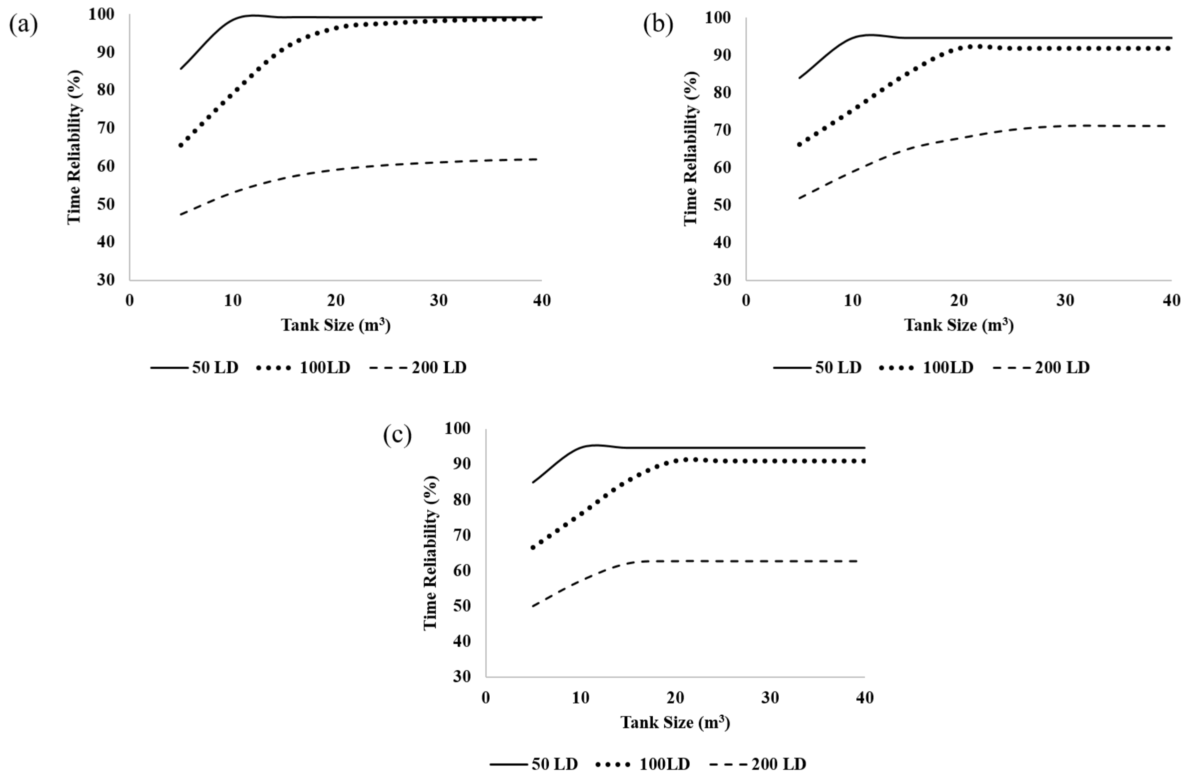

Figure 2: Time reliability curves for (a) Khulna, (b) Mongla and (c) Jessore

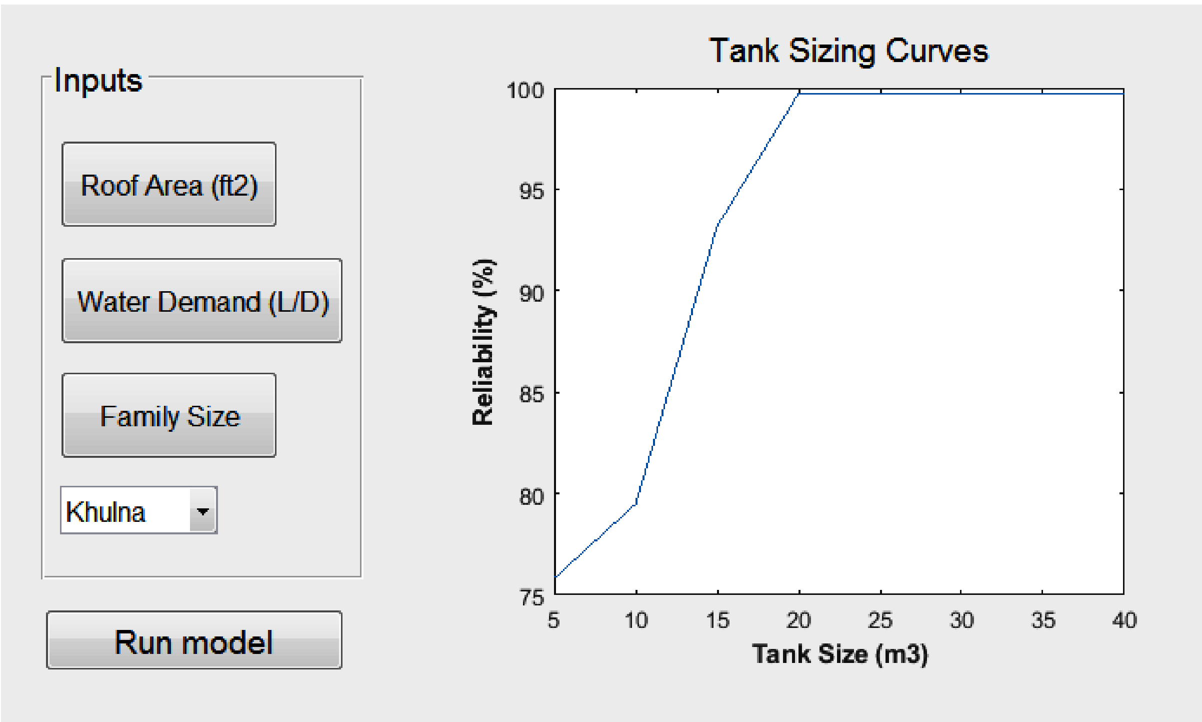

Figure 3: Graphical user interface for the RWH tank sizing

4. CONCLUSIONS

This study develops a graphical user interface to get reliability-based storage tank sizing curves. This user-friendly GUI would encourage people in coastal areas implementing RWH system. This paper also does a comparison of RWH reliability between three adjacent coastal districts in Bangladesh. Both volumetric and time reliability curves show similar trend between the study sites suggesting that RWH system designed according to precipitation scenario of any southwest coastal districts should work for the whole region. RWH shows promise to meet lower household water demand. However, for higher water demand, consistently lower reliability with storage tank size increase indicates that household either needs to extend the roof catchment to harvest more water or manage other sources to meet their excess water demand.

REFERENCES

Akter, A., & Ahmed, S. (2015). Potentiality of rainwater harvesting for an urban community in Bangladesh. Journal of Hydrology, 528, 84–93. https://doi.org/10.1016/j.jhydrol.2015.06.017

Bashar, M. Z. I., Karim, Md. R., & Imteaz, M. A. (2018). Reliability and economic analysis of urban rainwater harvesting: A comparative study within six major cities of Bangladesh. Resources, Conservation and Recycling, 133, 146–154. https://doi.org/10.1016/j.resconrec.2018.01.025

Ghimire, S. R., & Johnston, J. M. (2019). Sustainability assessment of agricultural rainwater harvesting: Evaluation of alternative crop types and irrigation practices. PLOS ONE, 14(5), e0216452. https://doi.org/10.1371/journal.pone.0216452

Hoque, M. R. (2009). Access to safe drinking water in rural Bangladesh: Water governance by DPHE. Retrieved from http://dspace.bracu.ac.bd/xmlui/handle/10361/279

Islam, M. A., Akber, Md. A., Rahman, Md. A., Islam, Md. A., & Kabir, Md. P. (2019). Evaluation of harvested rainwater quality at primary schools of southwest coastal Bangladesh. Environmental Monitoring and Assessment, 191(2), 80. https://doi.org/10.1007/s10661-019-7217-6

Islam, M. M., Afrin, S., Ahmed, T., & Ali, M. A. (2015). Meteorological and seasonal influences in ambient air quality parameters of Dhaka city. Journal of Civil Engineering (IEB), 43(1), 67–77.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015a). A comparative analysis between the application of rational formula and SWMM model for modeling community rainwater harvesting system. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015b). Reliability Analysis of Community Rainwater Harvesting System Considering Precipitation Variability Due to Climate Change. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., Redwan, A., & Rahman, M. M. (2015). Impact of Climate Change on Reliability of Rainwater Harvesting System: A case Study in Mongla, Bangladesh. Proceedings of 10th Global Engineering, Science and Technology Conference. Dhaka, Bangladesh.

Islam, M. M., Chou, F. N.-F., & Kabir, M. R. (2011). Feasibility and acceptability study of rainwater use to the acute water shortage areas in Dhaka City, Bangladesh. Natural Hazards, 56(1), 93–111. https://doi.org/10.1007/s11069-010-9551-4

Islam, M. M., Chou, F. N.-F., Kabir, M. R., & Liaw, C.-H. (2010). Rainwater: A Potential Alternative Source for Scarce Safe Drinking and Arsenic Contaminated Water in Bangladesh. Water Resources Management, 24(14), 3987–4008. https://doi.org/10.1007/s11269-010-9643-7

Islam, M. M., Afrin, S., Ahmed, T., & Ali, M. A. (2014). THE INFLUENCE OF METEOROLOGY ON PARTICULATE MATTER CONCENTRATION IN THE AIR OF DHAKA CITY. Proceedings of 2nd International Conference on Advances in Civil Engineering 2014 (ICACE-2014). Chittagong, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2014). Development of a Design Tool for Sizing Storage Tank of Rainwater Harvesting System in Coastal Areas of Bangladesh Under Future Climatic Scenario. Proceedings of 2nd International Conference on Advances in Civil Engineering 2014 (ICACE-2014). Chittagong, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015). Correlation Between the Performance Indicators of Community Rainwater Harvesting System. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2016). RUNOFF SIMULATION USING SWMM MODEL AND RELIABILITY ASSESSMENT OF COMMUNITY RAINWATER HARVESTING SYSTEM. Proceedings of 8th International Perspective on Water Resources and the Environment. Colombo, Sri Lanka.

Jenkins, G. A. (2007). Use of continuous simulation for the selection of an appropriate urban rainwater tank. Australasian Journal of Water Resources, 11(2), 231–246. https://doi.org/10.1080/13241583.2007.11465327

Khan, A. E., Xun, W. W., Ahsan, H., & Vineis, P. (2011). Climate Change, Sea-Level Rise, & Health Impacts in Bangladesh. Environment: Science and Policy for Sustainable Development, 53(5), 18–33. https://doi.org/10.1080/00139157.2011.604008

UNICEF. (2018). Better access to safe drinking water. Retrieved October 28, 2019, from https://www.unicef.org/bangladesh/en/better-access-safe-drinking-water

Wahab, S. T., Mamtaz, R., & Islam, M. M. (2016). APPLICABILITY OF WATER SENSITIVE URBAN DESIGN (WSUD) IN DHAKA CITY. Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD2016). Khulna, Bangladesh.

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LINKING AIR QUALITY TO METEOROLOGY: A MULTILINEAR REGRESSION APPROACH

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ABSTRACT

Dhaka, the capital of Bangladesh, is one of the most polluted cities in the world in terms of air quality. Particulate matter (PM) concentrations of the city frequently exceed the national air quality standards. Although meteorological parameters play a vital role in air quality through downwind transportation and formation of the secondary PM, few studies have been conducted so far to explore the association between meteorology and air quality. In this paper, we apply a multiple linear regression approach to build a statistical model with PM as response variable, and daily mean temperature, precipitation, relative humidity, solar radiation, wind speed, and wind direction components as potential predictors. For analysis, we employ 24-hour average fine ($PM_{2.5}$) and coarse ($PM_{2.5\text{-}10}$) particulate matter concentration and meteorological data for the year 2002 to 2004 as this work expands the work by Islam, Afrin, Ahmed, & Ali . The result depicts that meteorological variables can explain 57% and 35% variability in the 24-hour average $PM_{2.5}$ and $PM_{2.5\text{-}10}$ concentration respectively when only the direct influence of the parameters is considered. After the inclusion of interaction terms among the parameters, the $PM_{2.5}$ model performances improve by 12% although there is no improvement for coarser fraction. The relative humidity is the most dominating factor explaining 72% of the total variability explained by the $PM_{2.5\text{-}10}$ model. Under a humid environment, there is a reduction of coarser particles as the settling and wet deposition of the particles is fostered by high moisture content. Oppositely for $PM_{2.5,}$ temperature, wind speed, and wind direction are the most influential parameters. They altogether explain 94% of the total variability explained by the $PM_{2.5}$ model. Similar to relative humidity, temperature has an inverse relationship with both PM fractions due to the radiative cooling by particles and also for the shutdown of specific PM sources during the non-winter period. Overall, the outcome of this study provides deeper insight regarding the influence of meteorology and their interaction on PM concentrations. The statistical approach developed in the paper is powerful to develop PM forecasting model for predicting the next day PM given the forecasted meteorological data.

Keywords: *Particulate matter, Meteorology, Multivariate, Regression, Variability.*

1. INTRODUCTION

According to the 'Global Burden of Disease' study, air pollution is the dominant driver of global mortality compared to other different types of pollution including water, soil, chemical, and metals, occupational (Cohen et al., 2017). Every year, outdoor and indoor air pollution attributes to around 8 million premature deaths globally (WHO, 2016) and for Bangladesh this number is around 15000 (Mahmood, 2011). Among different pollutants, particulate matter with aerodynamic diameter less than 10 µm (PM_{10}) are more strongly associated with negative health outcomes. A good number of studies have provided evidence of strong positive association between PM concentrations and all-cause mortality, respiratory morbidity, possibly cardiovascular mortality, morbidity (Bae & Hong, 2018; Zheng, Pozzer, Cao, & Lelieveld, 2015). In Bangladesh, concentrations of these particulate matters frequently exceed the Bangladesh national ambient air quality standard (NAAQS) and U.S. NAAQS, especially during winter months (Hossain & Easa, 2012; Rahman, Mahamud, & Thurston, 2019). During this period, PM concentration remains 5 to 6 times higher than the non-winter monsoon concentration. Specifically, PM is the most concerning air pollutant for Dhaka city (Majumder, Sihabut, & Saroar, 2019; Rahman et al., 2019), which is the capital of Bangladesh. According to WHO (2016), Dhaka city is the third most polluted city in the world in terms of poor air quality. It is also one of the most densely populated cities in the world. The current population of Dhaka is around 20 million. This huge population of the city is constantly exposed to this high concentration of PM mostly due to unplanned urbanization, industrialization, and rapid population growth. A recent study by Tasmin et al. (2019) found association of Short-term exposure to PM with worse lung function of school children in Dhaka experiencing high pollution. Surrounding brick kilns operation, Fossil fuel combustion, industrial operation, vehicular emission, re-suspension of dust from unpaved roads and soil, metal smelter, fugitive Pb, Zn sources are the primary source of particulate matter in this city (Begum, Nasiruddin, Randal, Sivertsen, & Hopke, 2014; Islam et al., 2015).

Given the poor air quality of the city and elevated level of particulate matter concentration in the ambient air, a detailed understanding of the dynamics and drivers of air pollution has become a critical research area to explore. However, limited studies have been conducted so far addressing this issue due to the lack of concern and data availability as the city does not have any well-distributed network of air monitoring. Among the existing literature, studies mostly focused on trend analysis (B. A. Begum & Hopke, 2018; Rahman et al., 2019), source apportionment (Begum et al., 2014; Salam, Hossain, Siddique, & Shafiqul Alam, 2008) and seasonal variability assessment of the air pollutants (Islam & Afrin, 2014; Islam et al., 2015). Although the metrological parameter has been proved to be a significant driver of air pollution (Leung et al., 2017; Tai, Mickley, & Jacob, 2010) very few studies have explored the potential impact of meteorology on the air quality of Dhaka city (Afrin, Islam, Ahmed, & Ali, 2014; Islam et al., 2015; Islam, Saroar, & Ahmed, 2018; Kayes et al., 2019). Kayes et al. (2019) applied multiple linear and non-linear regression models to explore role of meteorological parameters on both particulate and gaseous air pollutants. However, this study was limited to only three meteorological variables – temperature, relative humidity, and rainfall. Islam et al. (2015) determined bivariate 'Pearson correlation coefficient' between meteorological parameters and air pollutants at the Shangshad Bhaban site. This study considered solar radiation and wind speed in addition to the other variables considered by Kayes et al. (2019). In addition, Islam et al. (2018) assessed the effect of meteorological parameters on seasonal variation of particulate matter on a different site located at Darus-Salam, Dhaka using multilinear regression and cross-correlation approach between PM_{10} and $PM_{2.5}$.

None of the previous studies considered the role of wind speed in their regression models. However, the literature suggests a strong association of wind direction with high concentrations of PM components (Leung et al., 2017; Tai et al., 2010). In this paper, we included wind speed and direction components in our regression model, which is an extension of our previous analysis (Islam et al., 2015), which was based on bivariate correlation analysis. In this new work, we employed stepwise multivariate regression analysis to explain the influence of meteorological parameters on the overall

PM concentration of Dhaka city in order to give a better insight regarding the drivers of air pollution. The unique feature of the stepwise regression method keeps only the significant predictors in the final model. Our model also considers the interaction between meteorological variables to assess the combined impact of different types of meteorological variables. Additionally, we quantified the relative importance of the different significant meteorological parameters affecting the 24-hour variation of the ambient particulate matter concentration.

2. METHODOLOGY

2.1 Study Area and Data Source

Dhaka is located in the center of the country. This city has a tropical wet and dry climate with an annual mean temperature of 25°C. Compared to the other major cities of the county, air quality of Dhaka city is worse. Hence, this paper focuses on the air quality of Dhaka city. We collected 24-hour average PM concentration data from the 'Shangshad Bhaban' Continuous Air Monitoring Station (CAMS). This is an urban air monitoring site located close to the heavily trafficked Rokeya Sharani (~150 meters) and Manik Mia Avenue (~300 meters) and started operation in 2002. This site measured the 24-hour average $PM_{2.5}$ (particles with aerodynamic diameter < 2.5 µm) and PM_{10} (particles with aerodynamic diameter < 10 µm) concentrations using high volume PM samplers for the period April 2002 to May 2004. After that period, PM concentrations were reported as monthly average for this site. Hence, we consider the 24-hour average particle concentration data from April 2002 to May 2004 in our analysis. To keep consistency with our previous analysis paper (Islam et al., 2015), we split the total PM_{10} concentrations into two size fractions, the finer fraction with $PM_{2.5}$ and the coarser fraction named $PM_{2.5-10}$ consisting particles' size ranging in between 2.5 µm and 10 µm. In order to assess the influence of meteorological parameters over air quality we consider the concurrent daily average atmospheric temperature, rainfall, relative humidity, and solar radiation recorded at the same site. For daily wind speed and prevailing wind direction, we used the data recorded by Bangladesh Meteorological Department (BMD) as 'Shangshad Bhaban' CAMS did not report daily wind speed and direction for that period. On the other hand, BMD monitors daily data from all meteorological parameters since 1953 and located within 4km from the CAMS site. The meteorological variables included in this study are listed in Table 1.

Table 1: List of meteorological parameters

Parameter	Abbreviation	Unit
Temperature	T	°C
Rainfall	R	cm
relative humidity	RH	%
solar radiation	SR	W/m^2
wind speed	WS	m/s
North-South component of wind direction	CosWD	-
East-West component of wind direction	SinWD	-

2.2 Statistical Analysis

This paper used the stepwise regression method to develop generalized linear models considering multiple variables for the monitoring site. We use the 24-hour average particulate matter concentration (both $PM_{2.5}$ and $PM_{2.5-10}$) as response variables and all the listed parameters in Table 1 as predictive variables. In this stepwise regression approach, the choice of predictive variables was carried out considering both forward and backward selections of variables. The final model only retains the significant predictors based on the p-value for the F or chi-squared test of the change in the deviance by adding or removing the term. In our analysis, we define a significance level of $P < 0.05$ and also the upper and lower model type. To consider the independent impacts by the individual predictors we set the upper model types as 'linear', while set the upper model type as 'interaction' to incorporate the interaction between meteorological variables. We used the adjusted R^2 value instead of the ordinary R^2 value to explain the model's predictive power, as adjusted R^2 gives an unbiased estimate of the population R^2. We simulate two sets of stepwise generalized linear models by including and excluding the interaction terms among the predictor variables. For each case, we regenerated the model for both $PM_{2.5}$ and $PM_{2.5\text{-}10}$. The schematic diagrams of the two sets of models considering all probable predictors are shown in equation (1) and equation (2).

$$PM = \beta 0 + \sum_1^k \beta_k X_k \quad (1)$$

$$PM = \beta 0 + \sum_1^k \beta_k X_k + inetraction\ terms \quad (2)$$

Where, PM could be either 24-hour average $PM_{2.5}$ or $PM_{2.5\text{-}10}$ during the study period considered, β0 is the intercept term or β1 to β7 are the regression coefficients for each of the seven independent meteorological variables. Finally, we applied dominance analysis (Azen & Budescu, 2003) to assess the relative importance of different predictors in a regression model. Following this approach, we also quantified the shared variance by individual predictors to the total variance or explaining power of a model.

3. RESULTS AND DISCUSSION

Considering only the linear terms of all meteorological parameters as per equation (1), the stepwise regression model can explain 57% and 35% variability of the 24-hour average $PM_{2.5}$ and $PM_{2.5\text{-}10}$ concentrations of the ambient air respectively (Figure 1). In this case of excluding interaction terms, temperature, relative humidity, and wind parameters are the most significant predictors for the $PM_{2.5}$ model. In contrast, the wind parameter does not have any significant influence in predicting the $PM_{2.5\text{-}10}$ concentrations during the study period considered. The estimated intercept, regression coefficients and other model parameters for both $PM_{2.5}$ and $PM_{2.5\text{-}10}$ models are presented in Table 2 and Table 3 respectively.

Table 2: Significant parameters of the $PM_{2.5}$ regression model considering only the linear terms of all meteorological parameters as predictor variables

	Estimate	**Standard Error**	**t-Statistics**	**P-Value**
Intercept	416.86	34.10	12.23	2.2E-28
T	-8.39	0.75	-11.26	6.0E-25
RH	-1.20	0.30	-3.95	9.7E-05
WS	-11.41	3.24	-3.52	4.9E-04
SinWD	-10.08	5.13	-1.96	5.0E-02
CosWD	11.98	4.17	2.87	4.4E-03

Table 3: Summary statistics/ Parameters of the $PM_{2.5\text{-}10}$ regression model considering only the linear terms of all meteorological parameters as predictor variables

	Estimate	**Standard Error**	**t-Statistics**	**P-Value**
Intercept	298.80	18.06	16.55	8.3E-45
T	-2.51	0.38	-6.62	1.6E-10
RH	-2.27	0.20	-11.57	4.5E-26

As shown in Table 2, temperature, relative humidity, wind speed has a negative association with 24-hour average $PM_{2.5}$ concentration. Although wind speed coming from the typical wind direction for a specific season showed weak correlation with particle concentrations (Islam et al., 2015), their inclusion in the regression model along with wind direction components increases the explaining power of the $PM_{2.5}$ regression model. These findings also highlight the potential role of wind direction as a model predictor, which has not been previously explored by previous studies. The role of temperature, relative humidity obtained in this study is in agreement with the results obtained by the previous literature (Islam et al., 2015; Islam et al., 2018; Kayes et al., 2019). Likewise the negative association of wind speed obtained in this study, another study (Islam et al., 2018) based on the data of Darus Salam CAMS also found strong negative correlation with wind speed.

The positive association with the North-South component and negative association with the east-west component suggests that $PM_{2.5}$ concentrations increase when winds come from north and west directions. This makes a sense as wind is transporting particles from the brick-kiln clusters located in the north-west of the city (Islam & Afrin, 2015). Overall, from the t-statistics, it can be said that temperature is the most influencing meteorological parameter among the all other predictors. For the $PM_{2.5\text{-}10}$ regression model, only temperature, relative humidity is the significant predictors (Table 3). Opposite to $PM_{2.5}$ model, relative humidity has a higher impact on the total variability of the $PM_{2.5\text{-}10}$ model than temperature. With the increase in moisture content the coarser particles become more susceptible to the different physical processes within the atmosphere. Consequently due to settling and wet deposition, the particle concentration reduces.

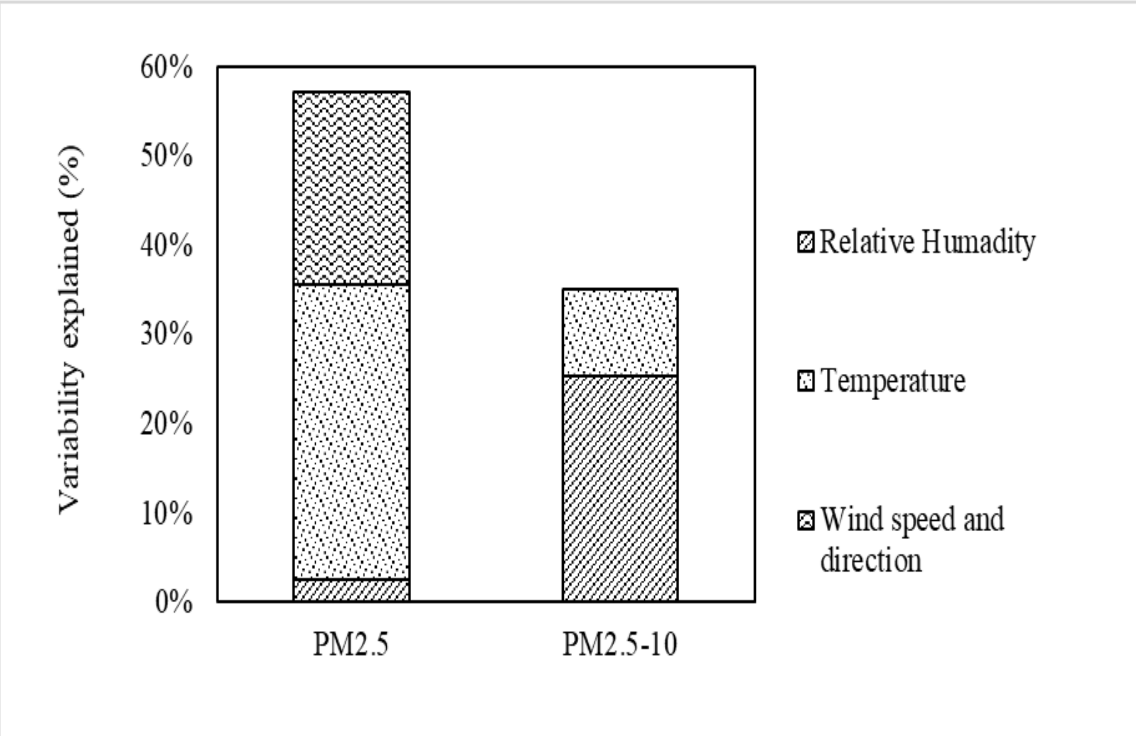

Figure 1: Relative importance of different meteorological variables in explaining the total variability

Using dominance analysis, we further quantify the proportional contribution of each variable to the variation explained directly in the model. Figure 1 represents the total variability as well as the shared variability explained by the significant meteorological parameter influencing the particulate matter concentration. Temperature can explain 58% of the total variability, whereas wind speed and wind direction altogether can explain 38% of the total variability explained by the $PM_{2.5}$ model. Although relative humidity has a small influence over $PM_{2.5}$ concentration, it can explain 72% of the total variability of coarser particles with the rest of the variability explained by temperature.

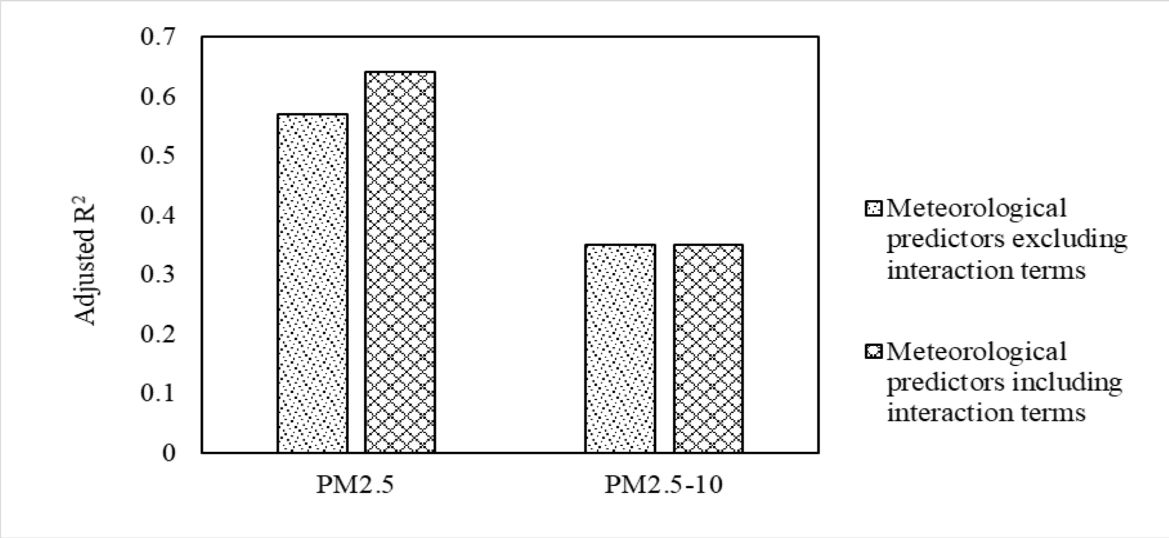

Figure 2: Influence of interactions terms among the meteorological predictors over the model performance

After incorporating all meteorological variables along with their interaction as per equation (2), the model performance for $PM_{2.5}$ increased by 12% than that if no interaction is considered among model parameters (Figure 2). Consequently, the resulting $PM_{2.5}$ model can explain 64% of the total variability of the 24-hour average $PM_{2.5}$ concentrations. In contrast, even after the addition of the interaction terms, there was no improvement in the model performance depicting negligible influence of meteorological interaction over coarse particles (Figure 2). The estimated intercept, regression coefficients and other model parameters for $PM_{2.5}$ model are summarized in Table 4. As shown in Table 4, while considering the interaction terms, all considered meteorological parameters show significant influence alone or in association with other parameters.

Table 4: Summary statistics of the stepwise regression model considering $PM_{2.5}$ as the response variable and all meteorological variables and their interaction terms as predictor variables

	Estimate	**Standard Error**	**t-Statistics**	**P-Value**
Intercept	963.43	98.89	9.74	1.1E-19
R	-228.08	96.70	-2.36	1.9E-02
T	-11.25	1.47	-7.65	2.6E-13
RH	-6.77	1.09	-6.19	2.0E-09
SR	-1.85	0.35	-5.27	2.6E-07
WS	-128.87	38.46	-3.35	9.1E-04
SinWD	107.62	35.11	3.07	2.4E-03
CosWD	12.39	3.86	3.21	1.5E-03
R:T	-9.74	2.36	-4.12	4.9E-05
R:RH	5.11	1.47	3.49	5.6E-04
R:SR	0.42	0.22	1.97	5.0E-02
T:WS	2.24	0.74	3.03	2.6E-03
RH:SR	0.02	0.00	4.81	2.3E-06
RH:WS	0.77	0.37	2.08	3.9E-02
RH:SinWD	-1.17	0.45	-2.61	9.6E-03
WS:SinWD	-18.17	6.23	-2.92	3.8E-03

4. CONCLUSIONS

Meteorology plays a significant role in explaining the variability of 24-hour average PM concentrations. In addition to the detailed understanding of the different sources of air pollution, knowledge of the meteorological drivers affecting air quality is essential to further reduce or mitigate this national problem. Similar to previous literature, the findings of the study highlight the strong negative association of temperature and relative humidity with the increase of particulate matter concentrations. Interestingly, this study also revealed the potential role of wind speed and direction over the fine particulate matter concentrations of Dhaka city, which was not explored explicitly by the previous literature. All the meteorological parameters considered in this paper altogether can explain 64% and 35% of the total variability of fine and coarse particulate matter respectively suggesting that there are other drviers of PM variability in Dhaka, and a detail source apportionment study can be done in future to identify those factors (e.g. vehicle, brick kilns, industry and construction works). Although the data used in this study is quite back-dated, the method applied in this study is powerful and gives a deeper understanding of the role of different weather parameters. Moreover, Begum et al. (2018) recently showed that the air quality of Dhaka has been stable over the past decade by analyzing the long term air quality data of Dhaka city, which justifies the use of this older dataset of this paper. In conclusion, this kind of regression model is useful for the development of particulate matter prediction models incorporating meteorological parameters. This method is also helpful for policymakers to assess the relative importance of different variables while implementing any policy in a cost-effective way.

REFERENCES

Afrin, S., Islam, M. M., Ahmed, T., & Ali, M. A. (2014). The Influence of Meteorology on Particulate Matter Concentration in the Air of Dhaka City. *2nd International Conference on Advances in Civil Engineering (ICACE-2014)*, Chittagong, Bangladesh.

Azen, R., & Budescu, D. V. (2003). The Dominance Analysis Approach for Comparing Predictors in Multiple Regression. *Psychological Methods*, *8*(2), 129–148. https://doi.org/10.1037/1082-989X.8.2.129

Bae, S., & Hong, Y. C. (2018). Health effects of particulate matter. *Journal of the Korean Medical Association*, *61*(12), 749–755. https://doi.org/10.5124/jkma.2018.61.12.749

Begum, B. A., & Hopke, P. K. (2018). Ambient air quality in Dhaka Bangladesh over two decades: Impacts of policy on air quality. *Aerosol and Air Quality Research*, *18*(7), 1910–1920. https://doi.org/10.4209/aaqr.2017.11.0465

Begum, B., Nasiruddin, M., Randal, S., Sivertsen, B., & Hopke, P. (2014). Identification and Apportionment of Sources from Air Particulate Matter at Urban Environments in Bangladesh. *British Journal of Applied Science & Technology*, *4*(27), 3930–3955. https://doi.org/10.9734/bjast/2014/11247

Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K., … Forouzanfar, M. H. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*, *389*(10082), 1907–1918. https://doi.org/10.1016/S0140-6736(17)30505-6

Hossain, K. M. A., & Easa, S. M. (2012). Pollutant dispersion characteristics in Dhaka city, Bangladesh. *Asia-Pacific Journal of Atmospheric Sciences*, *48*(1), 35–41. https://doi.org/10.1007/s13143-012-0004-8

Islam, M. M., & Afrin, S. (2014). Air Quality Status of Dhaka City and Effects of seasons, Weekends, Eid and Hartal Days. *2nd International Conference on Advances in Civil Engineering (ICACE-2014)*, Chittagong, Bangladesh.

Islam, M. M., & Afrin, S. (2015). The Influence of Brick Kilns on Seasonal Variation of Particulate Matter The Influence of Brick Kilns on Seasonal Variation of Particulate Matter Concentration in Dhaka City. *11th International Conference on Mechanical Engineering (ICME 2015*), Dhaka, Bangladesh.

Islam, M. M., Afrin, S., Ahmed, T., & Ali, M. A. (2015). Meteorological and seasonal influences in ambient air quality parameters of Dhaka city. *Journal of Civil Engineering*, *43*(1), 67–77.

Islam, N., Saroar, M. G., & Ahmed, T. (2018). Meteorological Influences on Atmospheric Particles in Darus Salam Area of Dhaka City. In *Proceedings of the 4thInternational Conference on Civil Engineering for Sustainable Development (ICCESD 2018),* (pp. 1–12). KUET, Khulna, Bangladesh.

Kayes, I., Shahriar, S. A., Hasan, K., Akhter, M., Kabir, M. M., & Salam, M. A. (2019). The relationships between meteorological parameters and air pollutants in an urban environment. *Global Journal of Environmental Science and Management*, *5*(3), 265–278. https://doi.org/10.22034/gjesm.2019.03.01

Leung, D. M., Tai, A. P. K., Mickley, L. J., Moch, J. M., Van Donkelaar, A., Shen, L., & Martin, R. V. (2017). Synoptic meteorological modes of variability for fine particulate matter (PM 2.5) air quality in major metropolitan regions of China. *Atmos. Chem. Phys. Discuss. Chem. Phys. Discussion started*. https://doi.org/10.5194/acp-2017-916

Mahmood, S. (2011). Air Pollution Kills 15,000 Bangladeshis Each Year: The Role of Public Administration and Government's Integrity. *… of Public Administration and Policy Research*, *3*(May), 129–140.

Majumder, S., Sihabut, T., & Saroar, M. G. (2019). Assessment of knowledge, attitude, and practices against inhaled particulate matter among urban residents in Dhaka, Bangladesh. *Journal of Health Research*, *ahead-of-p*(ahead-of-print). https://doi.org/10.1108/jhr-12-2018-0168

Rahman, M. M., Mahamud, S., & Thurston, G. D. (2019). Recent spatial gradients and time trends in Dhaka, Bangladesh, air pollution and their human health implications. *Journal of the Air and Waste Management Association*, *69*(4), 478–501. https://doi.org/10.1080/10962247.2018.1548388

Salam, A., Hossain, T., Siddique, M. N. A., & Shafiqul Alam, A. M. (2008). Characteristics of atmospheric trace gases, particulate matter, and heavy metal pollution in Dhaka, Bangladesh. *Air Quality, Atmosphere, and Health*, *1*(2), 101–109. https://doi.org/10.1007/s11869-008-0017-8

Tai, A. P. K., Mickley, L. J., & Jacob, D. J. (2010). Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2.5 to climate change. *Atmospheric Environment*, *44*(32), 3976–3984. https://doi.org/10.1016/j.atmosenv.2010.06.060

Tasmin, S., Ng, C. F. S., Stickley, A., Md, N., Saroar, G., Yasumoto, S., & Watanabe, C. (2019). Effects of Short-term Exposure to Ambient Particulate Matter on the Lung Function of School Children in Dhaka, Bangladesh. *Epidemiology (Cambridge, Mass.)*, *30*, S15–S23. https://doi.org/10.1097/EDE.0000000000001012

WHO. (2016). *Monitoring Health for the SDGs, sustainable development goals, World Health Organization*. https://doi.org/10.1017/CBO9781107415324.004

Zheng, S., Pozzer, A., Cao, C. X., & Lelieveld, J. (2015). Long-term (2001-2012) concentrations of fine particulate matter (PM2.5) and the impact on human health in Beijing, China. *Atmospheric Chemistry and Physics*, *15*(10), 5715–5725. https://doi.org/10.5194/acp-15-5715-2015

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EVALUATING THE NOISE ABSORPTION PERFORMANCE OF ACOUSTIC PANELS MADE OF SOLID WASTES

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ABSTRACT

Noise pollution and solid waste management are the most burning environmental issues worldwide particularly in developing countries. Inefficient management and disposal system of solid waste are obvious causes of environmental pollution in most megacities. Not only solid waste but also the noise pollution caused by machines, vehicles, and industries are liable for environmental degradation. Therefore, the aim of this research is to investigate the potential of turning solid wastes into acoustic panels for using as noise absorbers in reducing noise and providing a sustainable solution for solid waste management. Four locally available solid waste materials such as poultry feathers (PF), jute fiber (JF), tea leaves (TL) and human hair (HH) wastes are used to make acoustic panels for absorbing noise in which polyester resin is used as a binder. The noise drops are 11.68, 9.42, 9.18 and 10.77 dB for JF, TL, PF and HH panels respectively. The physical properties such as tensile strength and core shear strength of these panels are also investigated. The results show that tensile strength and the core shear strength of these panels are 22.17 MPa and 52.98MPa for JF, 6.35 MPa and 31.94MPa for PF, 10.16 MPa and 45.79 MPa for HH, 8.53 MPa and 21.41 MPa for TL wastes panels respectively. It can be concluded that the acoustic panel made of JF waste shows the maximum noise absorption capacity with higher tensile and core shear strength as compared to ther panels. All other panels also show satisfactory performance in absorbing noise at different magnitudes.

Keywords: *Noise pollution, Solid waste, Acoustic panels, Sound absorption.*

1. INTRODUCTION

Noise is generally unwanted sound which is caused by machines, transportation systems, engines and aircrafts (Bratu et al., 2011). Noise breaks concentration in works, disturbances in sleep, interferences in speech etc. Increased uses of mechanical and electrical appliances are influencing the noise pollution at homes and industries (Rimantho et al., 2019). Therefore, noise control is an important issue in assuring acoustically pleasant environment for human beings. Achieving a pleasing environment, sound absorbent materials are used within rooms and enclosed working areas to reduce the noise intensity. Thin, lightweight and low-cost materials which absorb sound in wider frequency are strongly desired (Ersoy & Küçük, 2009). Conventional materials such as glass fibers, open cell foams, and acoustic tiles are often used as the sound absorbent materials (Mahzan et a., 2009; Zulkifli et al., 2010). Recently, several investigations have been carried out considering natural mineral as the filler material of the sound absorbent such as wood, rubber and tea leaves (Ersoy & Küçük, 2009; Mohanty & Fatima, 2015; Wong et al., 2017; Yang et al., 2003). Natural fibers have many advantages as compared to the synthetic fibers, for example low weight, low density, low cost, acceptable specific properties and recyclable (Mahzan et al., 2009; Malawade & Mahamuni, 2018). One of the most important issues in developing noise reduction materials is the use of various solid waste materials. The use of composite noise absorber panels made of solid waste materials in reducing noise have two major advantages; namely noise control at low production cost and sustainable solid waste management. Bangladesh is facing serious environmental degradation and public-health risk due to the disposal of solid wastes on streets and other public areas, and contamination of water resources by uncontrolled dumping sites. The drainage system also clogged by indiscriminately dumped wastes. Manufacturing of noise aborsoption panels by using solid wastes will not only provide a solution in reducing noise pollution but also will help to develop a solid wastes management system.

Therefore, the present study aims to fabricate noise absorbing panels by using solid waste materials bonded together with polystyrene and hardener. In addition, the study also investigates the acoustical and physical properties of the noise absorbing panels, and evaluates the performance of the panels in absorbing noise.

2. METHODOLOGY

2.1 Experimental design

Four specimens from the following waste materials having same size of 12 inch x 12ch in x 1/8 inch were made for investigating the acoustics and physical properties of the specimens. Table 1 shows the proportioning of the materials in preparing four different sound absorption panels (specimens) by using different solid waste materials.

Table 1 Proportions of different materials in preparing different sound absoption panels

Specimen	Name of Materials	Percentage by Volume
JF Panel (Jute fiber composite)	Waste jute fiber	58
	Polyester resin	21
	Hardener (Methyl Ethyl Ketone Peroxide)	01
TL Panel (Tea leaves composite)	Waste tea leaves	65
	Polyester resin	34
	Hardener (Methyl Ethyl Ketone Peroxide)	01
PF Panel (Poultry feather Composite)	Poultry feather waste	61
	Polyester resin	38
	Hardener (Methyl Ethyl Ketone Peroxide)	01
HH Panel (Human hair Composite)	Human hair waste	63
	Polyester resin	36
	Hardener (Methyl Ethyl Ketone Peroxide)	01

2.2 Preparation of the panels:

The following steps are followed to fabricate the sound absorption panels from the composition of different solid waste materials:

- Specified solid waste materials were dried after the collection and then cleaned to remove other unwantaed waste materials.
- After measuring and proportioning according to Table 1, materials were mixed and placed in the formwork.
- Casted materials were compacted properly and formworks were removed after 24 hours.
- The panels were joined together to make boxes for conducting the tests.

Jute Fiber   Poultry Feathers   Human Hair   Tea Leaves

Figure 1: Various types of solid waste materials

2.3 Experimental procedures for investigating acoustics properties

2.3.1 Sound absorption and noise reduction coefficient

Firstly, the performance of the four noise absorber panels is measured in terms of sound abosorption and noise reduction coefficients. The absorption coefficient denoted by α is defined as the ratio of energy absorbed by a material to the energy incident upon its surface. The variations of sound absorption coefficients for every panel were investigated at different frequencies of 125, 250, 500, 1000, 2000, and 4000 Hz following the ISO 10534-2 standard (International Organization for Standardization, 1998). Furthermore, the Noise Reduction Coefficient (NRC) is defined as the amount of sound energy absorbed upon striking a particular surface. The NRC was the average value of the absorption coefficient of the material, which was investigated at the frequencies of 250, 500, 1000, and 2000 Hz. It was rounded off to the nearest multiple of 0.05. An NRC of 0 indicates perfect reflection and an NRC of 1 indicates perfect absorption. The following steps were followed to determine the sound absorption coefficient and noise reduction coefficient of the four absorption panels:

1. Speaker was turned on and sound frequencies of 125, 250, 500, 1000, 2000, and 4000 Hz were generated.
2. The incident sound and absorbed sound were recorded without and with putting the composite noise absorber panels into the sound-tight glass box respectively for all frequencies.
3. The sound absorption coefficient was calculated by decibel drop which was calculated from the incident sound and absorbed sound.
4. Noise reduction coefficients were calculated from the sound absorption coefficient at the frequencies of 250, 500, 1000, and 2000 Hz.

Figure 2: Acoustic properties test of Composite panels

2.4 Experimental procedures for investigating physical properties:

2.4.1 Tensile strength test and three point bending test

A central region called the gauge length is expected to failure and two end regions are clamped into a grip mechanism connected to a test machine. This test specimen can be used for tensile and core shear stress test. Tensile strength tests of these composite panels are performed in IEE Lab of the University (DUET). Tensile test technique, ASTM D 3039M-17 and three point bending test technique ASTM C 393-00 at a speed of 3 mm/min were used to determine the tensile strength and the core shear stress (American Society for Testing and Materials, 2000, 2017).Three samples of each specimen were tested, and force versus stroke values were recorded.

3. RESULTS AND DISCUSSION

3.1 Acoustic properties of composite panels

3.1.1 Sound absorption coefficient (α)

Figure 1 shows the variations in sound absorption coefficients for different panels. The results show that all the sound absorption coefficients are increased with the increasing the sound frequency upto 2000 Hz and then the coefficients are slightly decreased with the increasing sound frequencies from 2100 to 4000 Hz . The absorption coefficients are higher for the panel made of waste jute fibre as compared to the other panels. Furthermore, Figure 1 shows that jute fibre composite panel shows the better performance in absorbing more noise while poultry feather composite panel shows the lowest performance. The tea leaves composite panel and human hair composite panel show nearly similar performance in reducing the noise level.

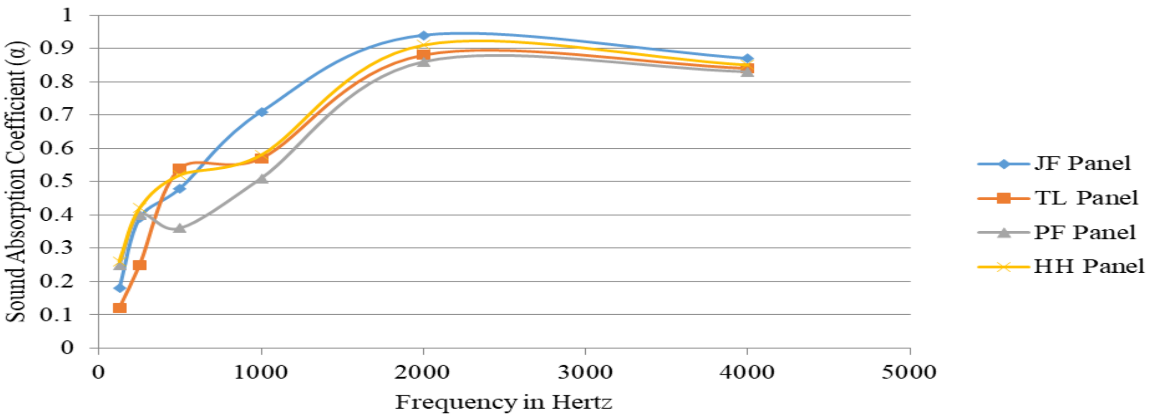

Figure 1. Variations in sound absorption coefficients at different frequencies

3.1.2 Noise Reduction Coefficient (NRC)

Figure 2 shows the values of noise reduction coefficients for all composite noise absorber panels. The higher the NRC values, the higher the noise reduction capacity. The results show that the highest NRC value (0.65) is obtained for the panel made of waste jute fiber and the lowest value (0.50) is obtained for the poultry feathers composite panel. The panels made of waste tea leaves and human hair waste show same NRC value 0.55.

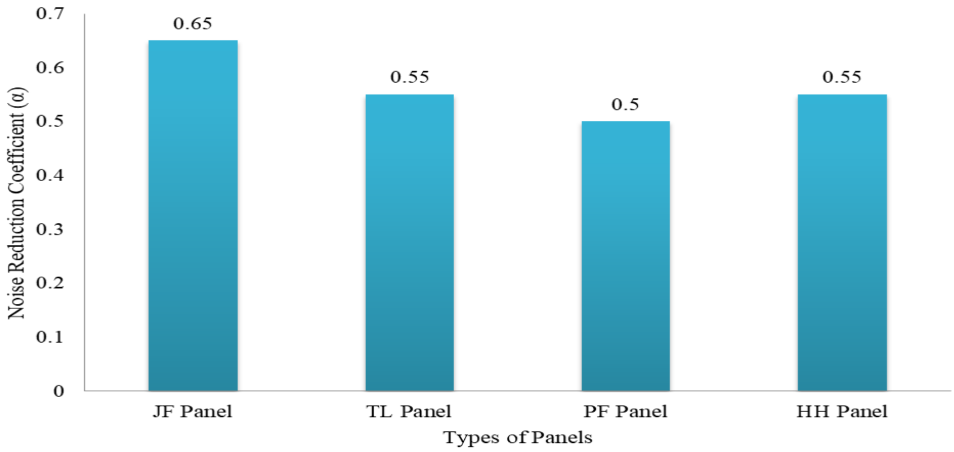

Figure 2. Variations in noise reduction coefficients

The variations in noise drop at dB scale against different frequencies are shown in Figure 3. The drop of noise levels for all panels upto the frequency 1000 Hz is negligible while the drop is remarkable at frequencies from 1000 to 2000 Hz. Maximum noise drop for all panels occurs at frequency nearly 2200 Hz. The jute fiber composite panel drops the maximum noise level 11.68 dB. Both the Tea leaves and poultry feather composite panels drop noise level 9.4 dB, and tea leaves composite panel drops noise level 10.77 dB.

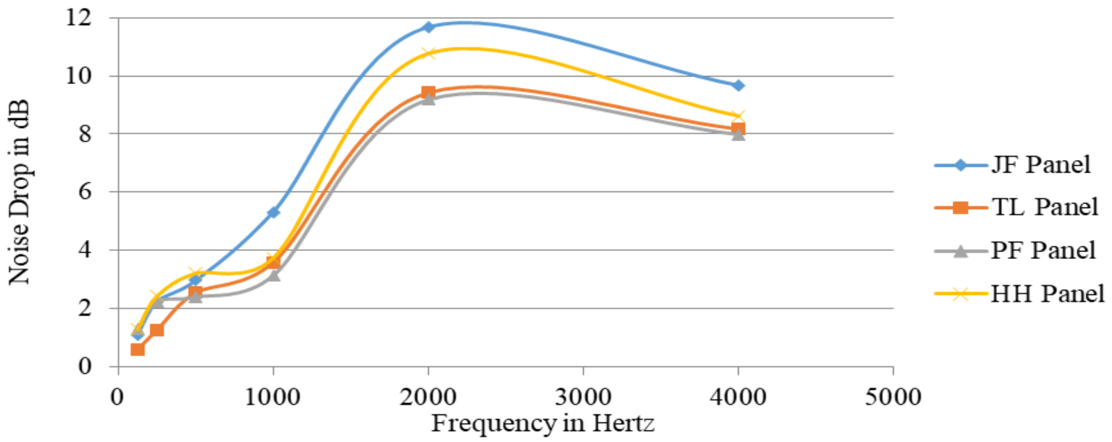

Figure 3. Variations in noise level drop for the four panels

3.2 Physical properties of composite samples

3.2.1 Tensile strength of composite samples

Figure 4 shows the graphical representation of the tensile strength of all sound absorber composite panels. The maximum tensile strength 22.17 MPa is obtained for waste jute fiber composite panel and the minimum tensile strength 6.35 MPa is found for poultry feathers composite panel. The jute fibre composite panel shows higher tensile strength as compared to the other panels.

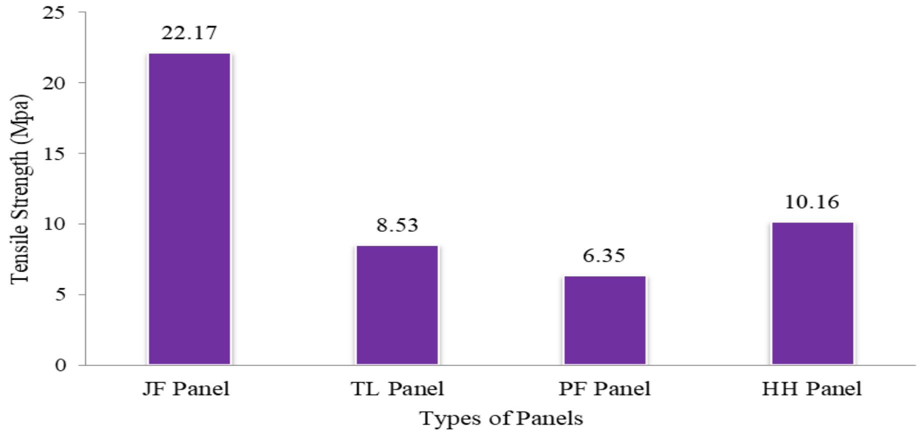

Figure 4. Tensile strength for the four panels

3.2.2 Three point bending test of composite panels

The graphical representation of the core shear stress (τ) of the composite panels is shown in Figure 5. Results represent that the maximum and minimum core shear stress are 52.98 Mpa and 21.41 Mpa for jute fiber composite panel and tea leaves composite panel respectively. The jute fibre and human hair composite panels results higher (~30 -20 Mpa) core share strength as compared to tea leaves and poultry feathers composite panels.

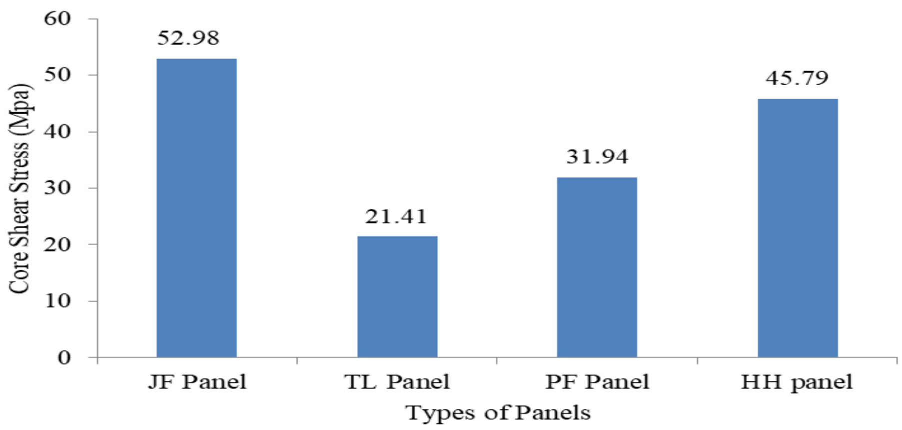

Figure 5. Core shear stress (τ) for the four panels

4. CONCLUSIONS

In this study, the diffuse sound absorption coefficients and physical properties of different noise absorption panels, fabricated by various types of solid waste materials such as jute fibre, poultry feathers, used tea leaves and human hair waste, have been investigated. The sound absorption coefficients have been determined based on the sound absorption capacity at specified frequencies of 125, 250, 500, 1000, 2000 and 4000 Hz. The physical properties such as tensile strength and cores shear strength have also been conducted. The study has shown that the average sound absorption coefficient at specified frequency (e.g., 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz) for all panels made of jute fibre, waste tea leaves, poultry feathers, human hair waste are ranged from 0.12 to 0.92 while the noise level drops ranged from 1 to 12 dB. Tensile strengths are 22.17 MPa, 8.53MPa, 6.35 MPa and 10.16 MPa for the panels made of jute fiber, waste tea leaves, poultry feathers, and human hair waste respectively while the core shear strengths are 52.98 Mpa, 21.41 Mpa, 31.94 Mpa and 45.79 MPa for the same panels respectively. The important finding of this study is that the jute fibre composite panel shows better performance in absorbing more noise. In addition, the jute fibre composite panel shows higher tensile and shear strength as compared to other panels. The jute fibre composite panel might be used as noise absorber in wall, ceiling and floor. All other panels also show satisfactory performance and the possible application of all these panels might be in decorative works.

In this study, the four composite noise absorption panels are fabricated manually. If the composite panels are fabricated by an automatic machine, then there is a good possibility to get more accurate results because it is too difficult to made uniform cross section in manual process. Furthermore, sound absorption coefficient depends on the roughness of the surface. Therefore, the surface roughness of these composite panels can be investigated in future studies.

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REFERENCES

American Society for Testing and Materials. (2000). *Standard Test Method for Flexural Properties of Sandwich Constructions* (ASTM Standard No. C393-00). https://doi.org/10.1520/C0393-00

American Society for Testing and Materials. (2017). *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials* (ASTM Standard No. D3039 / D3039M-17). https://doi.org/10.1520/D3039_D3039M-17

Bratu, M., Ropota, I., Vasile, O., Dumitrescu, O., & Muntean, M. (2011). Sound-absorbing properties of composite materials reinforced with various wastes. *Environmental Engineering and Management Journal*, *10*(8), 1047–1051. https://doi.org/10.30638/eemj.2011.152

Ersoy, S., & Küçük, H. (2009). Investigation of industrial tea-leaf-fibre waste material for its sound absorption properties. *Applied Acoustics*, *70*(1), 215–220. https://doi.org/10.1016/j.apacoust.2007.12.005

International Organization for Standardization. (1998). *Acoustics — Determination of sound absorption coefficient and impedance in impedance tubes — Part 2: Transfer-function method* (ISO Standard No. 10534-2). Retrieved from https://www.iso.org/standard/22851.html

Mahzan, S., Zaidi, A. M. A., Yahya, M. N., & Ismail, M. (2009). *Investigation on Sound Absorption of Rice-Husk Reinforced Composite*. Proceedings of MUCEET2009 Malaysian Technical Universities Conference on Engineering and Technology June 20-22, 2009, MS Garden, Kuantan, Pahang, Malaysia.

Malawade, U. A., & Mahamuni, K. J. (2018). *A Review on Non Traditional Sound Absorbers*. *118*(24), 1–20.

Mohanty, A. R., & Fatima, S. (2015). Noise control using green materials. *Sound and Vibration*, *49*(2), 13–15.

Rimantho, D., Yulianti, N. H., & Pane, E. A. (2019). Utilization of the organic and inorganic solid waste as acoustic material. *ARPN Journal of Engineering and Applied Sciences*, *14*(8), 1502–1506.

Wong, K., Ahsan, Q., Putra, A., Subramonian, S., & Nor, M. J. M. (2017). Preliminary study on the sound absorption behavior of spent tea leaves filled with natural rubber latex binder. *Jurnal Teknologi*, *79*(5–2), 59–64. https://doi.org/10.11113/jt.v79.11284

Yang, H. S., Kim, D. J., & Kim, H. J. (2003). Rice straw-wood particle composite for sound absorbing wooden construction materials. *Bioresource Technology*, *86*(2), 117–121. https://doi.org/10.1016/S0960-8524(02)00163-3

Zulkifli, R., Zulkarnain, & Nor, M. J. M. (2010). Noise control using coconut coir fiber sound absorber with porous layer backing and perforated panel. *American Journal of Applied Sciences*, *7*(2), 260–264. https://doi.org/10.3844/ajassp.2010.260.264

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PREDICTION OF SOLID WASTE GENERATION WITH ANFIS AND ITS COMPARISON WITH SYSTEM DYNAMIC MODELING: A CASE STUDY OF KHULNA CITY

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ABSTRACT

The prediction of Municipal solid waste (MSW) generation plays an important role in solid waste management. The MSW is mainly generated by human activities. Accurate forecasting of MSW generation is difficult for sustainable management system and planning. In addition, to the population growth and migration, underlying economic development, household size, employment changes, and the impact of waste recycling would influence the solid waste generation interactively. This study was conducted to estimate the MSW generated in Khulna city from 2019 to 2040. The objectives of this study are to find out the influential variable that affect the generation of MSW generation and to predict the future MSW generation in Khulna city. In this study adaptive neuro fuzzy inference system (ANFIS) through MATLAB and system dynamic modeling (SDM) were implemented. In this analysis, population, educated people, uneducated people, MSW generation rate, effect of urban population growth, fuel consumption and number of trips of trucks was considered as input and forecasted value of MSW as output. There are two steps for analysis one was testing and another one was training. To check the performance of this selected models, the prediction parameters like R^2, RMSE, MSE and ARE were considered. The comparison of the results from these models will be performed to select a best model for the prediction of MSW generation rate in Khulna city. All the results in this study can be utilized as part of solid plans for renewable energy development and eco-environmental recycle industry which require MSW as raw material. In this study, results show that three input variables such as educated people, fuel consumption and number of trips of trucks were good enough to predict MSW generation in Khulna. It is estimated that the amount of generated MSW in Khulna will increase at a per capita rate of approximately 2.08% annually. On the other hand, SDM were improved to predict the MSW through Stella software. In this model, the same input variables were used for comparison. The estimation of waste quantum during the period of 2019-2040 shows that, the MSW in the study area can be expected by ANFIS model using MATLAB as around 330774 ton and using system dynamic modeling through Stella is around 307681 ton by the year 2040. It has been found out from previous data that the generation rate of people is approximately 2.6% annually. The central idea in this work is to utilize radial basis function approach of ANFIS model and SDM so as to minimize the discrepancy between the predicted values and observed values of MSW. In addition, result reveals that SDM showed comparatively better results than that of ANFIS. Therefore, the SDM might be used for the prediction of MSW generation rate in Khulna, Bangladesh. This study offers a new perspective on both forecasting and modeling for the prediction of MSW in Khulna city, Bangladesh.

Keywords: *Khulna city, MSW, ANFIS, SDM and Prediction, Waste generation rate.*

1. INTRODUCTION

Civilization and industrialization are related with various waste products. Disposal of waste product is a challenge now-a-day. Sometimes some non-biodegradable materials often lead to waste disposal crisis (Bos M. et al., 1993). Human health and environment can be protected by proper solid waste (Koroneos C. J. & Nanaki E. A., 2012). Both quality and quantity of municipal solid waste (MSW) are changing with time due to influences of variable life style and consumption behaviors (Unnikrishnan S. & Singh A., 2010). Prediction of MSW is crucial for sustainable waste management, it is key element for planning and selecting the handling, treatment and disposal options (Beigl P. et al., 2008). However, due to influence of multiple factors that change with time, solid waste forecasting is complex task (Younes S M. K. et al., 2013). As a result of rapid development, urbanization, increase per capita income, and consumption behaviors, the solid waste generation increases dramatically in Khulna. Khulna is Bangladesh's third-largest city, after Dhaka and Chittagong. In the south-western part of the country, on the Rupsha and Bhairab Rivers, it covers an area of 59.57 square kilometers (23.00 sq. mi). The district covers 4,394.46 square kilometers (1,696.71 sq. mi) and had a population of 1188000 (2011 census). Khulna is south of Jessore and Narial, east of Satkhira, west of Bagerhat and north of the Bay of Bengal. It is part of the Ganges Delta, the world's largest river delta. The Sundarbans, the world's largest mangrove forest, is in the southern part of the delta. Khulna is in the northern part of the district, and the Mayur River is the western boundary of the metropolitan area. A literature survey was done to evaluate the recent applications of artificial intelligence (AI) based modeling studies in the environmental engineering field. The results of the literature survey showed that most AI based prediction models were implemented for the solution of water/waste water (56%) and air pollution (31%) related environmental problems compared to solid waste (14%) management studies. ANFIS is a dynamic data driven model, uses feed forward network to search for a fuzzy membership function between an inputs and outputs (Shafie A. E. et al., 2011). It combines the powers of fuzzy logic and the neural networks (Noori R. et al., 2009). Moreover, it can be used for short, medium- and long-term forecasting (Mordjaoui & Boudjema, 2011). The fuzzy inference system contains five functional blocks (i) rule base that contains the if-then rules (ii) data base (iii) decision making (iv) fuzzification block that gives the degree of matching (v) defuzzification that transforms the fuzzy results into crisps (Subasi A., 2007). The fuzzy inference system usually employs the input historical data in order to tune and develop the final shape of membership function using either an only backpropagation algorithm or in association with least square method (Ghandoor A. A. & Samhouri M., 2012). However, there are some limitations while employing ANFIS model. If the number of generated rules N for a system with n inputs and p premises is ($N=P^n$) therefore, it might become unaffordable to use ANFIS for problems with several variables. A small increment in the input variables can increase the number of rules and consequent parameters. To remove this error the best input combinations that minimize the model error can be used. RMSE (Lin et al., 2013) and the coefficient of determination (R^2) were used to evaluate the appropriate input selection and model performance and ability to produce precise forecast (Shafie A. E. et al., 2011). However, ANFIS has become more popular due to its accuracy, efficiency and capability of large amount of nonlinear and noisy data. For instance, it is used to predict the MSW in Khulna city using population, educated and uneducated people's, fuel consumption and number of trips of trucks. Again, another analysis was done using system dynamic modeling (SDM) through Stella. This study represents a new approach-system dynamic modeling-for the prediction of MSW in Khulna with limited samples and data available. Where the system environment is not fully defined and understood, system dynamic modeling can be used there for forecasting practice. It can also be used when the database is not sufficient to support the traditional statistical forecasting analysis. To address the impact on sustainable development city wide, the practical implementation was done by a case study in Khulna city. It represents various trends of MSW generation associated with a model using a system dynamic simulation tool-Stella. Finally, the forecast result will be helpful the decision makers properly establishment of sustainable waste management plans. As having seasonal pattern of generating waste, ANFIS and SDM through Stella is used to predict the MSW generation rate in Khulna city.

2. METHODOLOGY ADOPTED

2.1 Case study and data collection

Khulna is located in the south-western part of Bangladesh shown in Figure 1. It covers an area of 59.57 square kilometers with a population of 1344000 in 2015. According to the report of Khulna City Corporation, in latest years the growth rate of population in Khulna city is 2.6% which city has been caused in expanding the MSW generation and as a result making a problem for the MSW management system. According to the CD report, the current actual collected MSW per day is 35% only, whereas, MSW generation rate is 0.40 Kg per capita per day. In the other hand, the rapid population growth rate and urbanization cause the significant fluctuations of MSW generation in this city which consequently results many problems for MSW management system. According to existed reports the amount of generated MSW in Khulna is 450-500 tons per day (Rafizul I. M. & Mahanta P. K.), thus offering an appropriate model for estimating the quantity of generated waste and its fluctuation can be useful for true programming and deciding which is made by related organizations.

Figure 1: Khulna city as case study area (South-Western region of Bangladesh)

2.2 Input Parameters

The MSW generation in a city depends on population, income, living standard, employment and unemployment, educated and uneducated peoples, GDP, fuel consumption, number of trips of truck etc. In the ANFIS model analysis, five inputs and one output were used. In this study, for the prediction of yearly MSW generation, the five input parameters such as populations, educated peoples, uneducated peoples, fuel consumptions and number of trips of truck and hence discussed in the following articles. However, only reasonable variables that are available and affect MSW were used for the analysis. The input variables were population, uneducated people, educated people, fuel consumption (Liter) and number of trips of trucks. The output variable is annual MSW(Tons/Year) generation. There are other variables like family incomes, numbers of family member, family education level, individual income rate etc. However, these variables can’t be used to justify the MSW generation rate because some or most of these data are not available in country level. For the estimation of future quantity of populations, fuel consumptions, number of trips of truck, educated and uneducated peoples, the following Equations 1 and 2 were used.

$$\sum y = na + b\sum x \tag{1}$$

$$\sum xy = a\sum x + b\sum x^2 \tag{2}$$

Where, y=prediction input parameter, x=time deviation, n=number of samples, a and b are unknown variables.

2.2.1 Estimated population in study area

In this study, for the prediction of yearly MSW generation, the future population of Khulna city were estimated through least square method by using the following Equation 1. In addition, the population of 1344000 for the year of 2015 was considered. According to KCC report, the yearly increasing rate of population 2.6% was considered. The estimated amount of population for the year of 2019 to 2040 is shown in Figure 2.

$$Y = 1334350 + 46800X \tag{3}$$

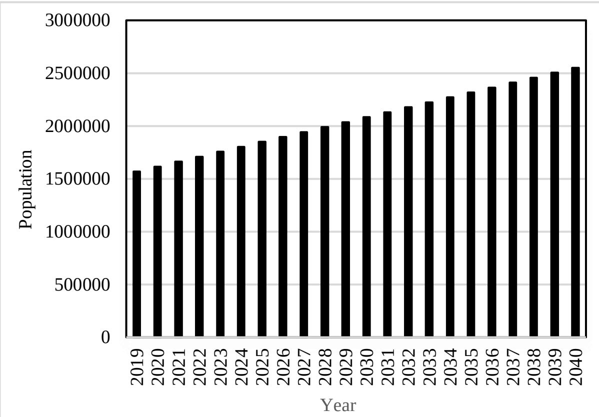

Figure 2: Estimated population of the study area

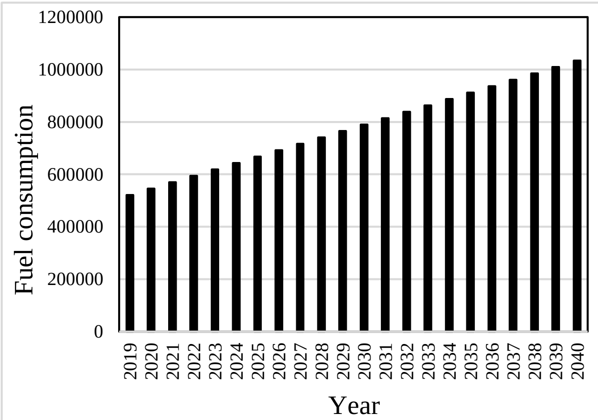

Figure 3: Estimated fuel consumption of the study area

2.2.2 Fuel Consumption

In the study for the prediction of fuel consumption, Equation 4 was used. In addition, the fuel consumption of 436542 liter for the year 2016 was considered. According to KCC report, the yearly rate of fuel consumption 6.5% was considered. The estimated values of fuel consumption for the year 2019 to 2040 is shown in the Figure 3.

$$Y = 423888.23 + 24403.05X \tag{4}$$

2.2.3 Number of trips of truck

Number of trips of trucks is directly related to MSW generation. In the study number of trips of trucks were predicted by using the Equation 5. By counting the trips of trucks, it can be easily found that how much waste is collected in a day. The number of trips of trucks of 53482 was considered for the year 2017. The estimated values of number of trips of trucks for the year 2019 to 2040 is shown in the Figure 4.

$$Y = 10914 + 42568X \tag{5}$$

2.2.4 Educated people's

The number of educated people is also another important factor for maintaining MSW generation rate. The educated people generate less MSW than the uneducated people. In the study number of educated people is estimated by the equation 6. According to KCC report, the yearly rate of educated people 2.9% was considered. The estimated values of number of educated people of 771783 was considered for the year 2012. The estimated values of educated people are shown in the Figure 5.

$$Y = 728436.75 + 9632.5X \tag{6}$$

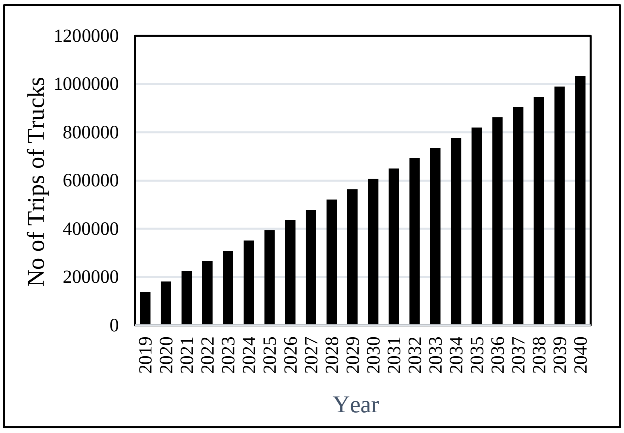

Figure 4: Estimated number of trips of the study area

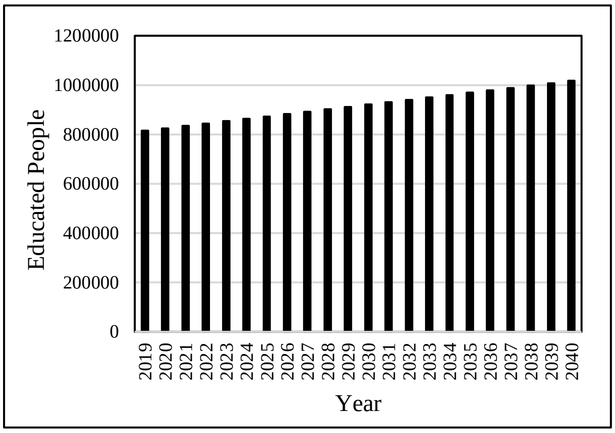

Figure 5: Estimated educated people of the study area

2.2.5 Waste Generation in Khulna

In Khulna city, the yearly MSW generation was found 188000, 195820, 200190, 204190, 208320, 214007, 218908, and 223809 tons for 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018 respectively. This yearly MSW generation rate was considered for forecasting of MSW generation rate for the year of 2019 to 2040. By using these previous data, future prediction was done in this study through ANFIS and system dynamic modeling.

2.3 Soft Computing Systems

In this study, for forecasting of MSW in Khulna city, ANFIS and SDM (System dynamic modeling) were implemented. In these two systems, past input variables are needed to predict the future. In the study MSW was predicted from the year 2019 to 2040 by using these two-computing systems. By applying the fuzzy logic and system dynamic modeling both systems can predict the future outcome. Details of working procedure of these two models are given in the following articles.

2.3.1 Adaptive Neuro-Fuzzy Inference System (ANFIS)

Various models for different input parameters were analyzed using Neuro-Fuzzy Designer. For the prediction of MSW through ANFIS, the values of prediction parameters like root mean square error (RMSE) and regression coefficient (R^2) were considered to check the validity of the model. Details of ANFIS is given in the following articles:

2.3.1.1 Data processing

To train ANFIS, a Training data set has been loaded that contained desired input/target data of the system to be modelled. In this study, population, fuel consumption, number of trips of trucks, educated and un educated people were used as input and observed MSW was used as target which placed at last column for modelling a Training data set.

2.3.1.2 Workspace and load data

The input and output parameters were set in the workspace and at the time of training the data were loaded from workspace.

2.3.1.3 Generate FIS

For initializing and generating FIS, two partition methods Grid Partitioning of ANFIS and Subtractive Clustering Method of ANFIS can be used. In our study Grid Partitioning method was used. There are several choices for input membership function like trainmf, trapmf, gbellmf, gaussmf, gauss2mf, pimf, dsigmf and psigmf also only two choices for the output membership function: constant and linear. In the study gaussmf and constant membership function was used to predict the output.

2.3.1.4 FIS output and training

After generating the FIS training was done and RMSE was shown in the toolbox. Then the result was export to workspace for the final output.

2.3.1.5 Output of training from ANFIS

As the file was already exported to workspace, the only input and output was saved in the workspace in two different folders in work space. Then by typing the following code the final output was gained.

Output = evalfis (input, fismat)

The regression graph was found out for the value of R by typing the following code:

Plotregression (target, output)

Then by pressing the enter value regression graph and the value of R was shown in the screen.

2.3.2 System Dynamic Modeling

In most computer simulation applications in system dynamic model Stella software is used as it is very much user friendly. The procedure of these model development is designed based on a visualization process. They offer a flexible way for building variety of simulation models through stock, flow and converter shown in Figure 6. Simulations runs are entirely dependent on prescribed timeline. The following figure shows the diagram of flow, stock and converter. In the stock tons per service center should be inserted first and in the flow the tons rate should be in given as an input. By system dynamic process the final output can be found out by the converter through graph or table chart. The system will calculate dynamically the future MSW generation rate. In the study, it has been seen that the dynamic models presented characterize solid waste generation as exhibiting the behavior of linear growth. There are several simulations models which are used to estimate the solid waste generation. But in this study only one model is used and the driving factor in generation is population. Only considering the population, the final outcome is found out.

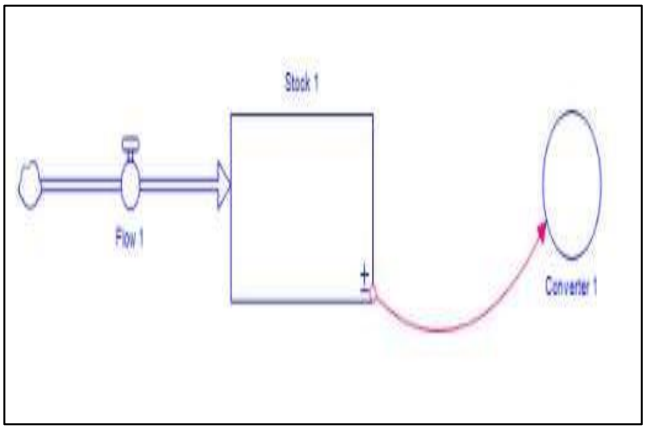

Figure 6: Stella diagram showing stocks, flow and converter

3. RESULTS AND DISCUSSIONS

3.1 Validation of Input Variables

The results of RMSE and R for the combination of input parameters is shown in Figure 7 and Figure 8, respectively. For the input combinations of educated people, fuel consumption and number of trips, the values of RMSE was minimum (435.37) and R was maximum (0.999). On the other hand, for the input combinations of uneducated people, fuel consumption and number of trips, RMSE was maximum and R was minimum and it's values were 4212.12 and 0.990, respectively. For this reason, the input combinations of educated people, number of trips and fuel consumption were selected for prediction of MSW. In these five inputs, the best three input combinations that has the minimum RMSE was used to predict the MSW. The best three combinations were educated people, fuel consumptions and no of trips of trucks.

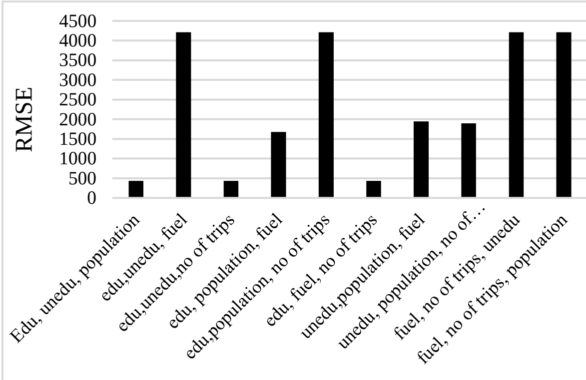

Figure 7: Input combinations against RMSE

In the Figure 9, it is seen that for 100 epochs the RMSE was minimum. For this in the ANFIS, 100 epochs is considered for getting the more accurate result.

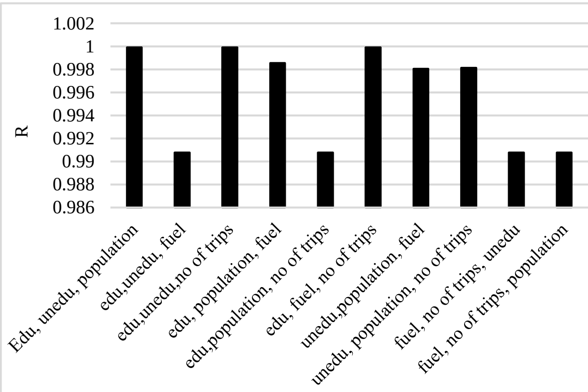

Figure 8: Input combinations against R

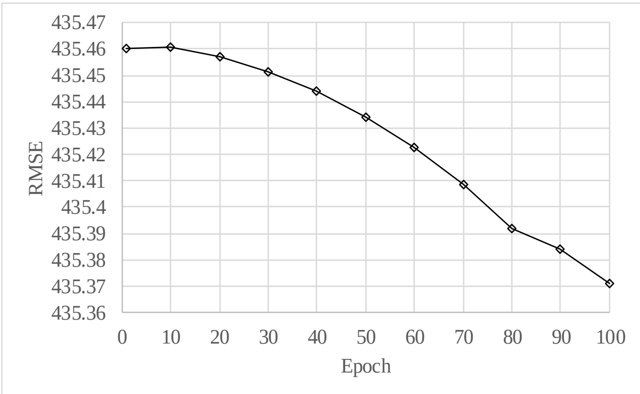

Figure 9: Model performance over 100 epochs.

3.2 Model Outcomes

The best three combintions is shown in Figure 10. In the graph, it is clear that the observed value of MSW and the predicted value of MSW is quite on the similar line. That's because the errors in our predicted data is too small. On the other hand, in Figure 11, the graph is plotted for the worst combinations. In the graph, it is clear that the observed line and the predicted line is quite different from each other as the RMSE is quite large for this input combinations.

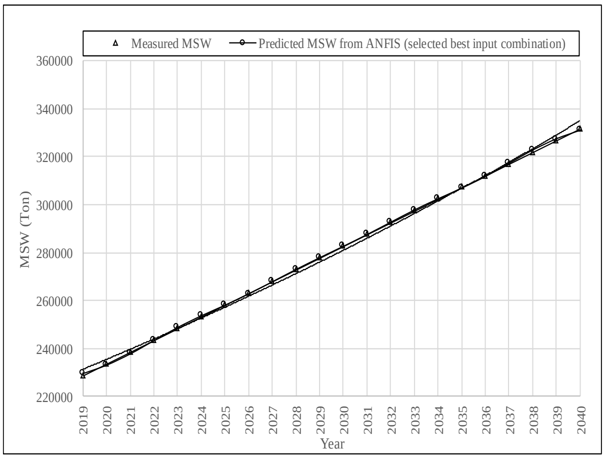

Figure 10: Measured MSW vs Predicted MSW (For best combination)

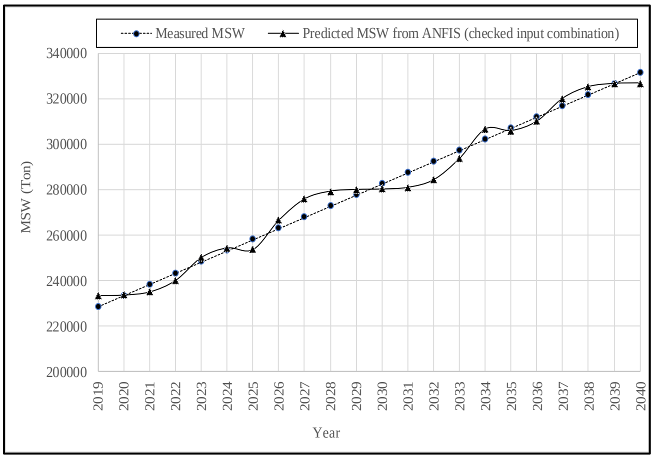

Figure 11: Measured MSW vs Predicted MSW (For worst combination)

At the same time, a simulation model was run through Stella showed in Figure 12. In the following model regression analysis was done in terms of educated people, fuel consumption and no of trips of trucks. The comparison performance of ANFIS and SDM through Stella is shown in the Figure 13.

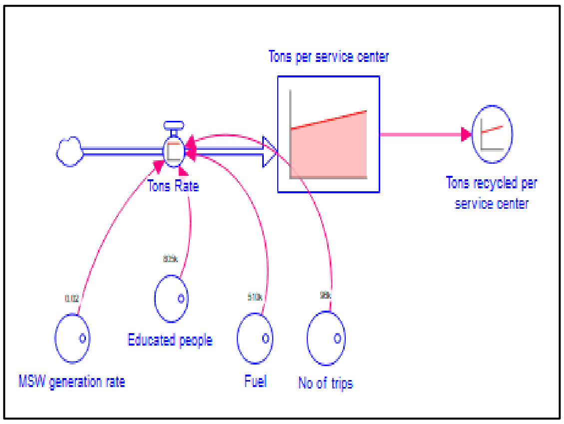

Figure 12: Generalized form of model used to simulate tons generated by historical amount generated.

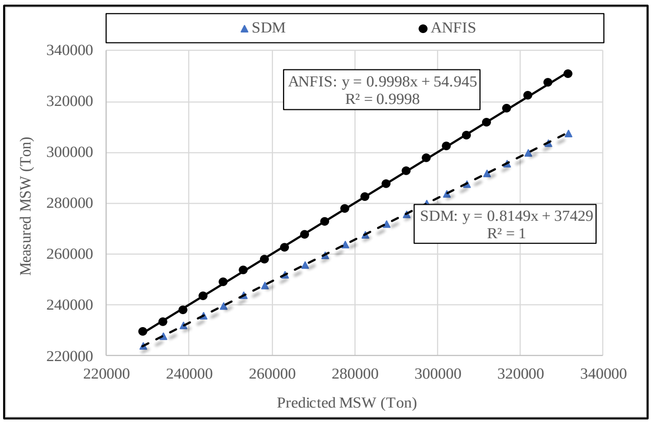

Figure 13: Comparison performance of ANFIS and SDM

4. CONCLUSIONS

Selecting proper input variables is essential to simulate relatively good models. Without proper input variables simulated models will not run properly and give comparatively low quality of result. So, it is important to select qualitative input variables to facilitate modelling in these countries. Thus, the model complexity can be minimized and the model usability can be maximized. In this study, results show that three input variables such as educated people, fuel consumption and number of trips of trucks were good enough to predict MSW generation in Khulna. It is estimated that the amount of generated MSW in Khulna will increase at a per capita rate of approximately 2.08% annually. On the other hand, SDM were improved to predict the MSW through Stella software. In this model, the same input variables were used for comparison. It has been found out from previous data that the generation rate of people is approximately 2.6% annually. The central idea in this work is to utilize radial basis function approach of ANFIS model and SDM so as to minimize the discrepancy between the predicted values and observed values of MSW. In addition, result reveals that SDM showed comparatively better results than that of ANFIS. Therefore, the SDM might be used for the prediction of MSW generation rate in Khulna, Bangladesh. This study offers a new perspective on both forecasting and modeling for the prediction of MSW in Khulna city, Bangladesh.

ACKNOWLEDGMENTS

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REFERENCES

Bos, E.,Vu, M. T., Massiah, E., Bulatao, R. A. (1993). *World Population Projections.* The World Bank: John Hopkins.

Koroneos, C. J. & Nanaki, E. A. (2012). Integrated solid waste management and energy production - a life cycle. *Journal of Cleaner Production*.

Unnikrishnan, S., Singh, A. (2010). Energy recovery in solid waste management through CDM in India and other countries. *Resources, Conservation and Recycling*, 630-640.

Beigl, P., Lebersorger, S. & Salhofer, S. (2008). Modelling municipal solid waste generation: A review. *Waste Management*, 200-214.

YounesS, M. K., Nopiah, Z. M., Nadi, B., Basri, A. (2013). Investigation of Solid Waste Characterization, Composition and Generation. *Asian Journal of Chemistry*.

Shafie, A. E., Jaafer O. and Akrami, S. A. S. (2011). Adaptive neuro-fuzzy inference system based model for. *International Journal of the Physical Sciences*, 2875-2888.

Noori, R., Abdoli, M. A., Farokhnia, A., Abbasi, M. (2009). Results uncertainty of solid waste generation forecasting by hybrid of wavelet transform-ANFIS and wavelet transform-neural network. *Journal Of Environmental Management*, 9991-9999.

Mordjaoui & Boudjema (2011). Forecasting and modeling electricity demand using ANFIS predictor. *Journal of Mathematics and Statistics*.

Subasi, A. (2007). Application of adaptive neuro-fuzzy inference system for epileptic seizure detection using wavelet feature extraction. *Computers in Biology and Medicine*, 227-244.

Ghandoor, A. A. & Samhouri, M. (2012). Projection of future transport energy demand of Jordan using adaptive neuro-fuzzy technique. *Energy*, 128-135.

Lin, K. P., Pai, P. F., Lu, Y. M. & Chang, P. T. 2013. Revenue forecasting using a least-squares support vector regression model in a fuzzy environment. *Information Sciences*, 220, 196-209.

Shafie, A. E., Jaafer O. and Akrami, S. A. S. (2011). Adaptive neuro-fuzzy inference system based model for. *International Journal of the Physical Sciences*, 2875-2888.

Rafizul, I. M., Mahanta, P. K. (n.d.). *Assesment of the Potential Human Health Risk of a Waste Disposal Site in Khulna.* Khulna.

ANALYSIS OF SURFACE WATER QUALITY ADJACENT TO THE WASTE DISPOSAL SITE IN KHULNA

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ABSTRACT

Surface water near waste disposal sites are vulnerable due to the easy accessibility of the disposed contaminants. Heavy metal contamination in surface water is one of the major quality issues in regards of the sources of drinking water. This study was conducted mainly to assess the effect of the heavy metal concentrations in surface water during dry and rainy season in the year of 2019. Surface water samples were collected from 25 sampling points adjacent to a selected waste disposal site at Rajbandh, Khulna, Bangladesh. In the laboratory, the concentration of heavy metals like Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As in surface water were measured. The metal contaminations were evaluated using contamination factor (CF), contamination load index (CLI) and water quality index (WQI). The heavy metal contamination index (HPI),metal quality index (MQI),ecological risk index (ER) and potential ecological risk index (PERI) were also computed to evaluate the level of contamination of surface water of these heavy metals.The results of the index showed that almost all the sampling points of surface water were moderate to highly contaminated. The results of water quality index (WQI) were then compared withWQI from fuzzy synthetic analysis to get accurate distinction between utilization purpose.Even though the conventional WQI showed the results having the water samples lower quality; WQI from fuzzy synthetic analysis showed optimistic results in number of cases. The conventional WQI of station 7 in dry season was in class D; however, WQI from fuzzy showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well.To treat the data sets Pearson correlation and cluster analysis has been done. Some heavy metals were positively correlated and the results of cluster analysis clearly states that the sources of heavy metal contamination are from two different sources of anthropogenic and geogenic.

Keywords: *Waste disposal site, Surface water, Heavy metal, Water quality indices, Fuzzy analysis, Water quality index, Pearson correlation, Cluster analysis.*

1. INTRODUCTION

The assessment of surface water quality is very important especially where it is considered to be used on drinking purpose. If the sources are under the threat of contamination it can lead to have various health issues including long term diseases(Satar, 2017). As the urbanization is growing fast; the disposed contaminants are also increasing in an alarming rate. Especially surface water sourcesin areas adjacent to waste disposal site are great concern due to the higher rate of possibility to get contaminated by the waste disposal site materials(Puri, 2015).These sources are more exposed to contamination. It is very important to know the rate of contamination and sources of contamination to manage the land and water resources. Identification and categorization of the contamination is a very important in management of ensuring potable water around the area. Seasonal variation also has a significant impact on the contamination rate. The variation in rainfall intensity, run off, agricultural method, atmospheric characteristics have strong effect on contamination(Rama Pal, 2017).Usually in clean water the concentration of heavy metal is very low and mostly subjected to other water quality parameter measures to ensure its drinking quality(World Health Organization, 1998). But the heavy metal concentration adjacent to waste disposal site gets additional concern along with other physiological water quality parameters as they are also relatively dependent on the heavy metal concentration. The sources of heavy metal in surface water can be geogenic or anthropogenic(APHA, 2012). The anthropogenic sources adjacent to disposal site is mainly for various waste, external disposal of waste, pesticide and chemicals from crop fields(Mohd Zahari Abdullah, 2016).

The study was assessed on the surface water of 25 different sampling site around the waste disposal site in Rajbandh, Khulna in both dry and rainy season. The study also evaluated the drinking quality of the water samples along with the possible adverse health impact on the habitants of the area.In the laboratory, the concentration of heavy metals like Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As in surface water were measured. The metals contaminations were evaluated using contamination factor (CF), contamination load index (CLI) and water quality index (WQI). The heavy metal contamination index (HPI),metal quality index (MQI), ecological risk index (ER) and potential ecological risk index (PERI) were also computed to evaluate the level of contamination of surface water of these heavy metals. The fuzzy synthetic evaluation technique was also done among ten of the water quality parameters to compare the conventional WQI with WQI from Fuzzy analysis. The results came out to be optimistic than conventional WQI and more distinct in classification to be (Chanapathi, 2019) useful for various purpose. The conventional WQI showed results of the water samples poor but WQI from fuzzy synthetic analysis showed improved results in number of cases. For example, the conventional WQI of station 7 in dry season was in class D; fuzzy showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well.In addition, the data sets were analyzed by cluster analysis (CA) and Pearson correlation analysis. From the CA the sources of heavy metal in surface water has been found to be anthropogenic and geogenic.The results of multivariate indices of all the sampling points seemed to be contaminated in terms of standard drinking limits (BIS, 1998).

2. METHODOLOGY ADOPTED

2.1 Description of Study area

The waste disposal site at Rajbandh, Khulnawas selected as case study. The geological coordinate of the radial center of the sampling points are 22.794722 (Latitude) & 89.499722 (Longitude).A location map of the study area with sampling details formulated by the software ArcGIS is shown in Figure 1.

2.2 Collection of Surface Water Samples

Before collecting surface water samples, the bottles were washed with distilled water and the bottles were air-dried. A solution prepared by concentrated nitric acid and distilled water was used as preservatives by adding to an amount of 2-3 mL to the bottles. The concertation of water and nitric acid was to the ratio of 1:1. The bottles were kept for about a day in order to prevent any precipitation of metal substance or biological contaminate activities and prepared for the sample collection. Total 25 location of surface water sources adjacent to the waste disposal site were selected for the sample collection. The sampling points included the nearby pond, pothole and confined water in the crop field. The locations were tracked by their GPS coordinates. Sample collection was done from the same location both in dry and rainy season.

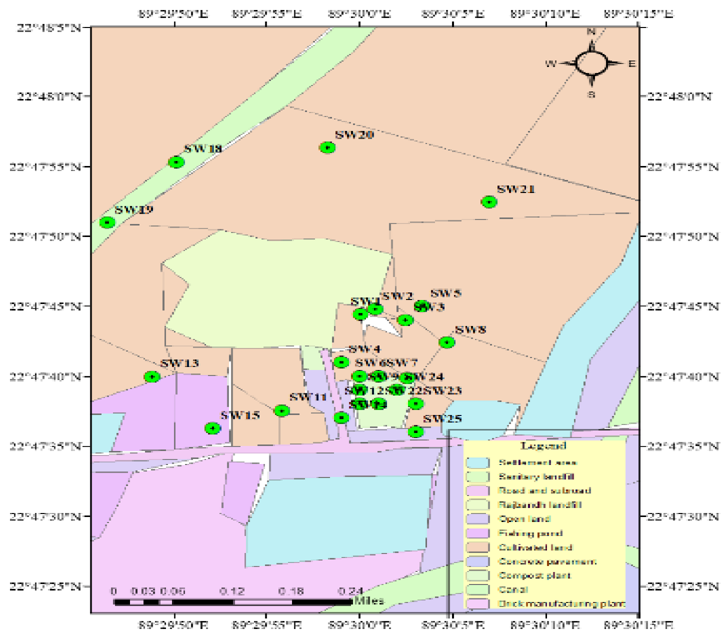

Figure 1: Location map showing sampling details of selected waste disposal site at old Rajbandh, Khulna.

2.3 Laboratory Investigations

The surface water samples in two different seasons were collected as well as the concentrations of heavy metal other physiochemical tests were measured according to the standard test methods.

2.4 Indices

To evaluate the various indices of the collected surface water samples this study was focused in physiochemical parameters and heavy metal contamination parameters. All the indices were determined to come to the point of decision of the sample water is contaminated or not. If contaminated, then to determine the severity of contamination with the reference of drinking water parameter. The indices were determined based on the research proposed by various researchers and hence discussed in the following articles.

2.4.1Contamination Factor

The contamination factor (CF) is determined by the following Equation[1], where C_{metal}= metal element concentration and $C_{background}$= background value of same metal element(S. Gupta, 2019). CF < 1 indicates low contamination, 3<CF<6 is considerable contamination and CF>6 refers very high contamination.

$$CF = \frac{C_{metal}}{C_{background}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

2.4.2 Heavy Metal Contamination Index

Heavy metal contamination index shows the composite influence of the heavy metal individually and rates the contamination rate(Singh, 2013). w_i= the weight associated with the heavy metal of concern and Q_i= sub index of i^{th} heavy metal. Here n is the number of heavy metal measured in the following Equation [2].

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

The critical value of HPI is 100. If HPI value crosses100 indicates that the water sample is critically polluted with the heavy metal content(Rama Pal, 2017).

2.4.3 Metal Quality Index

The higher the concentration of a metal substance in the water to the respective permissible limit the worse the quality of the water(Pal, 2017). The metal quality index MQI can be calculated by the following Equation [3]:

$$MQI = \sum_{i=1}^{n} \frac{M_i}{S_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Where M_i= observed heavy metal concentration and $S_{i=}$ permissible standard value of the respective heavy metal. MQI> 1 is a threshold of concern.

2.4.4 Potential Ecological Risk Index

Potential ecological risk index (PERI) is based on the summation of ER of heavy metals (Santos-Francés, 2017)by Equation [4]:

$$PERI = \sum ER \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

The Ecological Risk Degree for PERI proposed by as PERI<40 refers slight, 40<PERI<80 refers medium, 80< PERI< 160 refers strong,160< PERI < 320 refers very strong,PERI > 320 refers extremely Strong.

2.5Water Quality Index &Fuzzy Synthetic Evaluation of Water Quality Index

The water quality index (WQI) has been the most efficient method to determine the water quality of a certain water body approach consists of variousparameters. In this study, pH, DO, SS, Turbidity, COD, EC, Cl, SO_4, NO_3, Na has been used. 100 being the finest quality and 0 being the lowest of WQI value. The values of WQI was computed using Equation [5].

$$WQI = \frac{\sum_{i=1}^{n} w_i q_i}{\sum_{i=1}^{n} w_i} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Here, w_i= the weight of the parameter of concern [Table 3] and q_i= water quality parameter (Puri, 2015). Here n is the number of constituents (Bhatri N, 2011). In this study, the values of w_i and q_i were considered in accordance with BIS (1998). The class indicating by the WQI value is shown in Table 1.

Lately the increasing use of water the unclear distinction among the classification leaves major impact in critical area with possible source of high contamination. Using fuzzy synthetic evaluation, the uncertainties can be solved and the classification can be more focused so that the water that is not suitable for drinking purpose can be used for other purpose for the best utilization.(Ni-Bin Chang, 2001). The fuzzy membership functions were used for various parameter using MATLAB. The results of the individual functions merged to the ultimate result which differs from the conventional cases. Out of all the water parameters ten parameters like pH, DO, SS, Turbidity, COD, EC, Cl, SO_4, NO_3, Na were selected for this evaluation. The membership function of the parameters has been shown from Figure 2 to Figure 11. How the membership function in fuzzy evaluation works that may be understood by the rules shown inTable 2 with some parameters as example.In this study a comparison between traditional WQI and the results of WQI from fuzzy evaluation was done.

Table 1: Class with WQI values

Class	**WQI**
A	90-100
B	80-90
C	60-80
D	30-60
E	0-30

Table 2: Rules with membership functions in fuzzy logic

Parameter	**Rule 1**	**Rule 2**	**Rule 3**
pH	Excellent	Good	Good
DO	Excellent	Good	Poor
SS	Excellent	Poor	Good
Turbidity	Good	Very good	Very Good
class	Excellent	Good	Good

Table 3: Parameters with weightage and weightage limit

Parameter	unit	BIS limit	Weight(w_i)
pH	-	7.5	4
DO	mg/L	5	3
TSS	mg/L	200	2
Turbidity	NTU	5	2.4
COD	mg/L	300	3
EC	µS/cm	2000	2.5
Cl	mg/L	250	3
SO4	mg/L	200	3
NO3	mg/L	45	4
Na	mg/L	100	3

Table 4: Water quality classification with utility

Class	**A**	**B**	**C**	**D**	**E**
	1. Public water supply without treatment 2.Swimming	1.Public water supply (Conventional treatment needed) 2. Fishery 3. Can be used for sensitive aquatic species	1.Public water supply (Extensive treatment needed) 2.Fishery (Secondary level) 3. Industry water supply (Primary level)	1. Irrigation 2. Industrial water supply (Secondary level) 3. Can be used for tolerant aquatic species	Environment protection
pH	6.5-8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
DO	>6.5	>5.5	>4.5	>2.0	>2.0
SS	<25	<25	<40	<100	-
Turbidity	<5	5-10	10-20	20-250	>250
COD	<10	25	50	100	>100
EC	<100	1000	1750-2250	2250-4000	>4000
Chloride	0-50	50-100	100-300	300-500	>500
SO_4	<50	50-150	250	350	450
NO_3	<2.5	7.5	15	25	>25
Na	31.25	93.75	156	218	281.25

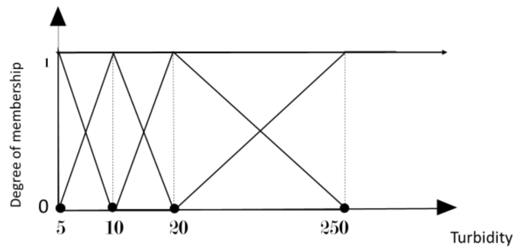

Figure 2: Membership function for turbidity

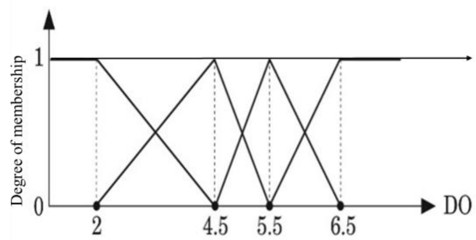

Figure 3: Membership function for DO

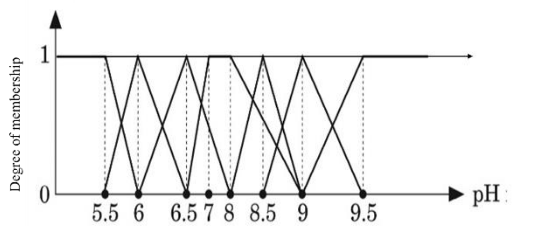

Figure 4: Membership function for pH

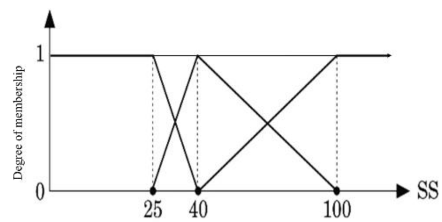

Figure 5: Membership function for SS

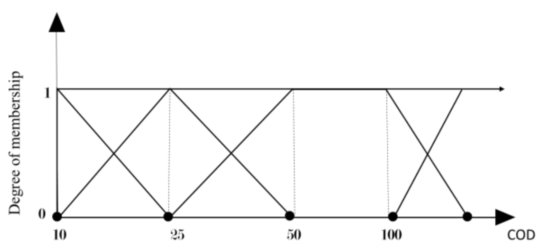

Figure 6: Membership function for COD

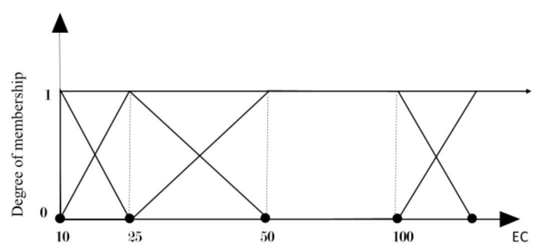

Figure 7: Membership function for EC

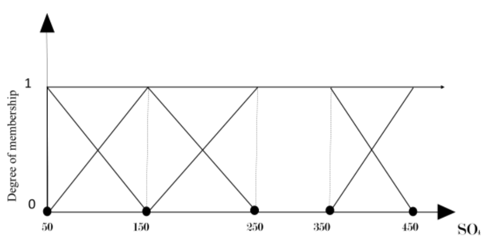

Figure 8: Membership function forSO_4

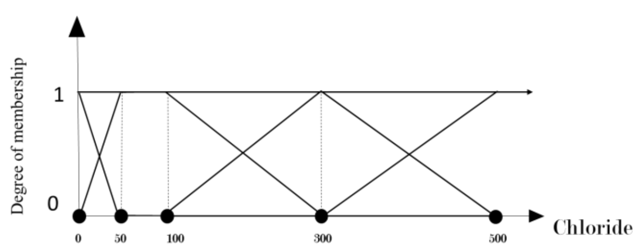

Figure 9: Membership function for Chloride

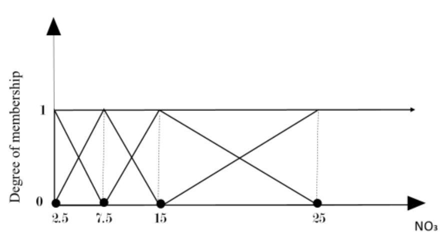

Figure 10: Membership function for NO_3

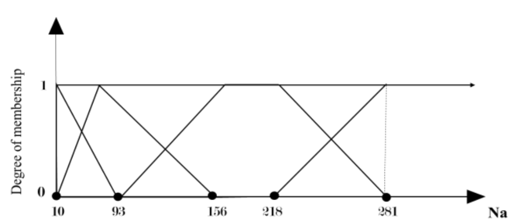

Figure 11: Membership function for Na

3. RESULTS AND DISCUSSION

The basis statistical analysis, results of various indices and the level of contamination, results from Fuzzy synthetic analysis as well as Pearson's correlations are analyzed and hence discussed in the following articles.

3.1 Basic Statistical Analysis

In the laboratory, the water quality parameters like pH, turbidity, electrical conductivity, sulphate, phosphate, nitrate, BOD, COD, DO, SS, TDS, Fe, Mn, Cr, Cu, Pb, Zn, Ni, Cd and As were measured for both dry and rainy seasons. The results of heavy metal are provided in Table 4. The heavy metal Zn showed maximum concentration of 1.06 mg/L and 1.7 mg/L in both and dry season respectively, while Cd minimum concentration of .00093 and 0.00095 in dry and rainy season, respectively. The standard deviation of Zn was highest in both dry and rainy season having the value of 0.2226 and 0.3267 respectively. Cd showed the lowest standard deviation of value 0.0023 and 0.0017 in dry and rainy season respectively.

Table 4: Basic statistical data of observed heavy metal in dry and rainy season

	Rainy season					Dry Season				
Metal	**Min**	**Max**	**Mean**	**SD**	**Variance**	**Min**	**Max**	**Mean**	**SD**	**Variance**
Fe	0.1200	0.6400	0.3296	0.1565	0.0245	0.1200	0.5000	0.3441	0.0864	0.0075
Mn	0.1060	0.8930	0.3474	0.1706	0.0291	0.1500	0.7600	0.3496	0.1442	0.0208
Cr	0.0020	0.0140	0.0062	0.0032	0.0000	0.0020	0.0140	0.0056	0.0031	0.0000
Cu	0.2000	0.8300	0.4717	0.1758	0.0309	0.2000	0.7200	0.4667	0.1310	0.0172
Pb	0.0100	0.0600	0.0299	0.0116	0.0001	0.0100	0.0400	0.0225	0.0075	0.0001
Zn	0.1793	1.0670	0.7093	0.2226	0.0496	0.4375	1.7000	0.8491	0.3267	0.1067
Ni	0.0200	0.1000	0.0479	0.0185	0.0003	0.0230	0.0690	0.0451	0.0124	0.0002
Cd	0.0009	0.0090	0.0041	0.0023	0.0000	0.0009	0.0065	0.0032	0.0017	0.0000
As	0.0148	0.0238	0.0188	0.0024	0.0000	0.0090	0.0300	0.0184	0.0051	0.0000

3.2 Multivariate Indices

The indices indicating the quality of sampled surface water in respect of contamination and drinkable parameter are determined for both the dry and rainy seasons with the increasing distance from the waste disposal site. The comparison between the results of dry and rainy seasons and the variation of the results in sampling location with the increasing distance from the waste disposal site are discussed in followings.

3.2.1 Contamination Factor

The contamination factor (CF) from heavy metals in surface water is shown in Figure 12. Cu being the highest in contribution of contamination factor and Fe was the least in regards of contamination. The variation in dry and winter season was very low. The CF of Zn was slightly higher in dry season than rainy season. Almost every metal showed their CF values in moderately contaminated.

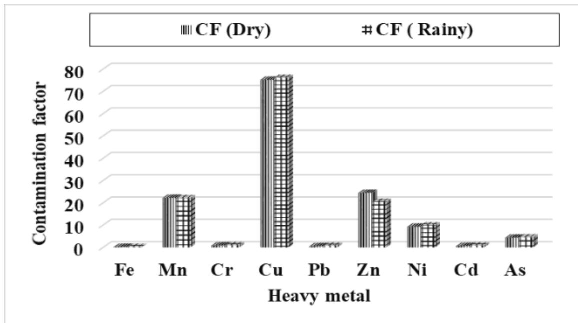

Figure 12: Contamination factor ofheavy metals in surface water for dry and rainy

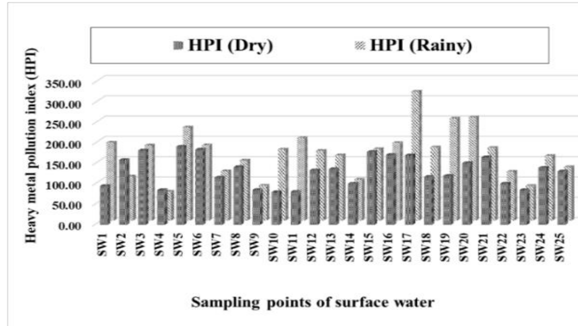

Figure 13: Heavy metal pollution index of surface water for dry and rainy seasons

3.2.2 Heavy Metal Contamination Index

Heavy metal contamination index of the sampling points is shown in Figure 13. HPI crossing 100 indicates critical contamination. In both seasons the HPI indicates critical contamination of heavy metals having higher values in rainy season than dry season.

3.2.3 Metal Quality Index

Metal quality index is shown in Figure 14. MQI of all the points in both rainy and dry season crossed 1. For MQI that is threshold concern. The MQI decreases with increasing distance from disposal site in both cases.

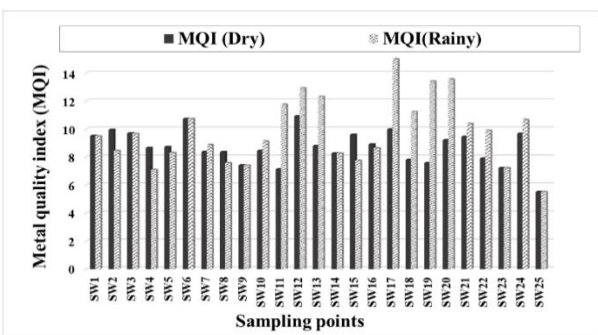

Figure 14: Metal quality index of surface water for dry and rainy seasons

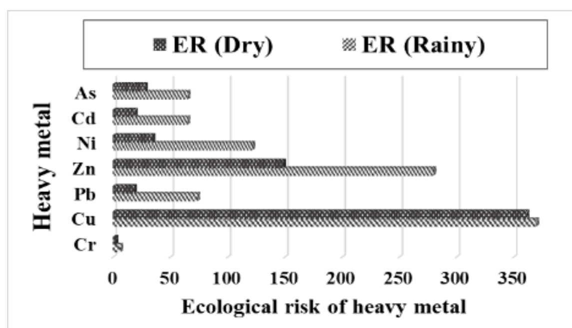

Figure 15: Ecological risk index of surface water for dry and rainy seasons

3.2.4 Ecological Risk Index&Potential Ecological Risk Index

Ecological risk index (ER)is shown in Figure 15 in respect of heavy metal. To calculate the ER one metal is to be taken as reference metal. In this study Fe was taken as reference metal. The ER of As, Cd, Pb and Cr was lower than Cu, Zn and Ni. The ER was lower in dry season and higher in rainy season. The ER range was ER< 30=Slight, 30< ER < 60=Medium, 60< ER < 120=Strong, 120< ER < 240=Very Strong,ER > 240=Extremely Strong.PERI was the summation of ER of all the sampling points shown in Figure 16. The PERI was seen to be lower in dry season and higher in rainy season and decreased thoroughly with the increasing distance of the points from the waste disposal site.

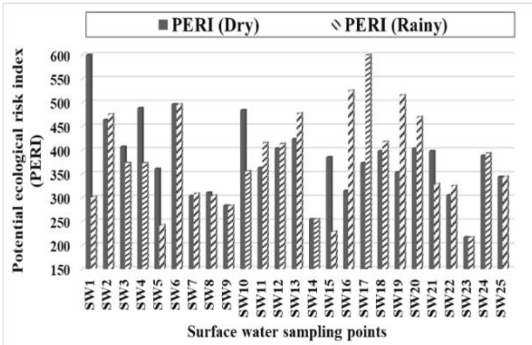

Figure 16: Potential Ecological Risk Index

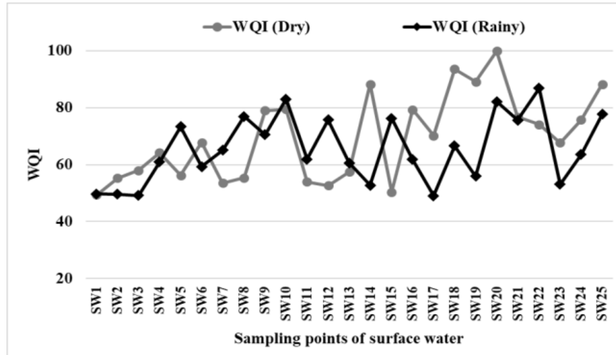

Figure 17: WQI of the surface water sampling stations

3.3 Water Quality Index &Fuzzy synthetic evaluation of Water Quality Index

The area near waste disposal site is critical location for decent water quality for drinking. The results of WQI in class are shown in Figure 17. The WQI values happen to be higher with the increasing distance from waste disposal site. The quality classes were mostly within C and D. Some of them were B and A generally having a distant from the waste disposal site. The requirement is mostly C and B based on the geological condition of the adjacent area. The WQI was found to be lower mostly in terms of requirement. But in fuzzy synthetic evaluation of simple fuzzy classification method and fuzzy information intensity the results are a bit upgraded in some cases which is shown in Table 5. This indicates that the water quality might not be drinkable without treatment in some conditions but can be used in other utility purposes. At station 12 the conventional WQI(Dry) was classified as D but the fuzzy analysis classification wasC indicating a higher quality. The plus (+) and minus (-) indicates the increasing tendency towards better or poor water quality condition. Comparing the outputs, fuzzy analysis indicates that the improvement potentiality was gradual with the increasing water sampling points with respect to the central point of the disposal site. At station 19 the WQI(Rainy) indicates the worst water quality condition D whereas the Fuzzy Synthetic Evaluation indicates relative optimistic condition C+. Similar result variation occurred in other cases.

Table 5: Comparison of WQI with Fuzzy evaluation

SL. No.	Require-ment	WQI (Dry)	Fuzzy method	WQI (Rainy)	Fuzzy method	SL. No	Require-ment	WQI (Dry)	Fuzzy method	WQI (Rainy)	Fuzzy method
SW1	C	D	D	D	D	SW14	C	B	C+	D	C+
SW2	C	D	C	D	C	SW15	C	D	C-	C	C-
SW3	C	D	C	D	C	SW16	C	C	C+	C	C+
SW4	C	C	C	C	C	SW17	C	C	C-	D	C-
SW5	C	D	C	C	C	SW18	B	A	B-	C	B-
SW6	C	C	C	D	C-	SW19	B	B	B	D	C+
SW7	C	D	C	C	B-	SW20	B	A	C	B	B
SW8	C	D	C+	C	C+	SW21	B	C	C-	C	C+
SW9	C	C	C+	C	B-	SW22	B	C	B	B	B+
SW10	C	C	C	B	C	SW23	B	C	C+	D	C+
SW11	C	D	C-	C	C-	SW24	B	C	B	C	B
SW12	C	D	C	C	C	SW25	B	B	B	C	B+
SW13	C	D	C+	C	C+						

4. PEARSON'S CORRELATION

Intermetallic relationships for surface water adjacent to the waste disposal site were significantly correlated by Pearson correlationfor both seasons using XLSTAT. The results for dry season are provided in Table 6. The correlation coefficient *r* indicates if there is a positive correlation and $r^2 > 0.5$ then the correlation among two metals is positive. In dry season the correlated metals are Fe-Cr, Zn-Ni, Cr-Pb. In rainy season Mn-Pb and Mn-Cu are positively correlated.

Table 6: Pearson correlation for dry season

	Fe	*Mn*	*Cr*	*Cu*	*Pb*	*Zn*	*Ni*	*Cd*	*As*
Fe	1								
Mn	-0.213	1							
Cr	0.505	-0.004	1						
Cu	0.170	0.465	0.434	1					
Pb	0.536	-0.272	0.689	0.011	1				
Zn	0.400	-0.340	0.050	0.288	0.076	1			
Ni	0.379	-0.232	0.073	0.097	0.100	0.514	1		
Cd	-0.219	-0.241	-0.486	-0.131	-0.202	0.140	0.078	1	
As	0.318	-0.652	0.085	0.046	0.023	0.573	0.453	0.073	1

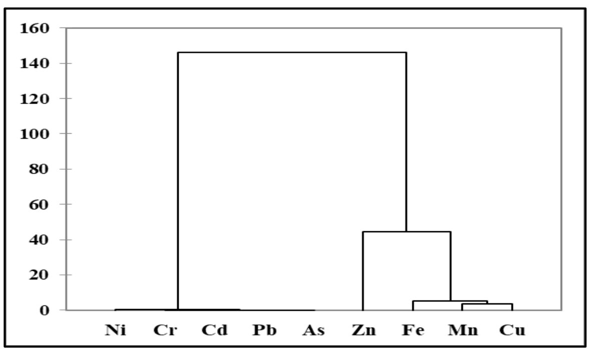

Figure 18: Dendrogram of the selected metals in surface water using ward's method in dry

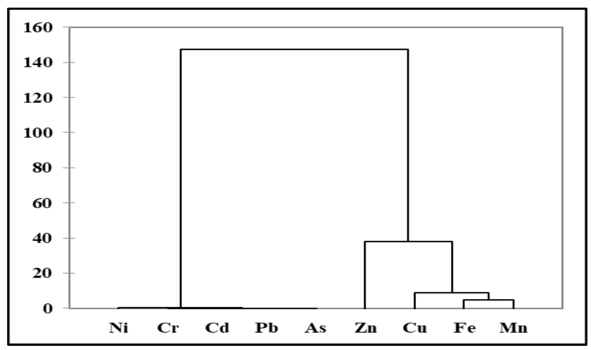

Figure 19: Dendrogram of the selected metals in surface water using ward's method in rainy

5. CLUSTER ANALYSIS

To treat data set of the heavy metal concentration cluster analysis has been performed in XLSTAT software. The metal classification was determined inputting z- transformation, squared the Euclidean distance as dissimilarity measure and ward's method of linkage(Mohd Zahari Abdullah, 2016). With regard to dendrogram for dry season and rainy season is shown in Figure 18 and Figure 19 respectively. In both season the sampling sites were grouped in two clusters. Cluster I includes the Ni, Cr, Cd, Pb and Aswhich indicates these metals are generated from anthropogenic sources and cluster II includes Zn, Mn, Fe, Cu which states that these metals are from geogenic sources.

6. CONCLUSION

In this study multivariate water quality indices were used to determine the overall water quality and the level of contamination. Regarding with heavy metal, the contamination level was also determined and the results were approached with Pearson correlation and cluster analysis (CA).Result reveals the contamination level of surface water categorizing into the severity level and also presented the variation in contamination level during dry and rainy seasons.Surface water in rainy season was generally more contaminated than dry season. Surface water closer to the waste disposal site was more contaminated than the farthest points. The level of contamination gradually decreases in relation to the increasing of sampling points.the conventional WQI of station 7 in dry season was in class D; WQI from fuzzy analysis showed the water quality was better in class C. Gradual improvement potential was seen in fuzzy analysis with the increasing distance from the waste disposal site as well.The fuzzy synthetic evaluation showed optimistic distinction in some of the cases which can be very useful indication for various utilization purpose. Nevertheless, all the points showed that the surface water was moderate to severe contaminated. The metal contaminants are contributed by two possible sources like anthropogenic and geogenic. The local city corporation necessitates proper water treatment policies and management planning of waste disposal site to control the quality of water and spread prohibition drinking this water without treatment.

REFERENCES

APHA. (2012). Standard Method of examination of water and waste water. USA: American Public Health Association.

Bhatri N, K. D. (2011). Water Quality Indices used for Surface Water Vulnerability assessment. India: Int J Ecol Environ Sci.

BIS. (1998). Indian Standard of drinking water specification IS. New Delhi: Bureau of Indian Standards.

Chanapathi, T. (2019). uzzy-Based Regional Water Quality Index for Surface Water Quality Assessment.

Mohd Zahari Abdullah, N. R. (2016). Assessment Of Surface Water Metal Pollution Based On Pollution Load Index (Pli) Supported By Multivariate Statistical Analysis. University Of Malaysia: Em International Issn.

Naresh Singh Yadav, A. K. (2018). Assessment Of Water Quality Using Pollution-Index In The Study Stretch Of River Chambal, India . Department Of Zoology, Bundelkhand University, Jhansi, Uttar Pradesh: Integrated Research Advances .

Ni-Bin Chang, H. W. (2001). Identification of river water quality using the Fuzzy Synthetic Evaluation approach. Taiwan: Journal of Environmental Managemen.

Pal, R. (2017). Assessment of Heavy Metal Pollution through Index Analysis for Yamuna Water in Agra Region, India. Uttar Pradesh, India: Excellent Publisher.

Puri, P. (2015). Application of water quality index (WQI) for the assessment of surface water. RTM Nagpur University, Nagpur: Europian Journal of Experimental Biology.

Rama Pal, R. D. (2017). Assessment of Heavy Metal Pollution through Index Analysis for Yamuna Water in Agra Region, India. Agra, India: Int. J. of Current Microbiology and Applied Sciences.

S. Gupta, K. S. (2019). Sources evaluation and ecological risk assessment of heavy metals accumulated within a natural stream of Durgapur industrial zone, India, by using multivariate analysis and pollution indices. Durgapur: Applied Water Science.

Santos-Francés, F. (2017). Geochemical Background and Baseline Values Determination and Spatial Distribution of Heavy Metal Pollution in Soils of the Andes Mountain Range (Cajamarca-Huancavelica, Peru). Peru: International Journal of Environmental Research and Public Health.

Satar, A. (2017). Indices of water quality and metal pllution of Nile river . Egypt: Aqu. res.

Singh, S. G. (2013). Assessment of Surface Water Quality Using Heavy Metal Pollution Index in Subarnarekha River, India. Subarnarekha River, India: Springer.

World Health Organization. (1998). Guidelines for drinking-water quality. USA: WHO.

LAND USE CHANGES AND ITS IMPACT ON ENVIRONMENT: A CASE STUDY ON URBAN AREA IN KHULNA ,BANGLADESH

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ABSTRACT

Land is a part of the physical environment with various natural uses. Temperature, rainfall, humidity, salinity plays a serious role to make the environment habitable for both human beings and other species. These factors changes with the change of land use pattern of an area. The transformation of land use in an unplanned way resulted in environmental degradation, rise in temperature, entropy, change of precipitation, humidity, eco-system. To fulfill the several needs of the people, the rapid changes in land use occur in an area which is one of the driven forces of its environmental change. The research purpose is to identify and analyze the changes of land use pattern and then to evaluate the impacts of some criteria for land use change (LUC) in urban area.

The study was conducted using the data for two different time section 2002 and 2018. The study area was selected as Mujgunni Ward No 9 and Nirala, Ward No 24 Khulna City Corporation, Khulna by observing the recent rapid environmental change in the study area through secondary data analysis and by reading some available research paper to see the environmental change with the change of land use pattern. Landsat 5(TM) and Landsat 8 (OLI) images has been used in ERDAS Imagine 2014 for the year 2002 and 2018 respectively to identify the land use scenario. To analyze the land use change, land use was classified into five categories such as Build up area, Agricultural Land, Vacant Land, Vegetation and Waterbody. GIS based analysis in ArcGIS helped to relate these land use change between both areas. The Mann-Kendall test, trend analysis and co-efficient of variation were calculated to show average annual and seasonal average temperature and total rainfall changes that occurred due to LUC in the last 16 years at the study area.

A GIS based satellite image of 2002 and 2018 analysis showing that 229.53 acres and 48.2 acres of the buildup area has increased at Mujgunni and Nirala respectively which indicates a high rate of LUC at Mujgunni. The present land use type percentage shows that Mujgunni is still the more environmentally sound than Nirala. But the land use conversion rate is causing environmental change at Mujgunni and Nirala. The result shows that the average temperature was increased by 1.01^0C with the increasing rate of 0.04162^0C/year. The trend analysis shows that the average temperature in spring, summer and autumn was increased with the rate of 0.1534^0C/year in spring, 0.02701^0C/year in summer, 0.0076^0C/year in autumn and decreased in winter with the rate of 0.00816^0C/year. This increasing rate of temperature melts the ice in the polar and rises sea water level. The value of Z and co-efficient of determination showed the significance level for different values. Again total annual rainfall increasing rate is 17.64 mm/year. Seasonal total rainfall has also been increased during the study period with the rate of 4.17 mm/year in spring, 5.69 mm/year in summer, 5.15 mm/year in autumn and 2.10 mm/year in winter. As the study revealed that land use change in an unplanned way has impacts on the environmental change. So, the study will help people to have a clear vision on the impacts of land use change in an unplanned manner.

Keywords: *Land use pattern, Environmental change, Mann-Kendal test.*

1. INTRODUCTION

After 1950, urban population has increased about 7 times which resulted in the massive transformation of vacant land, waterbodies, forest land, vegetation and agricultural land into built up area in the urban area. This massive transformation has influence in resource use, pollution and environmental degradation (Sarraf et al., 2004). The main purpose of this research is to identify and analyze the changes of land use pattern in two different wards, Ward No 24 Nirala and Ward No 9 Mujgunni in KCC boundary. And then to evaluate the impacts of some criteria for land use change. Environment is the physical, chemical and biological entity surrounded by us. All things in the world are the part of the environment. An environment that is made up of good, sound and beneficial ingredients for human health is called healthy environment. A healthy environment ensures sufficient waterbody, vegetation, greeneries, build-up and vacant land use needed to serve its people. Increase or decrement of any elements of the environment indicates environmental change. But rapid increment or decrement of any elements in an unplanned manner causes environmental degradation (Fattah et al., 2019). That changes the environment negatively by changing its temperature, precipitation, humidity, salinity, ecosystem, biodiversity.

Land is a part of the physical environment with various natural uses. Human being reshaped this physical environment and divided into a variety of land use categories for their different purposes. How and which purposes people are using this land category is Land Use Pattern (Tiwari & Sharma, 2013). Land use means the uses of land cover by human for their various purposes such as housing, industrial, commercial, agricultural, grazing, mining, and many other purposes to meet their requirements to improve their living standards and comfortable living conditions.

Land Use Change (LUC) is the change of land use categories naturally or by human being. With the passage of time, land use has been changing around the world, both in planned and unplanned way. Change of Land use pattern in a planned way defines development of any area (Bahadure & Kothakar, 2012). Land use change in an area in an unplanned manner impacts the environment by changing the temperature, average precipitation, salinity, humidity of the area. Temperature, eco-system, biodiversity, ground water level etc. are changing negatively for this reason. It would be a threat to future generations for the present generations unconsciousness.

Mann–Kendall (MK) test is widely used in many climatic time series like temperature, humidity, rainfall etc. and many hydrological time series for the assessment of significance of trends (Hamed, 2009). The MK test illustrates a non-linear trend test, which measures monotonously up and down patterns or trends over a certain period of time (Lamchin et al., 2019). It is also a rank correlation test between the ranks of observations and their time sequence (Hamed, 2009). A trend is a recurring pattern and the method of data collection in an effort to identify this pattern is trend analysis. According to (Mondal & Hashemi, 2018) Trend analysis is conducted to spot a prevalent trend to identify how a trend developed or would develop over time. In research, trend analysis has been conducted to identify the trend of temperature, rainfall, salinity, humidity etc. data over a certain period of time. In this research Mann- Kendall test method is used with an accuracy rate of 85% to calculate temperature data and rainfall data.

Increase of temperature enhances the Earth's entropy, leading to rise of water level by melting ice in the pole. According to (Cazenave et al., 2014), sea level started rising at a mean rate of approximately 3.1 mm/year since early 1990s. Every year, hundred acres of land are going underwater and many famous cities will go under water within 2050. Many environmental pollutions occurred due to the rise in temperature, which making the environment unsuitable for human living (Liang & Li, 2018). Many factors work behind this negative environmental change like different types of pollution, hazard, use of plastic, industrialization, urbanization, destruction of forest, population growth etc. In most of the research, urbanization is considered as most responsible factors for the negative environmental change.

According to (Hooke et al., 2012) nearly 50% of Earth's Land surface has been modified by human being and nearly 24% of Earth's surface area experienced decline in productivity and ecosystem function during the year 1981 and 2003. (Folland et al., 1991) said that in the last 50 years the increasing rate of Earth's temperature is 0.13^0C which is twice that the last 100 years. These are alarming people about the dire environment in the future. Bangladesh is also facing this environmental problem due to its rapid land use transformation and population growth rate. According to (Mohiuddin, et al., 2014), the average annual temperature increased by 6.8^0C in the last 100 years in Dhaka. According to (Mondal et al., 2017), the annual average temperature was increasing by 0.007^0C/year and total annual rainfall was also increased by 3.392 mm/year in Khulna during the year 1960-2012. These all researchs showed the variety of environmental change for many years. But recently, statistics show that the environment is changing mostly in Bangladesh due to its increasing population, unplanned development, natural disaster and man-made reasons. In this research, recent land use change and environmental change were calculated which representing the current scenario and current problems. The value of the coefficient of determination, R^2 was found lower in seasonal average temperature change trend analysis because the study time of this research has been considered only for 16 years where, (Mondal et al, 2017) analyzed the data for 52 years. The research compared the difference between the two recently developing areas about their present environmental situation and calculated the average temperature and annual rainfall changes with the change of different Land Use Pattern (Buildup, agricultural land, vacant land, vegetation and waterbody) at the study area while most of the previous research focused on only one or two types of land use pattern of an area. The research also finds out the possible eco-friendly and environmentally sound area and a potential area for future urban growth among the two study area which will be helpful for future sustainable development.

2. METHODS AND MATERIALS

2.1 Study Area

Khulna is the 3rd largest city and Bangladesh's 2nd port entry has been developed largely in an unplanned manner (Source: BBS 2011). The Khulna City Corporation area is 14.30 sq. miles with a population of 232633 is divided into 31 wards. According to BBS 2015, from 2001 to 2011 the annual population growth rate was 0.68 in Khulna. With the increment of population, the land use pattern and the environment of Khulna is changing in every year. The study area Mujgunni KCC ward No 9 in Figure 1(a) and Nirala KCC Ward No 24 in Figure 1(b) was selected due to their continuous development and land use transformation in the recent years. Table 1 represents some necessary information about the study area.

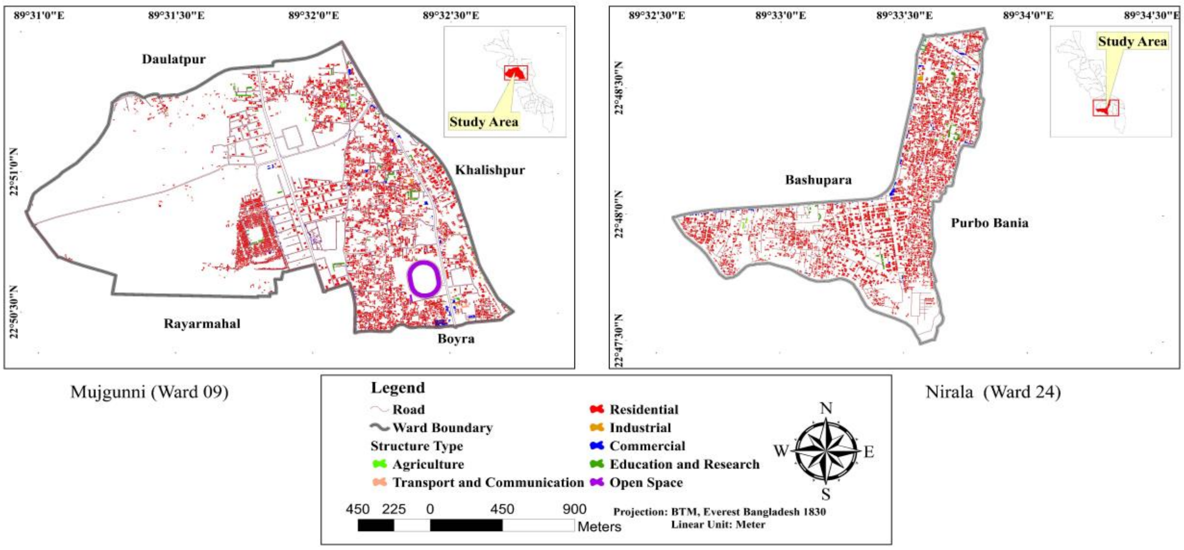

Figure 1: Study area map (a) Mujgunni KCC Ward No 9, (b) Nirala KCC Ward No 24 Khulna (source: Author 2019)

Table 1: Study area profile

Criteria	Mujgunni	Nirala
Ward No	9	24
Total Area	844.317 acres	392.7 acres
Population	31882	37889
Population density	38 person/acre	96 person/acre
Maximum Land Coverage	Buildup	Vegetation

(Source: BBS 2011)

2.2 Methodology

The study area was selected by reading some available research paper. The continual transformation of land use type in this area is also a reason for selecting the area. The study area was selected to see the environmental change like temperature and precipitation with the change of land use type or pattern. Other related papers most important and meaningful factors were selected and prioritized to analyze the data. To identify the land use pattern in the study area, Landsat 5(TM) and Landsat 8 (OLI) images having 30m resolution has been used in ERDAS Imagine 2014 for the year 2002 and 2018 respectively. For more accuracy of the data, atmospheric and radiometric correction has been conducted. To analyze the land use change, five types of land pattern has been selected such as Agricultural Land, Vacant Land, Vegetation, Waterbody and Build up area. GIS based analysis in ArcGIS helped to compare these land use change between both areas.

The monthly average temperature data and rainfall data on the Khulna station collected from the Bangladesh Meteorological Department over the study period 2002-2018. Seasonal mean values for the four seasons e.g. spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February) are determined from the monthly data and yearly mean values have also been calculated for the study period from meteorological department. In order to analyze the changing temperature and precipitation pattern, data were compiled for the station on a monthly, seasonal and annual basis. A very well-known method for trend analysis, Mann- Kendal Test method has been used for temperature and precipitation trend has been identified. And co-efficient of variation were calculated for measuring the level of significance of the average temperature and rainfall data.

3. RESULT AND FINDINGS

3.1 Land Use Type and Land Use Changes:

To identify the Land Use Type scenario at both in KCC Ward No. 9 and Ward No. 24, land use type was classified into 5 categories, namely agricultural land, vacant land, vegetation, waterbody and build up area. Supervised image classification in ERDAS IMAGINE 2014 helped to identify and measure the LUT in the year 2002 and 2018.

3.1.1 Land Use Change at Mujgunni KCC Ward No. 9

From GIS based satellite image analysis in 2002, it is found that the topmost land use type was vegetation 308.74 acres (37%) and then waterbody 208.19 acres (25%) showed in Table 2 and Figure 2(a). Build up area was only 64.99 acres (8%). The analysis shows that Build-up area was increased during the year 2002 to 2018 at both in Ward No-9 and Ward No-24. In 2018 total build up area increased to 294.52 acres at Ward 9 showed in Figure 2(b). Figure 3 describes that about 229.53 acres of built-up area increased at Mujgunni Ward No-9 that means 27% of the land converted into a buildup area in the last 16 years due to the growth of population and to increase the amenities for this increased population.

From the field survey, it is found that many shops, administrative, institutional, residential, commercial building and road has been constructed in the recent years at Mujgunni which reduces the agricultural land, vacant land, vegetation and waterbody area rapidly at Mujgunni showed in Figure 2(b). Figure 3 shows that about 45% of waterbody and 40% of agricultural land transformed into build-up area at Mujgunni. The transformation of waterbody area and agricultural land is mostly because of the land use type and for the economical purposes. The reason for this drastic reduction of waterbodies is that people have filled the waterbody with sand to build infrastructure on it in future. Still in Mujgunni, people are filling waterbodies which will be a threat to the water ecosystem in there and will increase the water logging problem and temperature more rapidly at the study area.

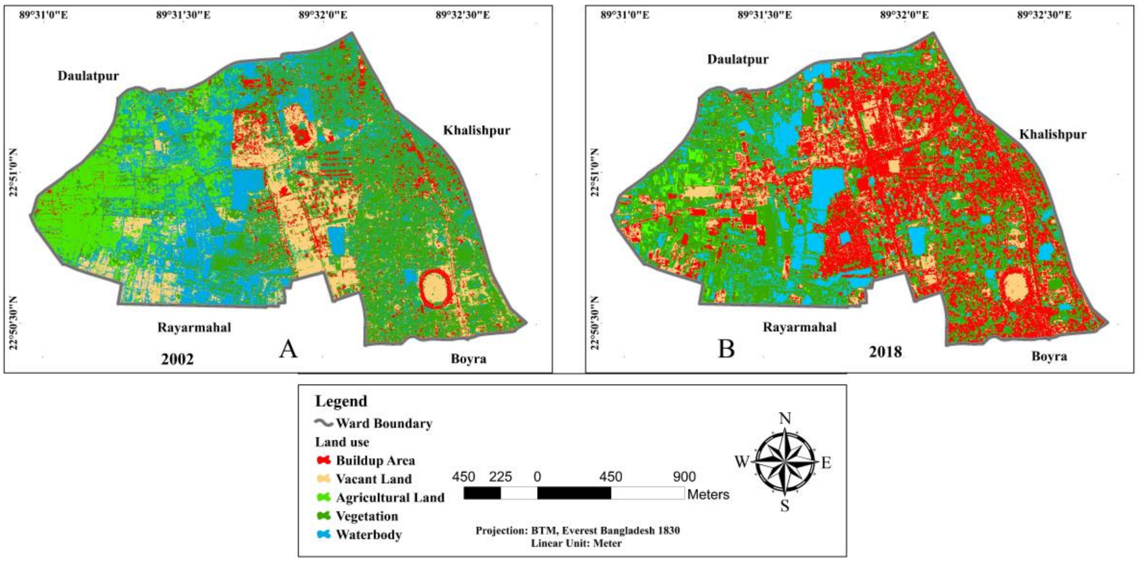

Figure 2: Land use map of Mujgunni KCC Ward No 9 (a) in 2002 and (b) in 2018. (Source: Author, 2019)

From the field survey 2019, it is found that most of the people of this area was dependent on agriculture for their income source. The reduction of the price of jute and agricultural products is the main reason of the reduction of agricultural land. And the growth of the need of land for residential purposes people gave priority to cash money rather than cultivating fish which is the main reason of the reduction of waterbody at Mujgunni. This drastic reduction of the waterbody, agricultural land and vacant land accelerates the environmental change at Mujgunni like increase of temperature, change of precipitation and humidity salinity and pH of the water.

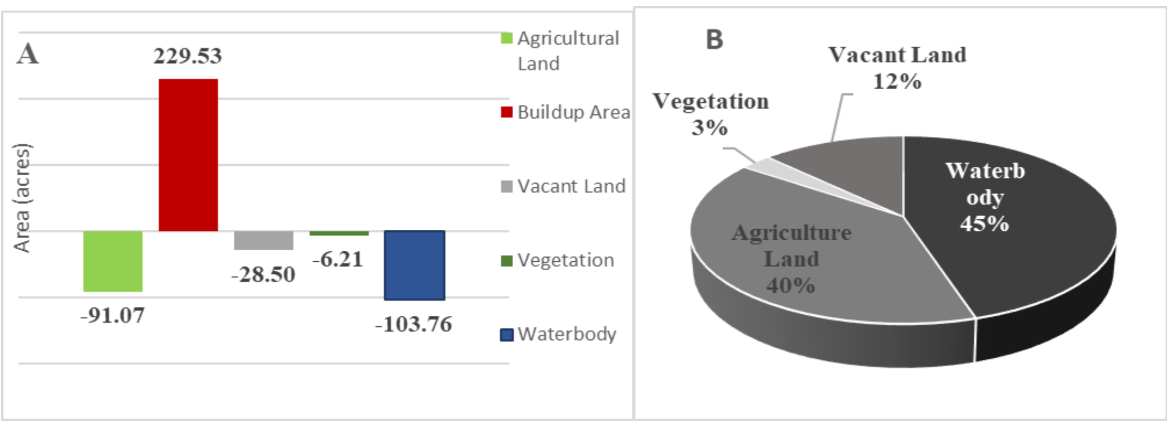

Figure 3: (a) Land Use Change scenerio (b) Transformation of different land use type into build up area at Mujgunni KCC Ward No 9 from 2002 to 2018 (Source: Author, 2019)

Table 2: Land Use Type scenario at the study area in 2002 and 2018 (Source: Author' calculation, 2019)

Land Use Type	Mujgunni Area (acres)		Nirala Area (acres)	
	2002	**2018**	**2002**	**2018**
Agricultural Land	125.77	34.70	35.6	31.2
Buildup Area	64.99	294.52	224.4	272.6
Vacant Land	136.63	108.13	45.1	14.5
Vegetation	308.74	302.53	70.5	68
Waterbody	208.19	104.43	17.1	6.4

3.1.2 Land Use Change at Nirala KCC Ward No. 24

GIS based satellite image classification in Figure 4(a) and Table 2 shows that in 2002, the topmost land use type at Nirala was build-up 224.4 acres (57%) and then vegetation 70.5 acres (18%) , vacant land 45.10 acres (11%), and agricultural land 35.5 acres (9%). But in 2018 with the growth of population and their demand of land for easy and better urban lifestyle, build up area was increased to 272.60 acres. At Nirala, about 30.6 acres of vacant land and 10.7 acres of waterbody transformed in the buildup area to provide housing and facilities to the people that showed in Figure 5.

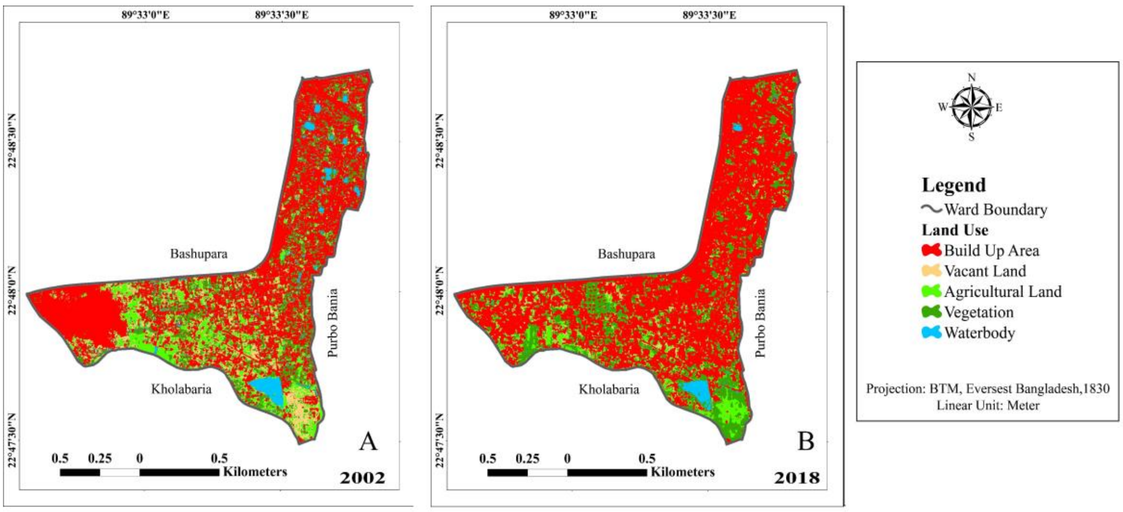

Figure 4: Land use map of Nirala KCC Ward No 24 (a)in 2002 and (b) in2018 (Source: Author, 2019)

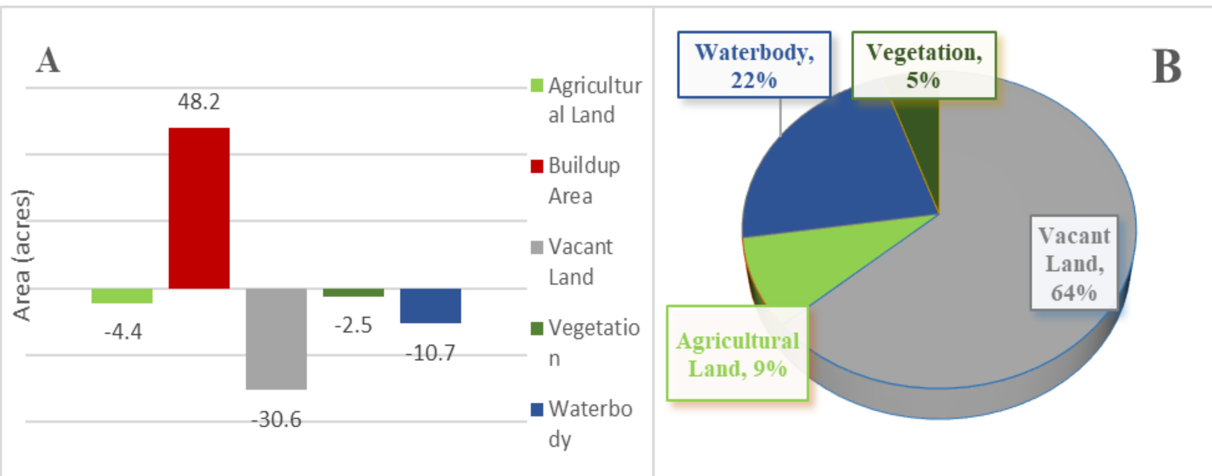

Figure 5: (a) Land Use Change scenerio (b) Transformation of different land use type to build up area at Nirala KCC Ward No 24 from 2002 to 2018 (Source: Author, 2019)

Figure 5(a) shows that nearly 48.20 acres of built up area increased at Ward- 24. This 48.20 acres of land have been used to build a new building to provide housing, amenities, service facilities and construction of roads. The demand for housing and employment is increasing day by day as the population increases. But compared to the demand, the amount of land is low. Considering the cost and adequacy people preferred vegetation, vacant land and waterbody for the development. This transformation of land use type played a negative impact on the environment.

Table 3 indicates the considerably more percentage of vegetation, build-up area, waterbody and vacant land area at Ward No 9 than Ward No 24. That means Ward No 9 is environmentally more sound than Ward No 24 and also have places for future sustainable development. The transformation of these land use type at Ward No 9 in a planned way will be a potential for ecofriendly sustainable development.

Table 3: Land Use percentage at the both study area in 2018

Land Use Type	**Nirala, Ward 24**	**Mujgunni, Ward 9**
Agricultural Land	8%	4%
Buildup Area	69%	35%
Vacant Land	4%	13%
Vegetation	17%	36%
Waterbody	2%	12%

(Source: Author' calculation, 2019)

3.2 Environmental Change

Two types of environmental changes, temperature and precipitation change has been calculated in this research from the year 2002 to 2018 by using Mann-Kendall Test.

3.2.1 Annual Average Temperature

As there is only one weather station in Khulna City, the data will same for all of the places in Khulna City. The data represent that the annual average temperature is increased in both KCC Ward No. 9 and Ward No. 24. In 2002, the average temperature was 25.34^{0}C and in 2018 it stood at 26.35^{0}C. The Mann-Kendall test trend analysis results in Figure 6 represents that the annual average temperature was increased by 0.04162^{0}C/year with its average 26.00588^{0}C.

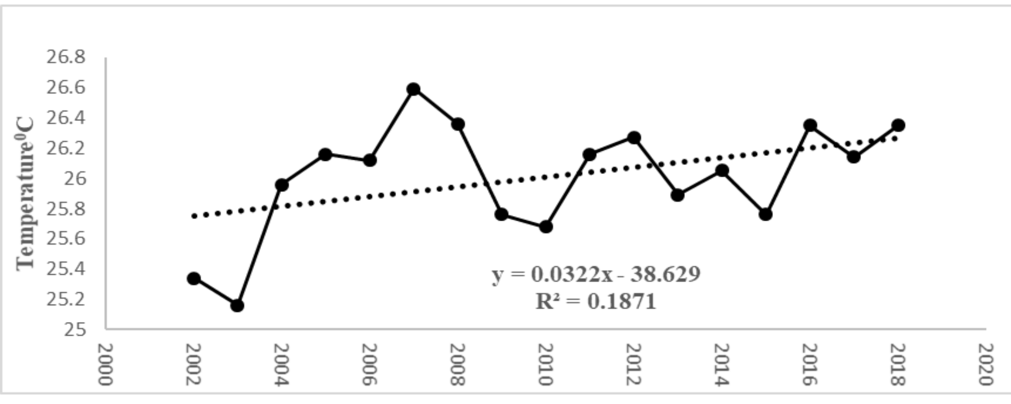

Figure 6: Average annual temperature trend at the study are from 2002 to 2018 (Source: Bangladesh Meteorological Department, 2019)

The increasing trend of average annual temperature coefficient of determination, R^2= 0.1871 which was significant. From the analysis, it is found that the maximum and the minimum observed temperature was 37.63^{0}C and 12.72^{0}C respectively in 2002. In 2018, the maximum observed temperature was 41.14^{0}C and the minimum observed temperature was 9.76^{0}C. It indicates that, the temperature during the summer is increasing and during winter it is decreasing en every year. Changes of land use type and population day by day are the reason behind this negative change.

3.2.2 Seasonal Avrage Temperature

Figure 7 A,B,C and D shows the overall seasonal variation of the average temperature of the both study areas for spring, summer, autumn and winter during the study time period 2002 to 2018 using Man-Kandell Test. The test shows an increasing trend in spring, summer and autumn season, but in the winter season decreasing trends. The value of the coefficient of determination (R^2) for the spring season in Figure 7(A) is 0.132 is moderately significant. Which indicates that the average temperature of spring season in Khulna have increased moderately. But in Figure 7(B), Figure 7(C) and Figure 7(D), the value of the coefficient of determination R^2 is 0.0115, 0.0475 and 0.0384 are not statistically significant. The lower value of R^2 indicates that the average temperature of these seasons has not changed much in the last 16 years in the study area. In rise of temperature in spring is 0.1534^{0}C/year, in Summer 0.02701^{0}C/year and in autumn 0.0076^{0}C/year, but the average decrease of the temperature in winter is 0.00816^{0}C/year.

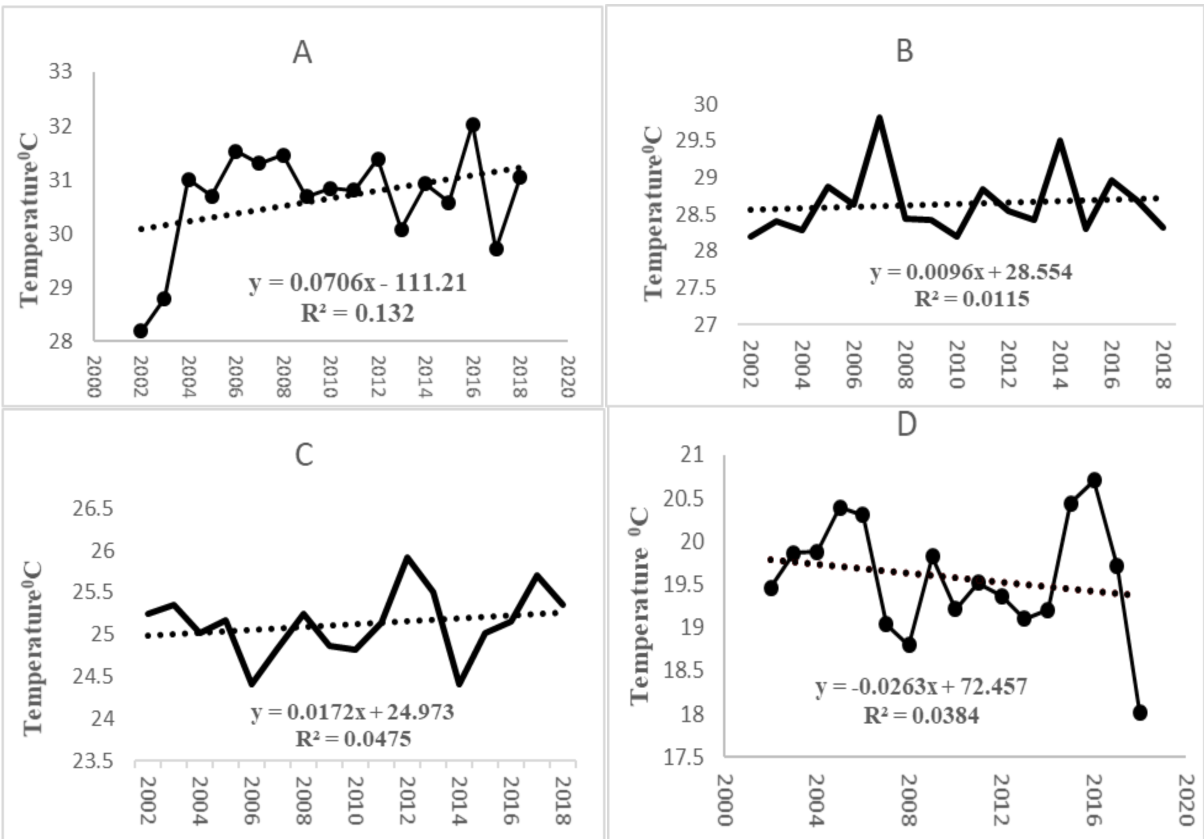

Figure 7: Average seasonal temperature trend for (A) Spring (B) Summer (C) Autumn (D) Winter season during the study period 2002 to 2018 (Source: Bangladesh Meteorological Department, 2019)

3.2.3 Annual Total Rainfall

The total annual rainfall in the study area is showing an increasing trend over the study period 2002 to 2018. Statistics show that the average total annual rainfall of the last 16 years is 1960.101 mm/ year. In 2002, the total annual rainfall was 1507.23 mm, but in 2018 it was found 2528.64 mm. This shows a positive increment of total annual rainfall in the study area during the study period. The highest annual rainfall 4324.81 mm measured in the year 2017 and the lowest annual rainfall 1306.03 was measured in the year 2005 in the study area. The trend analysis shows that the increasing rate of annual rainfall in the study area is 17.64 mm/year which is a positive sign for the environment.The increasing trend of precipitation coefficient determination, R^2= 0.4518 which was significant (Figure 8). Though annual rainfall has increased in the last 16 years, but the amount of waterbody has decreased due to which water logging and related problems are increasing day by day.

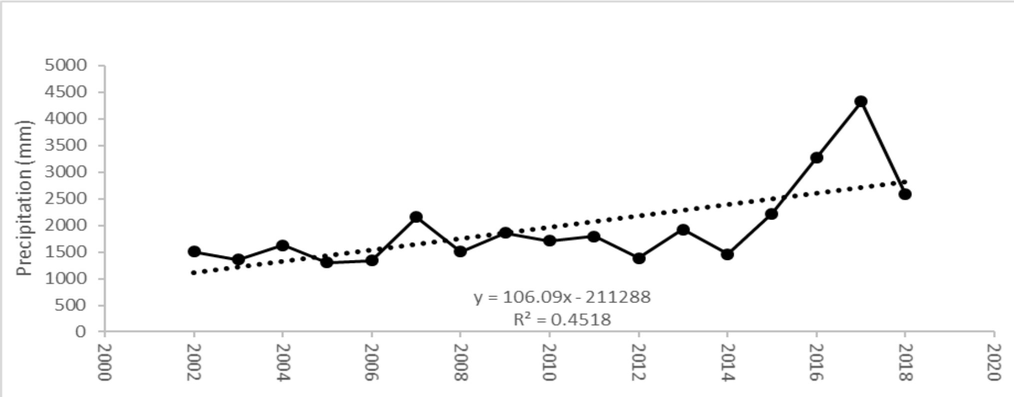

Figure 8: Total annual rainfall trend at the study are from 2002 to 2018 (Source: Bangladesh Meteorological Department, 2019)

3.2.4 Seasonal Total Rainfall

The overall seasonal variation of the total rainfall scenario during the study time period 2002 to 2018 in spring, summer, winter and autumn in the study area represents the gradual increasing trends in all season. The Mann-Kendall Test trend analysis shows that the increasing the total for the spring, summer, autumn and winter are 4.17 mm/year, 5.69 mm/year, 5.15 mm/year and 2.10 mm/year respectively showed in Fugure 9 A, B, C and D.

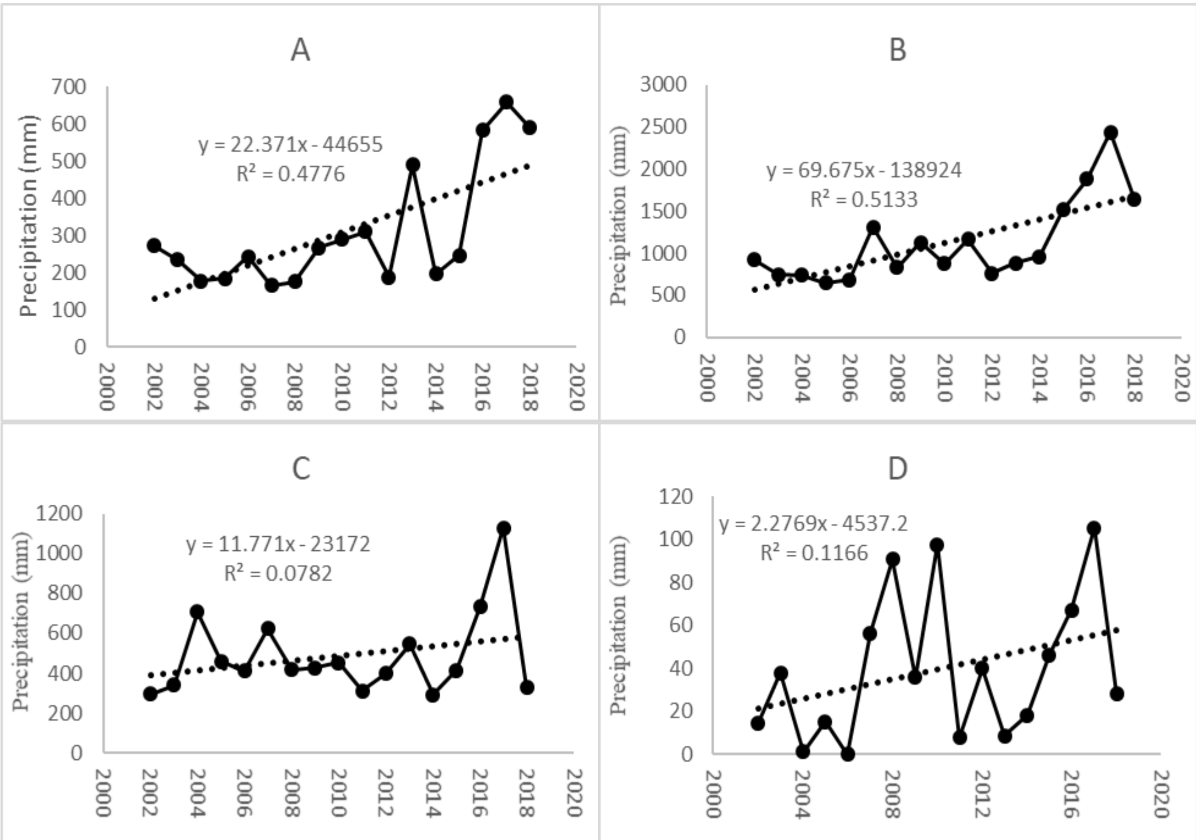

Figure 9: Total seasonal rainfall trend for (A) Spring (B) Summer (C) Autumn (D) Winter season during the study period 2002 to 2018 (Bangladesh Meteorological Department, 2019)

The value of coefficient of determination, R^2 for spring 0.4776, summer 0.5133, winter 0.1166 in Figure 9 (A), (B), (D) indicates that the result was statistically significant for all these season and the average rainfall has increased mostly during the summer season. But the value of R^2 for autumn 0.0782 in Figure 9 (C) indicates the poor increasing rate of average rainfall in autumn during the study period at the study area.

4. CONCLUSIONS

Transformation of land use type of an area in an unplanned and extensive manner critically affects the environment which results in the change of temperature, rainfall, humidity, salinity, etc. But the research focused on only the change of the average temperature and annual rainfall in a developed and a developing area due to their land use changes. The research showed Nirala as an already developed area and Mujgunni as a potential area for future sustainable development due to its moderate percentage of vegetation, waterbody and vacant space. The rapid transformation of land use resulted in the increasing trend of annual average temperature (by 0.04162^{0}C/year), seasonal average temperature, annual total rainfall (17.64 mm/year) and seasonal total rainfall during the study period. If the conversion rate of waterbody remains same, within a few days there will be a shortage of waterbody in Mujgunni that is what the people of Nirala are currently facing. The increase of temperature boosts the Earth's entropy, leading to rise of water level by melting ice in the pole. As a result, the lowland and coastal areas are becoming more and more destructive and many related problems are coming out. The result is a slight exception because of the high rate of land conversion in the recent years. The study exposed that land use change in an unplanned way has impacts on the environmental change. This type of research will concern people and will further help to plan an area by thinking about the aspects of environmental change for unplanned land transformation.

REFERENCES

Bahadure, S., & Kothakar, R. (2012, December). Social Sutanability and Mixed Land USe, Case Study of Neighborhoods in Nagpur, India. *Bonfring International Journal of Indutrial Engineering and Management Science*, *2*(4).

Cazenave, A., Dieng, H. B., Meyssignac, B., Schuckmann, K. v., Decharme, B., & Berthier, E. (2014, March). The rate of sea-level rise. *Nature Climate Change*, 1-4.

Fattah, M., Morshed, S. R., & Haque, M. (2019). Characteristics of Current Land Use Pattern of Urban Area A Case Study on Ward 24 (Nirala), Khulna City Corporation (KCC), Khulna, Bangladesh. *1st International Conference on Urban and Regional Planning.* Dhaka: Bangladesh Institute of Planners.

Folland, C. K., Karl, T. R., & Vinnikov, K. Y. (1991). Observed Climate Variations and Change. In J. T. Houghton, J. T. Jenkins, & J. J. Ephraums (Eds.), New York: Cambridge University Press, *Climate Change The IPCC Scientific Assesment* (pp. 195-239).

Hamed, K. H. (2009, February). Exact Distribution of the Mann–Kendall Trend Test Statistic for Persistent Data. *Journal of Hydrology, 365*(1-2), 86-94.

Hooke, R. L., Duque, J. F., & Pedraza, J. (2012, December). Land Transformation by Humans: A review. *GSA Today, 22*(12), 4-10.

Lamchin, M., Lee, W.-K., Jeon, S. W., Wang, S. W., Lim, C.-H., & Song, C. (2019). Corrigendum to "Mann-Kendall Monotonic Trend Test and Correlation Analysis Using Spatio-temporal Dataset: The Case of Asia Using Vegetation Greenness And Climate Factors" [MethodsX 5 (2018) 803–807]. *Corrigendum, 6*, 1379-1389.

Liang, L., & Li, J. (2018, November). agglomerations, The Effect of Urbanization on Environmental Pollution in Rapidly Developing Urban. *Journal of Cleaner Production, 237*.

Mohiuddin, H., Bhuiya, M. R., & Mamun, M. M. (2014). An Analysis of the Temperature Change of Dhaka City. *Proceedings of 5th International Conference on Environmental Aspects of Bangladesh [ICEAB 2014]*. Dhaka: ICEAB.

Mondal, A., & Hashemi, H. (2018, October). Intercomparison of Trend Analysis of Multisatellite Monthly Precipitation Products and Gauge Measurements for River Basins of India. *Journal of Hydrology, 565*, 779-790.

Mondal, K. K., Akhter, M. E., Hassan, S. Q., & Mallik, M. A. (2017, December). Study on Rainfall and Temperature Trend of Khulna Division in Bangladesh. Department of Physics. Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh. Retrieved from http://hdl.handle.net/20.500.12228/178

Tiwari, A. K., & Sharma, V. N. (2013). Land Use Pattern in Eastern Uttar Pradesh. *Population and Regional Development*, 164-176.

Sarraf, M., Larsen, B. & Owaygen, M., 2004. Cost of Environmental Degradation- The case of Lebanon and Tunisia, Washington, D.C: The International Bank for Reconstruction/ The World Bank.

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HYDROCHEMICAL ASSESSMENT OF THE GROUNDWATER QUALITY OF SYLHET CITY

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ABSTRACT

Most of the residents of Sylhet city depend on the groundwater supply provided by the Sylhet City Corporation (SCC). Thus, the present study points up on the groundwater hydrochemistry of this area to assess the quality for the health and daily uses of the residents of the city. Groundwater samples were collected from 20 pumps of Sylhet city during March 2019 and were analyzed for physico-chemical parameters such as Electrical conductivity (EC), Total dissolved solids (TDS), pH, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Nitrate (NO_3^{-}), Sulphate (SO_4^{2-}), Carbonate (CO_3^{2-}) and Bi-Carbonate (HCO_3^{-}). Hydrochemical assessment has been done based on different well-known diagrams. It also describes the main features that affecting the groundwater chemistry. It has been found that Mg-Na-Ca-Cl-HCO_3 is the hydrochemical facies that dominates in the groundwater of SCC area. Almost all the samples fall in the rock area and chemical weathering of the rock forming minerals is the main processes that contribute the ions to the water. Wilcox's diagram and US Salinity Diagram were used to evaluating water quality for irrigation and they show that most samples of groundwater were good for irrigation. A further detailed study is needed based on reliable statistical methods as well as on the basis of all possible parameters and pumps under SCC.

Keywords: *Groundwater, Hydrochemistry, Hydrochemical diagrams, SAR, USSL.*

1. INTRODUCTION

Groundwater chemical composition is directly connected to groundwater quality. According to Hounslow (1995), water quality is defined by the composition of physical, chemical and biological characteristics of a water sample. The chemical composition of groundwater is the combined result of water composition that enters the groundwater reservoir and the reactions with the minerals present in the rocks (Iliopoulos, Stamatis, & Stournaras, 2011; Zhu & Anderson, 2002). Most studies as Adams et al.(2001) and Alberto et al. (2001) showed that the groundwater chemistry is mainly a function of the interaction between water and mineralogical composition of the aquifer. Hydrochemical processes occur within this system are dissolution, precipitation, and ion exchange. These events take place among the flow of groundwater and also depend on the duration of residence that controls the evolution of the chemical composition of groundwater. Chenini & Khemiri (2009) noted that the chemical composition of groundwater is controlled by several factors, including composition of precipitation, mineralogy of the watershed and aquifers, climate and topography. These factors should be combined to specify different water types that vary spatially and temporally. Graphical techniques that can help in understanding the hydrochemical process includes bar chart, pie chart, stiff diagram, schoeller diagram, piper diagram and scattered plots etc. Hydrochemical studies involve in an in-depth evaluation of the chemical composition of groundwater and therefore offer a better understanding of possible changes in quality. Such studies also promote sustainable development and effective management of groundwater.

Most of the residents of Sylhet city depend on the water supply provided by the SCC. Thus, the quality of water distributed by SCC is vital for the health of the residents of the city (Md. Munna, Islam, Hoque, Bhattacharya, & Nath, 2015). The water resources in the SCC are mostly based on groundwater, which is generally over-pumped. Despite the fact that there is a major concern regarding the quality of water in this region, research on hydrochemical and water quality studies is very low here. As a result, the hydro chemical processes (evolution), origins, mixing and quality of the water resource in SCC area are not well known. Moreover, the sources of concentration elements and sensibility of available water to pollution are not clear. This leads to great uncertainty in understanding of the major hydrochemical processes, which is one of the main elements that controls the evolution of water chemistry. Such study is indispensable for the planning and management of the water resources of the area.

Therefore, a detailed study of the groundwater quality in SCC is very essential. In addition, to the best of researchers' knowledge, no attempt has ever been made to identify the groundwater quality in the area of SCC by hydrochemical assessment.

2. METHODOLOGY

2.1 Site Description

Sylhet City Corporation area is 27.36 sq km, located in between 24°51´ and 24°55´ north latitudes and in between 91°50´ and 91°54´ east longitudes. It is bounded by Sylhet Sadar upazila on the north, Dakshin Surma upazila on the south, Sylhet Sadar upazila on the east, Dakshin Surma and Sylhet Sadar upazilas on the west. It is consisting of 27 Wards and 210 Mahallas with population about 2,70,606. Therefore, SCC represents one of the most densely populated areas and it is a challenge to SCC to fulfil the water demand of population in this area (Figure 1).

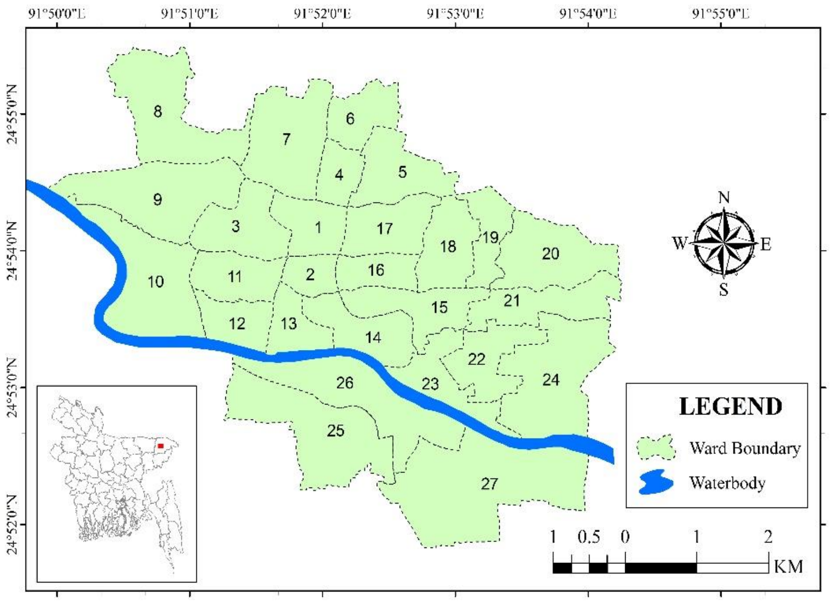


Figure 1: Administrative wards of Sylhet City Corporation

2.2 Pump Locations

At present groundwater is considered as the most important source of water supply in Bangladesh. In particular, the population density of Sylhet district is 990/km^2, which indicates a tremendous pressure on groundwater as it is the major freshwater source (Zafor et al., 2017). In the study area around 43 pumps are current operating. As described in Figure 2, 20 pumps were considered to determine the groundwater quality. These pumps were selected in such a way that the findings from this study would be generalized for the major area of the city. It should be noted that there is no pump in the south part of the city, consisting of the southern part from the Surma river.

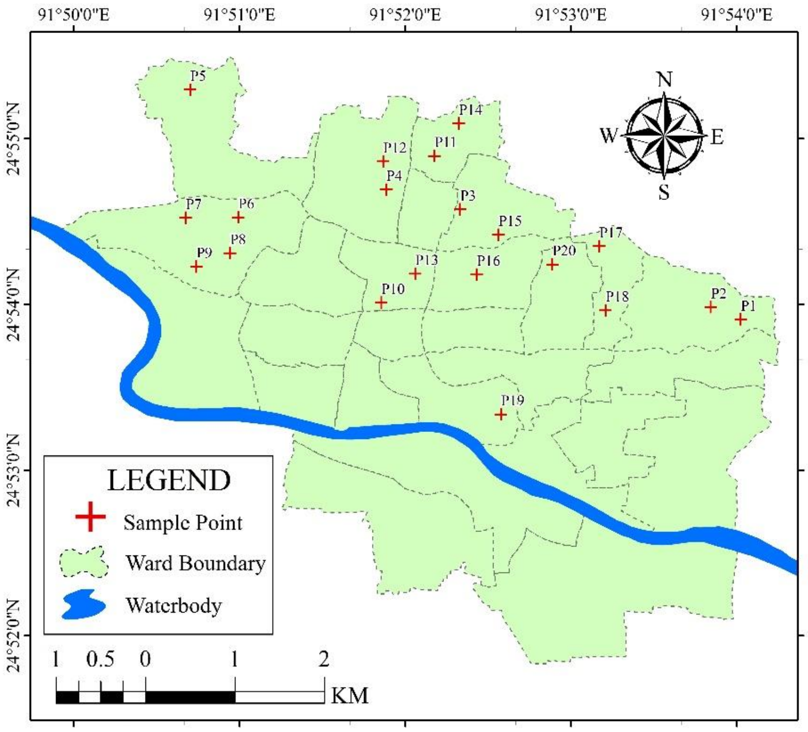


Figure 2: The Sampling pumps of Sylhet City Corporation

2.3 Data Collection and Processing

Water quality data were collected from the selected pumps during the pre-monsoon season in March 2019. The collected data are for the following parameters: Electrical conductivity (EC), Total dissolved solids (TDS), pH, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Nitrate (NO_3^{-}), Sulphate (SO_4^{2-}), Carbonate (CO_3^{2-}) and Bi-Carbonate (HCO_3^{-}). Physical parameters such as pH, TDS and EC were determined at on sites with a digital portable water analyser kit (Model Number: EZ9908). For the remaining analysis, every sample was stored in two sterile and dried polypropylene bottles of 500 ml each. One bottle from every sample was bought to the laboratory of DPHE Laboratory, Dhaka to evaluate Sodium (Na^{+}), Potassium (K^{+}) in each, by ASS. Another bottle from every sample was bought to the laboratory of CRTC Laboratory, Department of Civil & Environmental Engineering, SUST, Sylhet to analyse the rests. The test results were examined are presented in Table 1.

Table 1: Ionic variation of hydrochemical parameters of groundwater samples*.

ID	EC at 25ºC (mmohs/cm)	TDS	pH	K^{+}	Na^{+}	Mg^{2+}	Ca^{2+}	Cl^{-}	SO_4^{2-}	CO_3^{2-}	HCO_3^{-}	NO_3^{-}
P1	83	50	6.2	2.07	6	36.25	10.82	24	8	ND	42	0.5
P2	28	17	5.7	1.78	5	41.38	13.7	47	1.0	ND	74	0.7
P3	142	85	7.2	1.12	10	26.90	5.29	32	0.0	ND	55	0.8
P4	156	94	7.1	0.82	8	39.26	8.42	44	5	ND	71	1.1
P5	128	77	7.2	1.60	7	23.81	6.01	35	0.0	ND	72	0.4
P6	320	192	7.3	0.90	17	25.13	10.58	27	0	ND	142	0.2
P7	313	188	7.3	1.34	21	21.76	8.42	35	0	ND	144	0.6
P8	311	187	7.4	1.05	26	24.78	12.02	32	0	ND	145	0.5
P9	296	178	7.4	1.00	21	35.18	7.21	40	0	ND	144	0.4
P10	176	106	7.3	1.51	16	30.20	7.69	34	4	ND	109	0.7
P11	321	193	6.8	2.19	13	21.61	4.81	52	5.0	ND	61	1.8
P12	234	140	7.2	1.07	10	35.76	10.82	35	8.0	ND	86	2.2
P13	203	122	7.3	1.13	10	30.81	7.21	25	3.0	ND	97	1.0
P14	152	91	7.4	1.29	7	25.20	12.26	37	0.0	ND	76	1.6
P15	129	77	7.3	1.34	6	20	7.69	37	0.0	ND	72	0.6
P16	189	113	7.1	1.12	7	19.73	4.81	32	0	ND	75	0.8
P17	166	99	7.3	1.68	6	24.6	6.73	24	0	ND	56	0.1
P18	198	119	7.3	0.89	4	35.33	10.58	21	1	ND	99	1.3
P19	194	116	7.3	1.11	19	26.66	6.49	74	1	ND	88	0.9
P20	274	164	7.0	2.18	10	24.31	7.93	57	0	ND	46	2.8

*All values are in mg/L, except pH and EC in mmohs/cm. *ND* not detected

2.4 Graphical Methods for Hydrochemical Assessment

2.4.1 Stiff diagram

In a Stiff diagram a polygonal shape is created from four parallel horizontal axes extending on either side of a vertical zero axis. For a water sample, cations are plotted in milliequivalents per litre on the left side of the zero axis, one to each horizontal axis. Similarly, for the same sample, anions are also plotted in milliequivalents per litre on the right side, one to each horizontal axis. Stiff patterns are useful in making a rapid visual comparison between water from different sources.

2.4.2 Gibbs Diagram

Several factors control the chemistry of groundwater that can be related to the physical conditions of aquifer, bedrock mineralogy and weather condition. Gibbs Diagram helps to identify these controlling factors. The TDS vs. $Na^{+}/(Na^{+}+Ca^{2+})$ and TDS vs. $Cl^{-}/(Cl^{-}+HCO_3^{-})$ scatter plot are used to identify the occurrence of rock-water interaction processes (Gibbs, 1970) i.e. to identify the mechanisms that controlling the water chemistry. The diagram is divided into three fields, the rock-water interaction, precipitation and evaporation. In such diagrams, the samples lying at the centre of the curve indicate a source from the rock-water interaction.

2.4.3 Schoeller diagram

The Schoeller diagram is a histogram-type of diagram showing the log concentrations of solutes (the minor's component in a solution, dissolved in the solvent) in meq/L from a number of samples and shows the effects of mixing of waters. It is a semi-logarithmic plot, in which on the abscissa (on arithmetic scale), the various cations and anions are arranged in the order. In a typical Schoeller diagram, the concentrations of the main ionic constituents of each water sample (SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Ca^{2+}, Na^+/K^+) in meq/L are plotted on six equally spaced logarithmic scales, and points so plotted are then joined by straight lines. This diagram gives absolute concentration of different ions and not their relative concentration and, in addition, the concentration differences among various samples of groundwater.

2.4.4 Wilcox's diagram

For judging the suitability of water quality for irrigation, Wilcox proposed a diagram with respect to a combination of EC and the sodium percentage (%Na^+). This combination classifies the diagram into five zones of excellent too good with EC values less than 700 mmohs/cm (<700 mmohs/cm), good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable, with increasing salinity hazard and sodium hazard for irrigation.

2.4.5 US Salinity Laboratory (USSL) Diagram

This diagram was suggested by Wilcox and US Salinity Laboratory staff to evaluate the suitability of water for irrigation use. There is a significant correlation between the sodium adsorption ratio (SAR) values for irrigation water and the amount of sodium absorbed by the soil. The structure of the soil is due to the dispersion of clay particles, which can destroy if the water is high in sodium and low in calcium, which is used for irrigation purposes then the water is complex in cation exchange and can be saturated with sodium. USSL proposed an important criterion based on salinity and sodium hazards. The total dissolved solids, measured in terms of specific electrical conductance (EC), gives the salinity hazard of irrigation water. In addition to the risk of salinity, excess of sodium ions in water make it unsuitable for exchangeable calcium and magnesium ionized soils. If the percentage of Na^+ to $Ca^{2+} + Mg^{2+}$ is considerably above 50 in the irrigation water, soils containing exchangeable calcium and magnesium take up sodium in exchange for calcium and magnesium causing deflocculating and impairment of the tilth and permeability of soils. The sodium hazard in irrigation water is evaluated by determining SAR, which is given as

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

where the concentrations are expressed in meq/L.

3. RESULTS AND DISCUSSION

3.1 Reliability Checking for Hydrochemical Data

All collected ions from each pump/sample are presented in Table 2 in meq/L. In a water sample, in terms of meq/L, the total of major cations is supposed to be equal to the total of major anions.

Table 2: Ions in millirquivalents per liter (meq/L)

	Cations (meq/L)				Anions (meq/L)				
ID	**K^+**	**Na^+**	**Mg^{2+}**	**Ca^{2+}**	**Cl^-**	**SO_4^{2-}**	**CO_3^{2-}**	**HCO_3^-**	**NO_3^-**
P1	0.0529	0.2610	2.9830	0.5399	0.6770	0.1666	ND	0.6883	0.0109
P2	0.0455	0.2175	3.4050	0.6837	1.3260	0.0208	ND	1.2130	0.0152
P3	0.0287	0.4350	2.2140	0.2640	0.9026	0.0000	ND	0.9018	0.0174
P4	0.0210	0.3480	3.2310	0.4202	1.2410	0.1041	ND	1.1640	0.0239
P5	0.0409	0.3045	1.5950	0.2999	0.9872	0.0000	ND	1.1800	0.0087
P6	0.0230	0.7391	2.068	0.528	0.7616	0.0000	ND	2.3279	0.0043
P7	0.0343	0.9130	1.7910	0.4202	0.9872	0.0000	ND	2.3607	0.0130
P8	0.0269	1.1310	2.0390	0.5998	0.9026	0.0000	ND	2.3770	0.0109
P9	0.0256	0.9130	2.8950	0.3598	1.1280	0.0000	ND	2.3607	0.0087
P10	0.0386	0.6960	2.4850	0.3838	0.9590	0.0833	ND	1.7860	0.0152
P11	0.0560	0.5655	1.7780	0.2400	1.4670	0.1041	ND	0.9997	0.0391
P12	0.0274	0.4350	2.9430	0.5399	0.9872	0.1667	ND	1.4090	0.0478
P13	0.0289	0.4350	2.5350	0.3598	0.7052	0.0625	ND	1.5900	0.0217
P14	0.0330	0.3045	2.0740	0.6118	1.0440	0.0000	ND	1.2460	0.0348
P15	0.0343	0.2610	1.6460	0.3838	1.0440	0.0000	ND	1.1800	0.0130
P16	0.0287	0.3045	1.6240	0.2400	0.9026	0.0000	ND	1.2290	0.0174
P17	0.0430	0.2610	2.0240	0.3358	0.6770	0.0000	ND	0.9178	0.0022
P18	0.0228	0.1740	2.9070	0.5280	0.5923	0.0208	ND	1.6220	0.0283
P19	0.0284	0.8265	2.1940	0.3239	2.0870	0.0208	ND	1.4420	0.0196
P20	0.0558	0.4350	2.0000	0.3957	1.6080	0.0000	ND	0.7539	0.0609

However, an acceptable analysis may have a difference that is less than 10%. Unfortunately, in this study only 10 out of 20 water samples fulfilled the acceptable requirement of < 10%. While the most charge balance errors (CBE) of waters from various locations were sensible, it was too extreme for pump-1, which was way off with 42.64% (Table 3). This might identify the imprecision of the lab analysis, lack of ions or metals analysed. However, electrical imbalance may be due to the fact that the dissolved species of elements or compound that are buffering in minerals of the area might not be included in ions balance calculation. Despite these obvious discrepancies, the data provided in this study are of original. Hence, further studies are needed for proper understanding of the chemical composition of groundwater of SCC area. Nevertheless, the current study is one of the very first researches to interface hydro chemical techniques in groundwater quality analysis in Sylhet City Corporation.

Table 3: Charge balance errors of various water samples\

ID	∑Cations (meq/L)	∑Anions (meq/L)	CBE (%)	Data Quality	ID	∑Cations (meq/L)	∑Anions (meq/L)	CBE (%)	Data Quality
P1	3.8368	1.5428	42.64	Poor	**P11**	2.6395	2.6099	0.56	Good
P2	4.3517	2.575	25.65	Poor	**P12**	3.9453	2.6107	20.36	Poor
P3	2.9417	1.8218	23.51	Poor	**P13**	3.3587	2.3794	17.07	Poor
P4	4.0202	2.533	22.69	Poor	**P14**	3.0233	2.3248	13.06	Poor
P5	2.2403	2.1759	1.46	Good	**P15**	2.3251	2.237	1.93	Good
P6	3.3581	3.0938	4.10	Good	**P16**	2.1972	2.149	1.11	Good
P7	3.1585	3.3609	-3.10	Good	**P17**	2.6638	1.597	25.04	Poor
P8	3.7967	3.2905	7.14	Good	**P18**	3.6318	2.2634	23.21	Poor
P9	4.1934	3.4974	9.05	Good	**P19**	3.3728	3.5694	-2.83	Good
P10	3.6034	2.8435	11.79	Poor	**P20**	2.8865	2.4228	8.73	Good

3.2 Display of Water Quality Data

3.2.1 Stiff Diagram

The plots of major ions (based on meq/L) are presented in Figure 3 with Stiff diagrams, which clearly illustrate the ionic (cationic and anionic) dominance pattern of different water sources/pumps. It is obvious that Mg^{2+} among cations and Cl^- and/or HCO_3^- among anions dominate in almost all the samples of groundwater. However, in a board aspect, the Mg-Na-Ca-Cl-HCO_3 hydrochemical facies is dominant in the groundwater of SCC area.

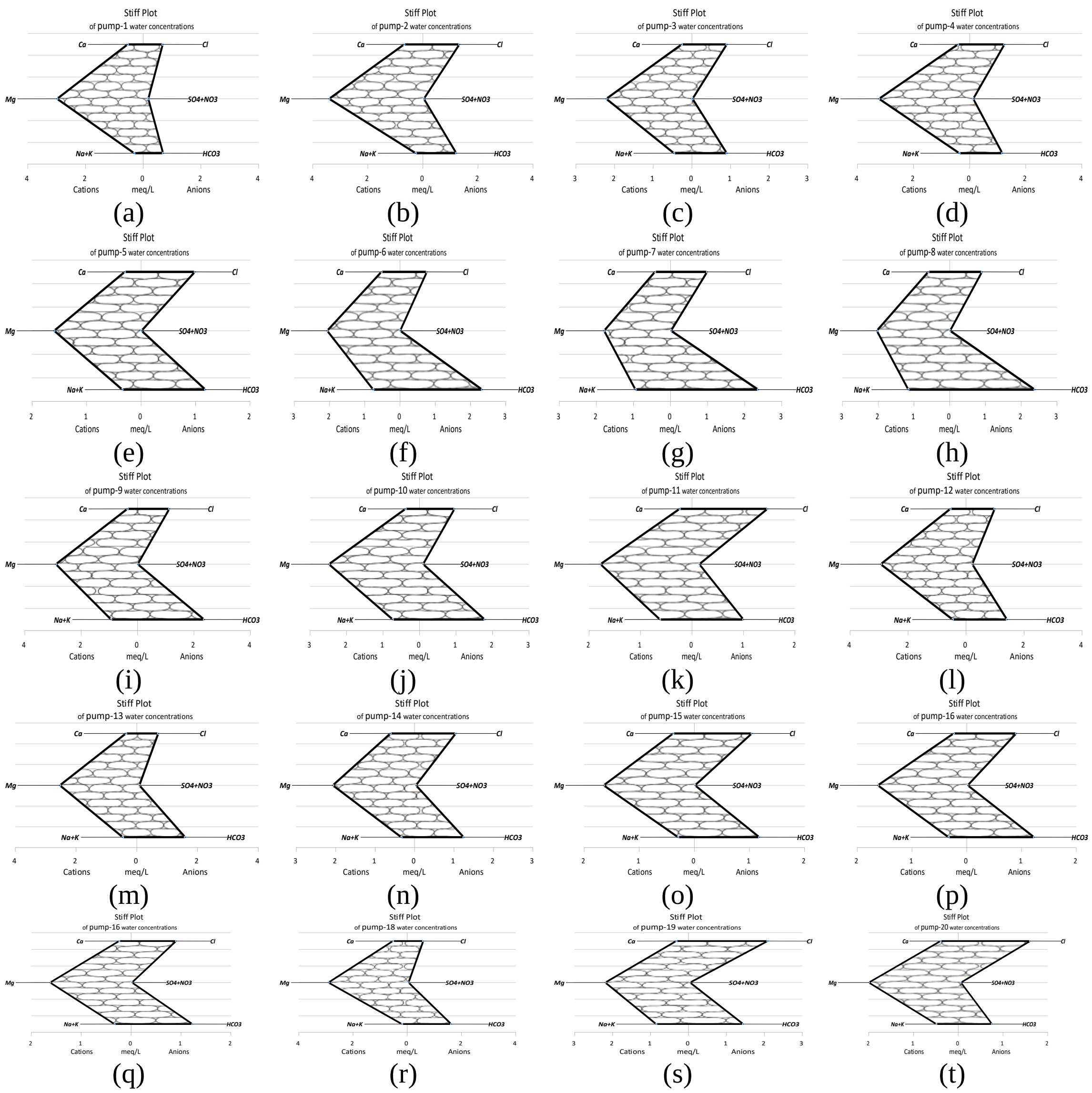
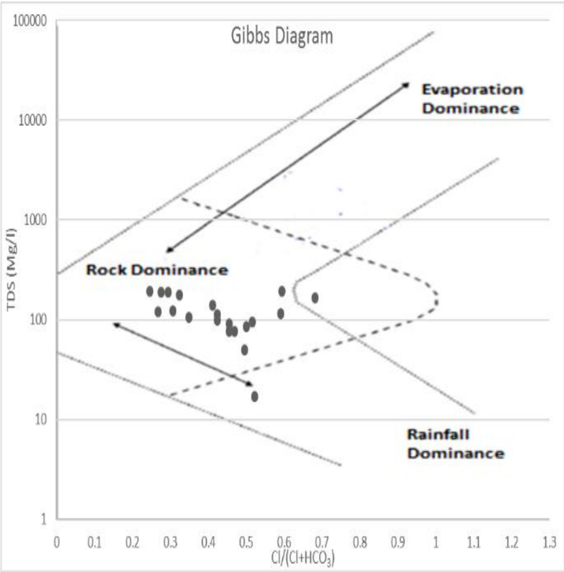


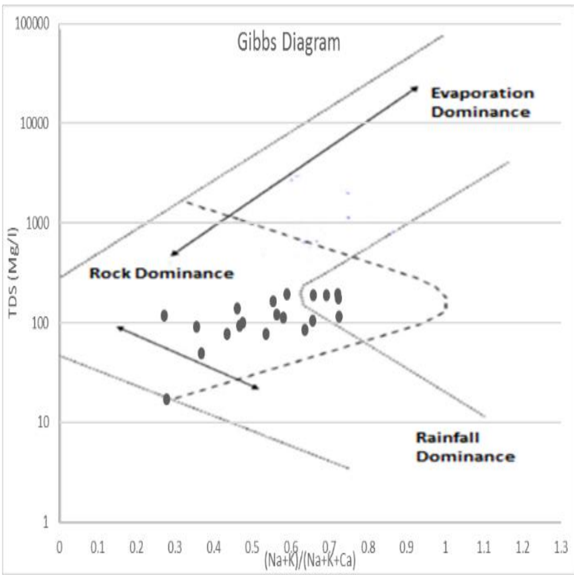
Figure 3: Stiff diagrams for all selected pumps.

3.2.2 Gibbs Diagram

Figure 4(a) and 4(b) represent Gibbs TDS vs. Na^+/ ($Na^+ + Ca^{2+}$) and TDS vs. Cl^-/ (Cl^-+HCO_3^-) scatter plots plotted using groundwater samples from the study area. The figures show that almost all the samples fall in the rock area. The Gibbs's diagrams suggest that chemical weathering of the rock forming minerals is the main processes that contribute the ions to the water in the study area. It is interesting to note that during pre-monsoon, precipitation has no dominating effect and no point falls on the precipitation dominating area. As the water quality data were collected from the selected pumps during the pre-monsoon season in March 2019, the conclusion from this diagram is more practical. Anthropogenic activities may also increase the TDS value (Hem, 1985) and then the samples tend to fall on evaporation dominance area. However, this is not the case in this study area. It contradicts with the finding from stiff diagrams that indicated anthropogenic activities have influence on the quality of ground water. It may for the fact that the cation Mg^{2+} is not considered here, which is the main dominant cation in the SCC area.



(a)



(b)

Figure 4: Gibbs plot for cations and anions in the study area

3.2.3 Schoeller Diagram

The Schoeller diagram in Figure 5 shows the log concentrations of ions SO_4^{2-}, HCO_3^-, Cl^-, Mg^{2+}, Ca^{2+} and Na^++K^+ in meq/L from the samples. It shows that, except and SO_4^{2-}, the selected waters are generally high in Ca^{2+}, HCO_3^-, Cl^-, Na^++K^+ concentrations, it is reflecting the possible mixing of the deep aquifers with the groundwater. All the water samples exhibit a unique pattern and similar “fingerprints”.

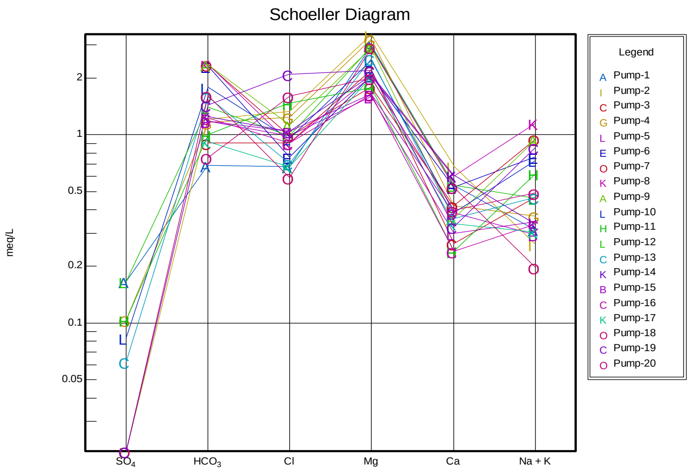


Figure 5: Chemical analysis of ground water plotted on the schoeller diagram

3.2.4 Wilcox's Diagram

As shown in Figure 6, the wilcox's diagram indicates that all of the groundwater samples fall in the fields of very good to good. Thus, the dwellers of the city can easily and effectively use the supplied water for irrigation purposes.

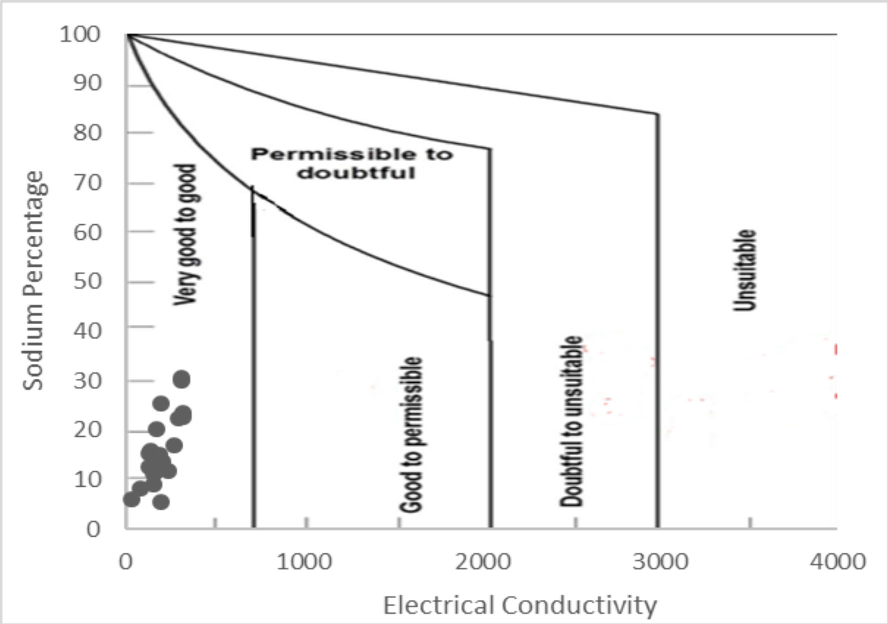


Figure 6: Wilcox's classification of groundwater quality for irrigation

3.2.5 US Salinity Laboratory (USSL) Diagram

From the below figure of USSL diagram, it is identified that 20 water samples (100%) of pre-monsoon seasons belongs to C1-S1 and C2-S1 types and suggesting that the groundwater of SCC area is good for irrigation purposes.

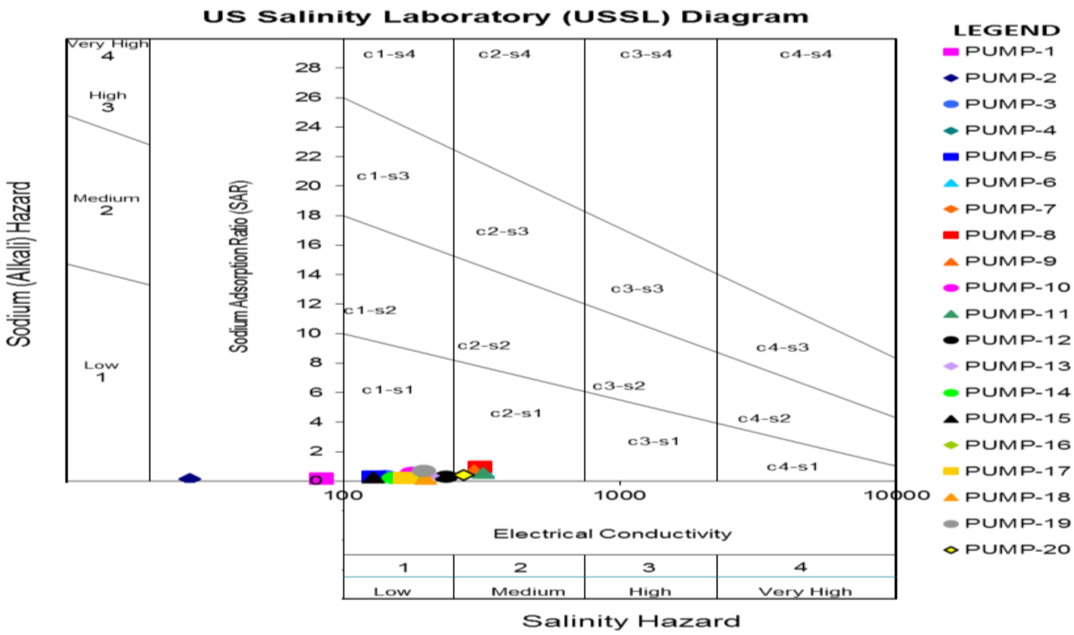


Figure 7: USSL diagram for classification of groundwater quality for irrigation

4. CONCLUSIONS

All the selected groundwater samples are dominated by Mg^{2+} among cations and Cl^- and/or HCO_3^- among anions. In a board aspect, Mg-Na-Ca-Cl-HCO_3 is the hydrochemical facies that dominates in the groundwater of SCC area. The fossil and mineralogical groundwater characterizes the Mg-Na-Ca-Cl facies in the middle part of the city, whereas the Mg-Na-Ca-HCO_3 facies in the western part which is linked with recently recharge water of $CaHCO_3$ type, atmospheric precipitation and dissolution of silicate minerals. The Gibbs's diagrams suggest that chemical weathering of the rock forming minerals is the main processes that contribute the ions to the pre-monsoon water in the study area. Almost all the water samples exhibit a unique pattern and similar "fingerprints". EC (salinity hazard), Sodium percent (Na%) and Sodium adsorption ratio (SAR) were used to assess the water quality for irrigation purposes. The water in the study area have been found very well for irrigation. Urbanization and agricultural activities are not responsible for water quality. This is because nitrate and sodium absorption ratios present in the study area are not high.

5. LIMITATIONS AND FURTUR STUDY

About 50% of the samples data (10 out of 20) have not passed the quality control tests, major ionic balance that is necessary for using classical hydrochemical plotting. Thus, some findings might be questioned. To ensure utmost reliability and validity in conducting a laboratory-based study on hydrochemical properties of water, a large sample size is required, which is absent in here. The direction of groundwater flow could not be fully assessed, because of inadequate data. Frequent monitoring of the pumps is also required for proper evaluation. This is not possible in this study. No comparison was made between the quality of groundwater and surface water, which is necessary for proper evaluation. There is no opportunity to compare the present study with others. This is because of the absence of available studies in SCC area that are in the line of this work. As this study aimed at to gain some knowledge about the underlying hydrochemical interactions, it has not yet investigated other approaches e.g. supervised classification techniques, state-of-the-art chemometrics techniques or pattern recognition processes including multiple linear regression (MLR), multivariate analysis, etc. As the continuation of current study, a further study will immediately be done using multivariate techniques.

6. RECOMMENDATIONS

The overall quality of groundwater is not harmful but continuous evaluation is necessary for proper maintenance. Because of continuous exploitation of groundwater for domestic uses and drinking purposes, the rock-forming minerals continue to dissolve; thereby there is a risk of resulting in a continuous increase in the TDS content of the study area. So, the alternative sources for water should be searched. It is suggested to use surface water with proper treatment. The absence of a reliable sewer collecting system directly resulted in the poor water quality in SCC area. Such a sewer collecting system should be developed. This will help to avoid anthropogenic effects. A detailed study is needed based on all possible parameters and all pumps under SCC. The study area is covered by different geological formations. Therefore, a detailed study with mineral and chemical composition of the rocks is further needed. Future studies should incorporate hydrological parameters into the chemical assessment e.g. water levels, thermal profiles, depth profiles (this was attempted in the field but not successful). Some of the pumps are maintained by government who have a limited budget. So, one option may be handover the pumps to private institutions, NGO's for batter maintenance.

REFERENCES

Adams, S., Titus, R., Pietersen, K., Tredoux, G., & Harris, C. (2001). Hydrochemical characteristics of aquifers near Sutherland in the Western Karoo, South Africa. *Journal of Hydrology*, *241*(1–2), 91–103. https://doi.org/10.1016/S0022-1694(00)00370-X

Alberto, W. D., María del Pilar, D., María Valeria, A., Fabiana, P. S., Cecilia, H. A., & María de los

Ángeles, B. (2001). Pattern Recognition Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality. A Case Study: *Water Research*, *35*(12), 2881–2894. https://doi.org/10.1016/S0043-1354(00)00592-3

Chenini, I., & Khemiri, S. (2009). Evaluation of ground water quality using multiple linear regression and structural equation modeling. *International Journal of Environmental Science & Technology*, *6*(3), 509–519. https://doi.org/10.1007/BF03326090

Gibbs, R. J. (1970). Mechanisms Controlling World Water Chemistry. *Science*, *170*(3962), 1088–1090. https://doi.org/10.1126/science.170.3962.1088

Hem, J. D. (1985). Study and interpretation of the chemical characteristics of natural water. In *Water Supply Paper*. https://doi.org/10.3133/wsp2254

Hounslow, A. (1995). *Water quality data : analysis and interpretation*. Retrieved from https://www.worldcat.org/title/water-quality-data-analysis-and-interpretation/oclc/31901359

Iliopoulos, V., Stamatis, G., & Stournaras, G. (2011). Marine and human activity effects on the groundwater quality of Thriassio Plain, Attica, Greece. In *Advances in the Research of Aquatic Environment* (pp. 409–416). https://doi.org/10.1007/978-3-642-24076-8_48

Md. Munna, G., Islam, S., Hoque, N. M. R., Bhattacharya, K., & Nath, S. D. (2015). A Study on Water Quality Parameters of Water Supply in Sylhet City Corporation Area. *Hydrology*, *3*(6), 66. https://doi.org/10.11648/j.hyd.20150306.12

Zafor, M. A., Alam, M. J. Bin, Rahman, M. A., Amin, M. N., Zafor, M. A., Alam, M. J. Bin, Amin, M. N. (2017). The analysis of groundwater table variations in Sylhet region, Bangladesh. *Environmental Engineering Research*, *22*(4), 369–376. https://doi.org/10.4491/eer.2016.152

Zhu, C., & Anderson, G. M. (Gregor M. (2002). *Environmental applications of geochemical modeling*. Cambridge University Press.

A CASE STUDY & LABORATORY INVESTIGATION ON THE PRESENCE OF SALINITY IN DRINKING & IRRIGATION WATER AT COASTAL AREAS IN BANGLADESH

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ABSTRACT

Salinity in coastal region is a common downside in Bangladesh which is predicted to be exacerbated by global climate change and sea-level rise. Salinity is largely the presence of dissolved inorganic solutes in aqueous solution. The presence of soluble salts within the groundwater and surface water bodies as well as in the soil is one of the major environmental concern worldwide. The freshly deposited alluviums in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides. Salt water intrusion due to reduction of freshwater flow from upstream, and over withdrawal of coastal groundwater and fluctuation of soil salinity are major problem of coastal regions. Due to the presence of salinity in groundwater further as surface water, the folks of the southwest region are plagued by issues associated with drinking, irrigation, agriculture, fisheries and alternative uses. This research was carried out in three districts (Patuakhali, Bhola and Barguna) which are located in the south-central region of Bangladesh to spot the salinity level and other water quality parameters from these areas. Relatable parameters such as salinity-Electrical conductivity (dS/m), chloride concentration (mg/l), Hydrogen ion concentration, Hardness, Salinity, and Iron concentration of the groundwater and surface water of these areas were determined by laboratory experiments. This was done by analyzing waste water samples in the laboratory of World University of Bangladesh. Besides, a questionnaire survey has been disbursed throughout field visits. To get an overall idea about the impacts of salinity on drinking water and agriculture, questionnaire interview was carried out in ten villages of these three districts. It has been discovered that in Patuakhali the highest percentage of people agreed that each drinking and irrigation water are littered with salinity. Besides, this study also found that 80% and 90% crop production in Patuakhali and Barguna is hampering for salt water in a winter season attributable to salinity and low well water layer. The study shows that the Bhola district's surface water has the highest electrical conductivity of 3749 µS/cm and the lowest electrical conductivity was found in the surface water of Barguna (190 µS/cm). An emperical equation has been used to measure the salinity of water directly from the Electrical Conductivity (EC) and compared with respective guideline. It has been found that Patuakhali district is in most vulnerable condition from the perspective of salinity. As per the opinion of the respondents, presence of salinity is creating severe problems in irrigation in all these three regions. In addtion, most of the people in these three districts agreed with the negative impact of salinity on health. Various water borne diseases like diarrhoea, skin problems, stomach pain and typhoid became very common in these regions. Again, Chloride concentration is also highest in surface water of Bhola, whereas Barguna district's surface water and Bhola district's deep tubewell water has equal and lowest value of chloride concentration. Based on the questionnaire assessment and laboratory test it is found that, overall water quality of these three areas is not advisable for both drinking and irrigation purposes.

Keywords: *Salinity, Coastal aquifer, Climate change, Sea-level rise, Freshwater, Questionnaire survey.*

1. INTRODUCTION

Salinity intrusion is among the main environmental issues throughout the globe. Bangladesh is a growing and developing country. This development is dependent on associate agricultural production system which constitutes the largest part of our economy. Along side the issues related to drinking water, salinity issues are impediments to both the agricultural and economic development. The coastal region is predicted to loss most crop in future compared to the other regions of the country (Hasan et. al, 2017). Most of the land remains fallow in the dry season (January- May) because of soil salinity, lack of good quality irrigation water and late draining condition (Karim *et al*., 1990) At present salinity is becoming a major concern to the people of the southwest region of Bangladesh. Although Hasan et. al, 2018 showed the decrease on production of Boro and Aman rice in Bangladesh; the software DSSAT was not capable of assessing the impact of salinity on the yield of crop. This study aims at examining the presence of salinity in the water bodies of coastal regions and taking a survey on the farmers to link the results of salinity on crop yield.

Salinity means the presence of major dissolved inorganic solutes (essentially Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}) in aqueous solution. These causes reduction in agricultural productivity, decline in the quality of water supplies for drinking, irrigation, and industrial use, loss of biodiversity and conjointly injury to urban infrastructure.

Electrical conductivity is a measure of the saltiness of the water and is measured on a scale from 0 to 50,000 uS/cm. When the irrigation water salinity exceeds the crop tolerance limit, the yield of the irrigated crop decreases significantly with time.

Table 1: Guidelines for irrigation water quality (Adapted from Victorian Irrigation Research and Advisory Committee, 1980, Quality aspects of farm water supplies)

Electrical conductivity(dS/m)	Use
0-0.3	• can be used for most crops on most soils with all methods of water application. • Little likelihood that a salinity problem will develop.
0.3-0.8	• can be used if a moderate amount of leaching occurs. • Plants with a medium salt tolerance can be grown, usually without special practices for salinity control.
0.8-2.25	• cannot be used on soils with restricted drainage. • Even with adequate drainage, special management for salinity control may be required. • not suitable for irrigation under ordinary conditions.
2.25-5.80	• Not suitable for human consumption or irrigation
Over 5.80	• Occasional emergency use for salt tolerant crops on permeable well drained soils under good management.

Table 2: The taste of drinking water is rated according to salinity as follows (Australian Drinking Water Guidelines)

Salinity (mg/L)	Quality
0-600	Good
600-900	Fair
900-1200	Poor
Over 1200	Unacceptable

Seawater intrusion is one of the major reasons behind groundwater salinity (Todd, 2001). The position of the saline-fresh water interface is dependent on through flow from the upper basin and local seasonal recharge. Groundwater salinity may also occur due to the following reasons-

i) Change in the position of saline-fresh water interface

ii) Presence of a saline front in the upper aquifer
iii) Presence of the saline wedge in deeper aquifer
iv) Up-coming of sea water.
v) Low seasonal recharge.

The main objective of the study is to evaluate aquifer salinity situation and its impacts on drinking water and agriculture in Patuakhali, Bhola and Barguna district's few selected areas. Besides, studying about the existing water use pattern of the people at coastal areas and assessing the quality of the water used in daily life were investigated in this research.

2. METHODOLOGY

The methodology employed in the study are questionnaire interview and application of participatory rural appraisal (PRA) tools to urge an understanding of the salinity condition in the study space, collection of secondary data, and eventually analysis of the information through questionnaire interview and PRA tool as well as secondary data in the context of research objectives. The data collected in the study area were mostly qualitative.
The study area was visited several times for assortment of water sample, photographic data collection and questionnaire survey. There we have meet native folks, farmers, fisherman and workers for concisely understanding the present environmental condition of our study area. Brief information about water salinity, water quality, problem with households and irrigation water quality of that area were collected. Figure 1 shows the flow chart of the methodology.

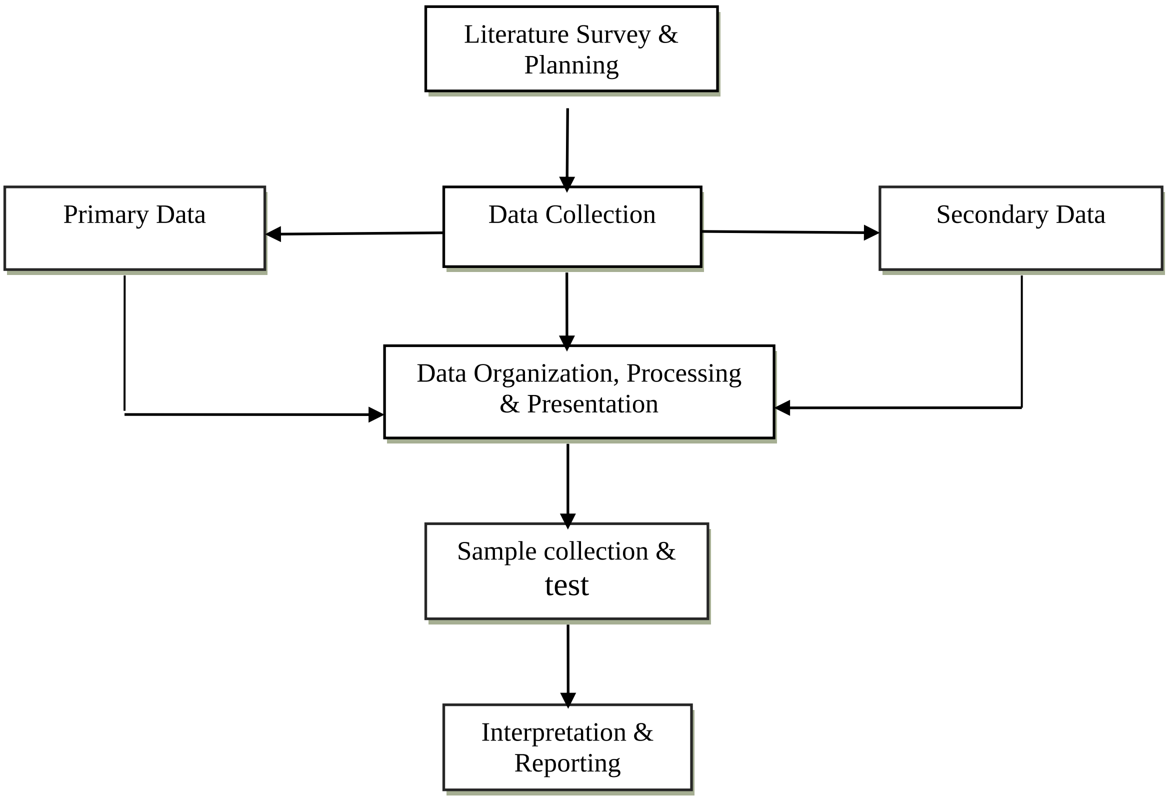

Figure 1: Flow chart presenting the methodology followed for the present study.

2.1 Collection of water samples

Water sample was collected from midstream by dipping each bottle at approximately 20 to 30 cm below the water surface. The sampling containers were property cleaned before use and rinsed with the water to be sampled before sampling.

2.2 Primary Data Collection

2.2.1 Questionnaire survey

A questionnaire survey has been carried out during two field visits. To get an overall idea about the impacts of salinity on drinking water and agriculture, questionnaire interview was carried out in thirteen villages under some Unions in these three districts. The information regarding demographic view of theses village under various union, the statistics of the number of people surveyed in this regions and total number of people living in those areas are provided in Table 4. It is to be noted that the data was directly collected from community report of population and housing census 2011 by Bangladesh Bureau of Statistics (BBS)

2.2.2 Primary data collection through PRA

Participatory Rural Appraisal (PRA) is extensively used in socio-economic survey. The PRA approach was employed in this study to assess people's perception about the salinity impact on drinking water and agriculture. The PRA has different type tools of which the Key informant interview and Transect walk were used.

2.2 Secondary Data Collection

Any research work requires the combination of field data (primary data) and existing data (secondary data) on the particular study area. The impacts of salinity for irrigation in the study areas, was estimated based on the secondary data sources.

2.3 Data analysis and plotting graphs

All the major and secondary data collected has been analyzed separately and carefully to confirm that the collected data is dependable and true. Finally, all the analyzed data have been integrated and presented as paragraphs, tables and graphs and putted in the report.

2.4 Laboratory Tests and Results

2.4.1 Measurement of Electrical Conductivity

Salinity is a measure of the amount of salts in the water. Because dissolved ions increase salinity as well as conductivity, the two measures are related. Conductivity is measured by a probe, which applies voltage between two electrodes. The drop in voltage is used to measure the resistance of the water, which is then converted to conductivity. The most commonly used EC units is deci-Siemens per metre (dS/m).

2.4.2 Measurement of Salinity

Salinity can be measured in various way. In most cases, it is directly calibrated from specific gravity, total dissolved solid (TDS), Electrical Conductivity and such other parameters. In this research, a calibration equation has been directly used to convert Electrical Conductivity to salinity.

$$Salinity = EC^{1.0878} \times 0.4665 \times 1000 \tag{1}$$

Where Electrical Conductivity is in ds/m and Salinity will be found in mg/L.

Along with the measurement of salinity some other essential parameters like Hardness, Chloride, Iron and Arsenic Concentration was also measured in conventional method.

3. RESULTS AND DISCUSSIONS

3.1 Results from Questionnaire Survey

The results of the study are presented in graphical form along with a discussion on the overall salinity situation in our study areas**.** Questionnaire survey was carried among people of different occupation. Besides, the statistical view of total number of people in various regions of the Unions in these three districts and the number of people surveyed in those area are provided in Table 4.

Table 3: Occupation of the respondents

Occupation	Patuakhali	Barguna	Bhola
Farmer	50%	90%	60%
Businessman	40%	-	-
Boat Craftman	-	-	10%
Motorcycle driver	10%	-	-
Fisherman	-	-	30%
Student	-	10%	-

Table 4: Statistical Data of the surveyed areas

<table>
<tr><th>Districts</th><th>Total Number of Unions in District</th><th>Name of the Unions surveyed</th><th>Villages surveyed</th><th>Total Population (adapted from community report of population and housing census 2013)</th><th>Number of people surveyed</th></tr>
<tr><td rowspan="5">Patuakhali</td><td rowspan="5">71</td><td rowspan="2">Mohipur</td><td>Mohipur</td><td>3569</td><td>35</td></tr>
<tr><td>Bipinpur</td><td>2132</td><td>21</td></tr>
<tr><td rowspan="3">Mithaganj</td><td>Mithaganj</td><td>1108</td><td>12</td></tr>
<tr><td>Aramganj</td><td>1005</td><td>12</td></tr>
<tr><td>Tegachhia</td><td>4526</td><td>44</td></tr>
<tr><td rowspan="4">Barguna</td><td rowspan="4">42</td><td rowspan="3">Barabagi</td><td>Natun Para</td><td>480</td><td>24</td></tr>
<tr><td>Pajrabhanga</td><td>759</td><td>37</td></tr>
<tr><td>Chowla</td><td>779</td><td>38</td></tr>
<tr><td>Gulisakhali</td><td>Gulisakhali</td><td>4133</td><td>40</td></tr>
<tr><td rowspan="4">Bhola</td><td rowspan="4">68</td><td rowspan="2">Char Manika</td><td>Dakshin Char Aicha</td><td>5246</td><td>50</td></tr>
<tr><td>Char Faruquee</td><td>472</td><td>22</td></tr>
<tr><td>Hazariganj</td><td>Char Fakira</td><td>7211</td><td>50</td></tr>
<tr><td>Char Fasson</td><td>Char Fasson</td><td>1590</td><td>16</td></tr>
</table>

Table 4 illustrates the various unions those were surveyed for this case study. Total population in corresponding areas was collected from community census reports of Patuakhali, Barguna and Bhola zilla published by Bangladesh Bureau of Statistics (BBS) Statistics and Informatics Division (SID).
It is noteworthy to mention that the quantity of respondents was taken as 5% of total population for the area having population less than 800 and 1% for the other regions.

3.1.1 Proportion of various water borne diseases due to presence of salinity

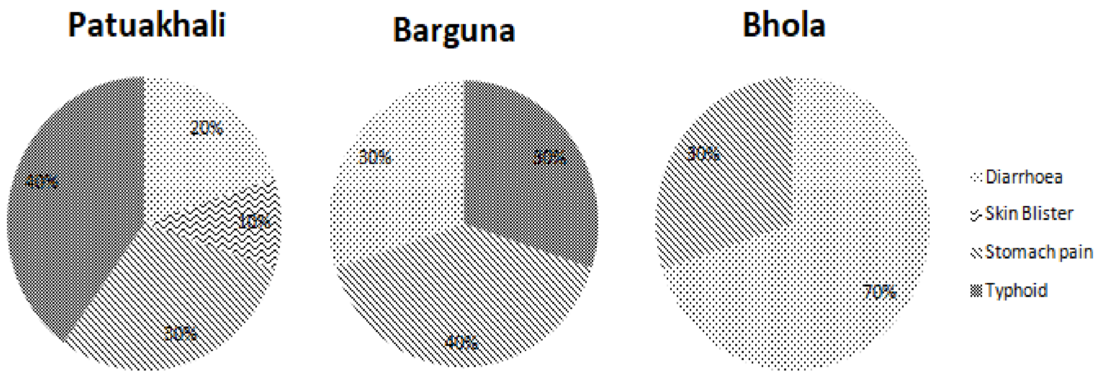

Figure 2: Water-borne diseases due to salinity according to the view of respondents

It is seen from figure above that, In Patuakhali 40% and Barguna 30% people are effected by typhoid fever. In Patuakhali 30%, Barguna 40%, Bhola 30% people are affected by stomach pain. In Patuakhali 20%, Barguna 30%, Bhola 70% people are effected by diarrhoea and 10% people in Patuakhali have skin blister by using salt water.

3.1.2 Wastage of crop due to presence of saline water

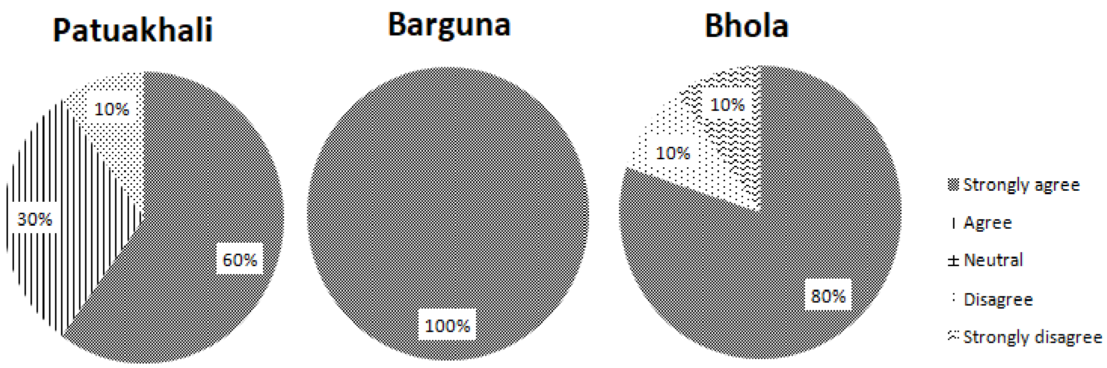

Figure 3: Respondents' thought about the wastage of crop due to presence of saline water

It is observed from figure 3 that the proportion of people who strongly agree that salt water destroys crop production are predominant in all three districts. Only 10% people both in Patuakhali and Bhola disagree with these phenomena.

3.1.3 Salinity Problem in drinking water

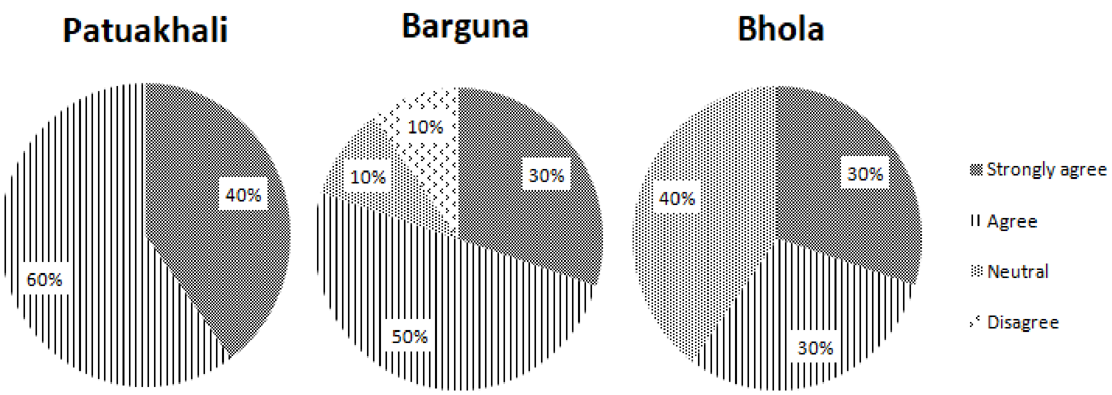

Figure 4: Percentage of people drinking salt water

Figure 4 represents that- majority of people in these three districts think that the drinking water contains salinity.

3.1.4 Salinity Problem in irrigation water

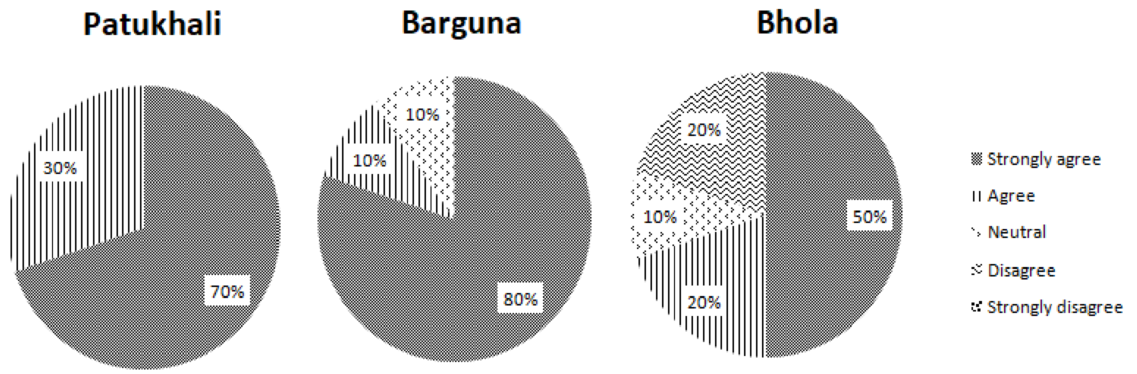

Figure 5: Respondents' opinions about the presence of salinity in irrigation water

It is clearly seen from the figure 5 that more than 50% people in Patuakhali, Barguna and Bhola experienced moderate level of salinity content in irrigation water. The proportions of people who disagreed with salinity problem in irrigation water are much lower in all three regions.

3.1.5 Respondents' opinion about effect of saline water on crop production

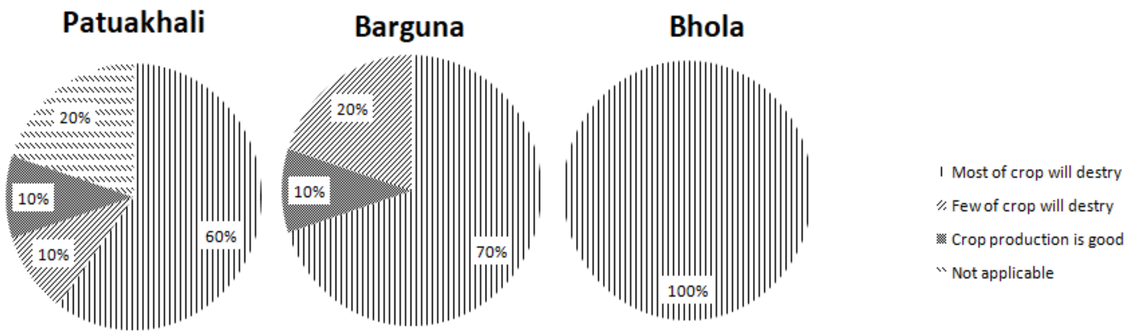

Figure 6: Effect of saline water on crop production:

Again, it has been found that 60% people in Patuakhali, 70% in Barguna and around 100% people in Bhola zilla gave their opinion on destruction of crop due to salinity.

3.1.6 Difficulties of collecting fresh water

Besides, another questionnaire survey was carried out about the difficulties of collecting fresh water which contains no salinity problems. The results are shown in figure below:

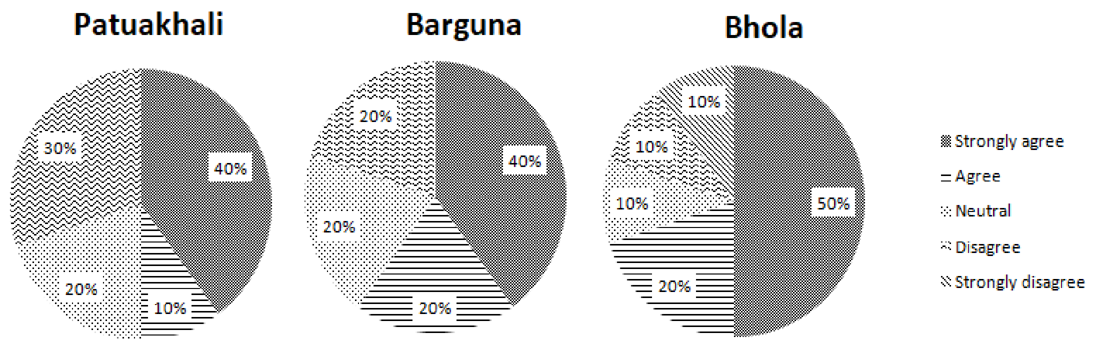

Figure 7: Difficulties in collecting fresh water

It is seen from figure 7 that, around 50% respondents in Patuakhali agree (Strongly agree 10% and agree 40%) and 30% disagree about their difficulties of collecting fresh water. In Barguna the proportion of people who agree with this problem is much higher (60% in total). In Bhola strongly 50% people rigidly agree and 20% nearly agree about this problem of collecting fresh water.

3.1.7 Seasons when crop production is hampered due to salinity

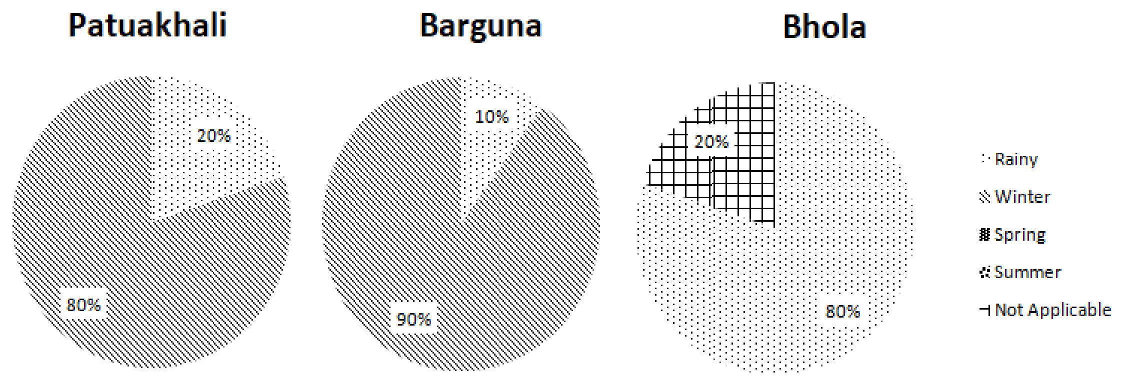

Figure 8: Seasons when crop production is hampered due to salinity

According to Figure 8, it is clearly observed that around 80%-90% crop damaged due to salt water is occurred during winter season both in Patuakhali and Barguna. Only exception is in Bhola where 80% crop production is hampered due to salinity in winter.

3.2 Results from Laboratory test

3.2.1 Electric Conductivity

The Standard value of EC of water according to Bangladesh Environment Conservation rule is 0.5-1.5 ds/cm. According to WHO standard the value is same. The EC value of surface water in Patukhali was 3.78 ds/m which was much higher than the values found in Barguna and Bhola zilla.(0.42 and 0.19 respectively). On the contrary, EC values of ground water were found 2.24 ds/m and 2.19 ds/m in Barguna and Bhola which are higher than that of Patuakhali. These higher values exceed both Bangladesh and WHO standards. On the authority of Table 1, Ground water of Bhola and Barguna districts is recommended for drinking purposes but special treatment and drainage should be provided prior to use for irrigation. But surface water of Patuakhali is absolutely unsuitable for drinking and not recommended for agriculture.

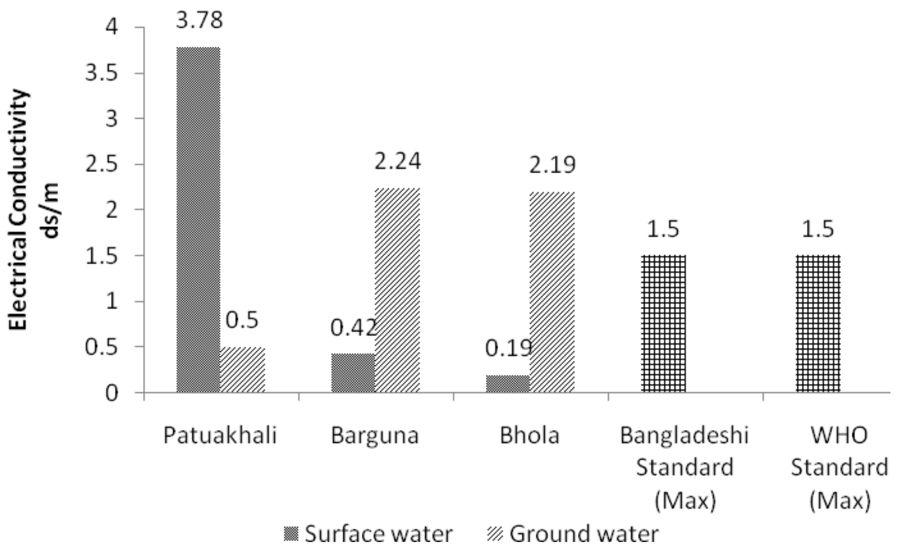

Figure 9: Electrical Conductivity of deep tube well water and surface water

3.2.2 Salinity

As mentioned before, salinity was determined using an imprical equation (stated as equation 1). Figure 10 shows that salinity is direct proportional to the values of EC measured. According to Table 2 surface water quality of Patuakhali zilla is considered as impermissible for drinking purposes as the salinity is over 1200 mg/L. Besides, the ground water quality in Barguna and Bhola districts are also very poor the since the salinity (1122 mg/L and 1094 mg/L) falls in the range of 900-1200 mg/L.

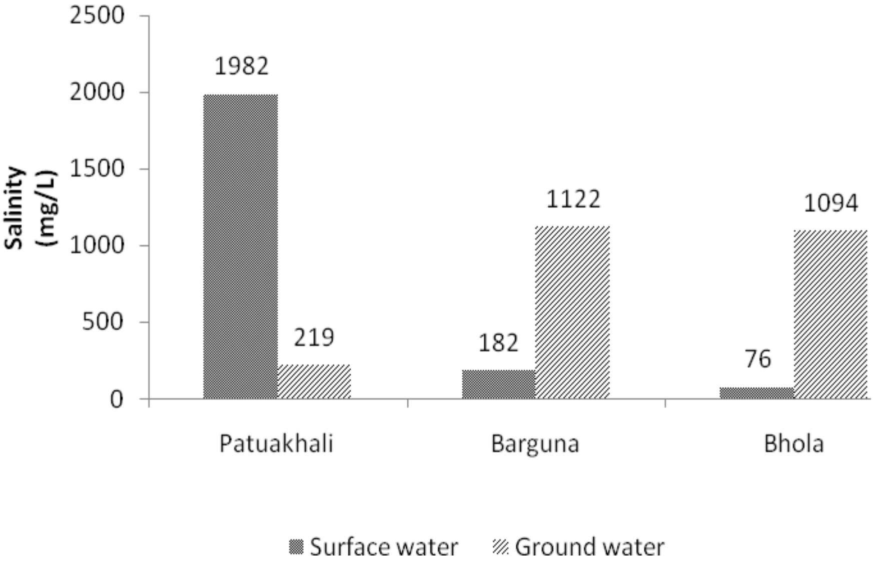

Figure 10: Salnity of surface water and ground water of three districts

3.2.3 Iron Concentration

According to Figure 11 both the surface water and ground water of Barguna contain high Iron concentration and both values exceed ECR 1997 and WHO standards, whereas the water quality of Patuakhali and Bhola seem satisfactory regarding Iron content.

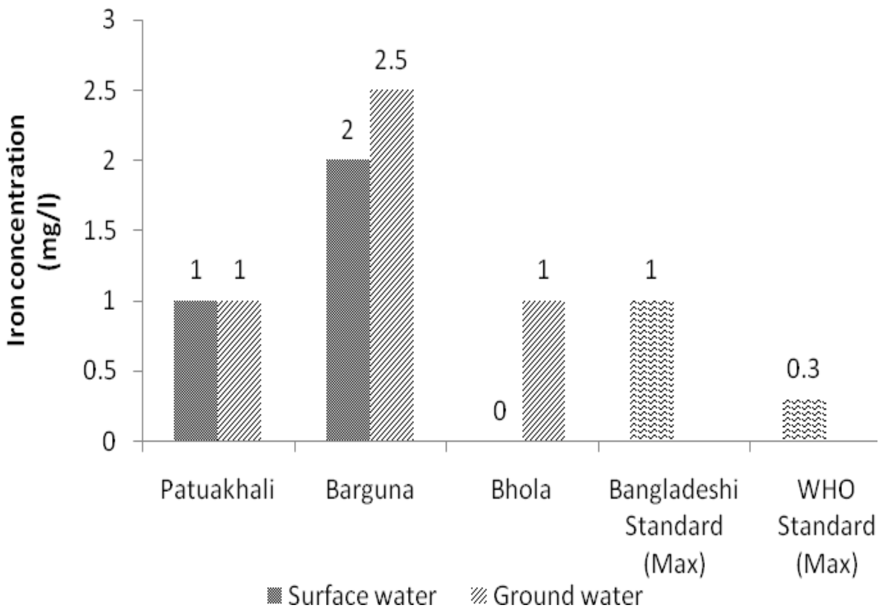

Figure 11: Iron Concentration in surface water and ground water of three districts

3.2.4 Hardness and Chloride Concentration

Figure 12 and 13 illustrate the hardness and concentration of Chloride in surface water and ground water in these three coastal areas. Only the hardness value surface water in Bhola and ground water in Barguna cross the maximum limit of hardness according to ECR 1997 and WHO standard. Turning to figure 13, it is seen that surface water in Bhola is about more than double than the maximum limit specified by ECR 1997 and WHO. Otherwise the amount of Chloride in water of other two districts are equal or below the maximum limit.

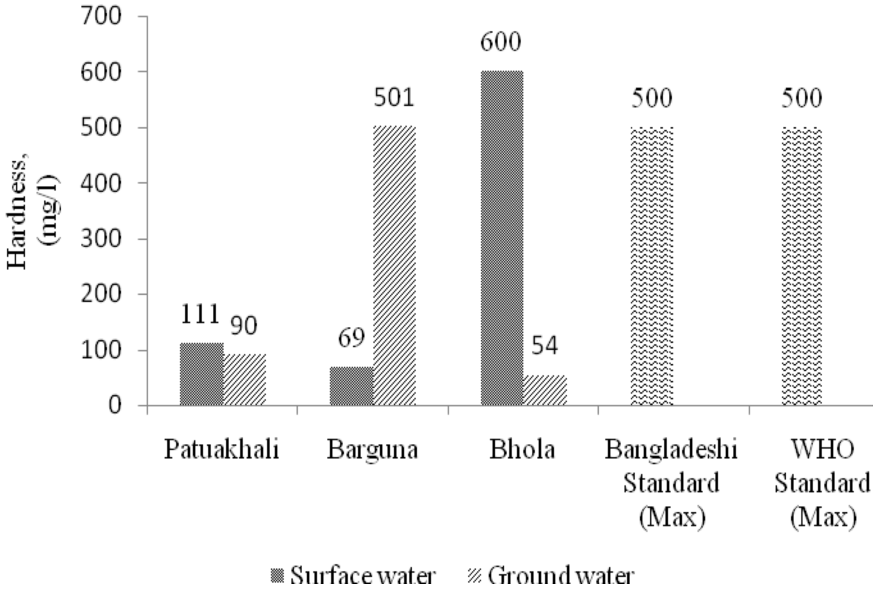

Figure 12: Hardness of surface water and ground water of three districts

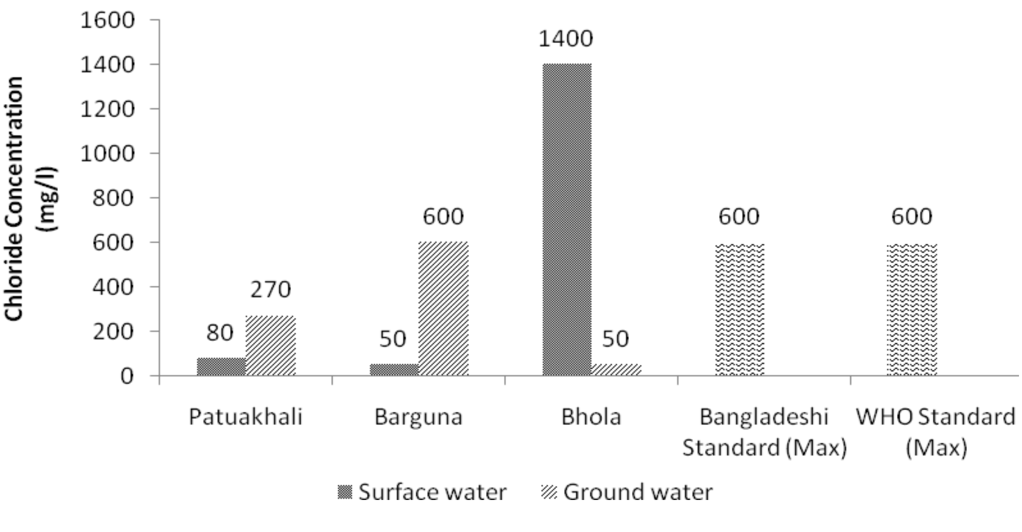

Figure 13: Chloride of surface water and ground water of three districts

4. CONCLUSIONS

The research has portrayed the impact of salinity on drinkable water and agriculture in the studied areas. From this investigation we came to know about the prevailing water use pattern of the people at coastal areas. From the questionnaire survey, it has been assessed that majority of respondents believe that both the drinking water and irrigation water contains moderate level of salinity and crop prduction is hampered undoubtedly. Specially salinity condition in Barguna is most vulnerable among these three districts keeping with the read of individuals. From the laboratory test, it has been found that surface water in Patuakhali has huge amount of Electrical Conductivity and salinity (3.78 ds/m and 1982 mg/L respectively) which surpass the utmost limit of these parameters specified by ECR 1997 and WHO Standard. Similarly, ground water in the other two districts also has moderate level of salinity. The experimental study also shows that, hardness and chloride concentration of Bhola surface water exceed the standard limit. Again, an excessiveness in Iron concentration in water of Barguna has found from this study. So it is an exigency to monitor the water quality from the perspective of salinity and quality parameters to ensure a sustainable water resource development.

ACKNOWLEDGEMENT

The author would like to express sincere gratitude to World University of Bangladesh for providing laboratory facilities for conducting this study**.**

REFERENCES

Australian Drinking Water Guideline.(2011) Website: https://www.epa.sa.gov.au/environmental_info/water_quality/threats/salinity

BADC (2007), Water Quality for Irrigation (2004-2007), Survey and Monitoring Project for Development of Minor Irrigation, Bangladesh Agricultural Development Corporation, Ministry of Agriculture, Dhaka.

BBS. (2011). Bangladesh Population and Housing Census 2011, Community Report: Barguna Zila, Bangladesh Bureau Of Statistics (BBS) Statistics And Informatics Division (SID) Ministry Of Planning, July 2013.

BBS. (2011). Bangladesh Population and Housing Census 2011, Community Report: Bhola Zila, Bangladesh Bureau Of Statistics (BBS) Statistics And Informatics Division (SID) Ministry Of Planning, July 2013.

BBS. (2011). Bangladesh Population and Housing Census 2011, Community Report: Patuakhali Zila, Bangladesh Bureau Of Statistics (BBS) Statistics And Informatics Division (SID) Ministry Of Planning, July 2013.

BWDB (2005), Southwest Area Integrated Water Resources Planning and Management Project in Bangladesh, Bangladesh Water Development Board, July 2005.

Hasan, A.S., Akhter, F and Rahman, M.M. (2018). "A study on the impact of high end emission on the crop yields at the coastal regions of Bangladesh." *1st national conference on water resource engineering (NCWRE 2018), 21-22 March 2018 pp (51-56), CUET, Chittagong, Bangladesh.*

Hasan, A.S., Islam, A.K.M.S. and Bala, S.K. (2017). Impact of extreme climate change on the production of BORO rice in Bangladesh using DSAAT 4.6. *Proccedings of the 6th international conference on water and flood management (ICWFM 2017) 4-5 March 2015 (384-397), IWFM, BUET, Dhaka, Bangladesh.*

Karim, Z., Hussain, S.G., Ahmed, M. (1990), Salinity problems and crop intensification in the coastal region of Bangladesh, BARC Soil Publication no.33, Dhaka

Mohammad, N (2009), Addressing Salinity to improve the well-being of vulnerable people in the southwest, RVCC Project, IDEAL Bangladesh.

Quality aspects of farm water supplies.(1980).Victorian Irrigation Research and Advisory Committee.Website: http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/salinity/measuring-the-salinity-of-water.

Standard, B. (1997). The environment conservation rules 1997. *Government of the People's Republic of Bangladesh, Dhaka*.

MODELLING OF ANFIS FOR PREDICTING WATER QUALITY INDEX OF SURFACE WATER ADJACENT TO THE WASTE DISPOSAL SITE IN KHULNA

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ABSTRACT

In present time, Fuzzy Inference System (FIS) is considered as a powerful apparatus for arrangement of numerous unpredictable designing frameworks when obscurity and uncertainity is related with the frameworks. ANFIS is generally known as legitimate insightful model for execution assessment of transient displaying and spatial variety of surface water quality factors. Recently, artificial insight calculations that are suitable for non direct estimating and furthermore managing vulnerabilities have been introduced to several areas of water quality guaging. As a rule, WQI refers a dimensionless number running from 0 to 100 (best quality) and assumes a significant job in assessing the surface water quality. The detailing of the WQI includes a progression of steps that incorporate creating scientific conditions called files dependent on watched water quality parameters, allotting a weighting element to every parameter contingent upon its significance in the examination, and finally applying a reasonable averaging equation to land at a solitary numeric worth. These means frequently make the calculations unwieldy and simultaneously limit the defined record to a specific parameters and topographical territories. Given the multifaceted nature of building up a WQI, there is a need to build up a computerized framework for information extraction from water quality information, which in this manner simplifies the estimation of the WQI and simultaneously covers an expansive scope of water quality criteria for a bigger extent of use. In this study, surface water samples were sampled from fourteen (14) stations within a selected waste disposal site at Rajbandh, Khulna, Bangladesh. In the laboratory, the concentrations of physical, chemical and biological parameters including pH, conductivity, chlorides, nitrates, phosphates, sulphates and TDS were measured. For ANFIS modelling thses studied parameters were considered as input parameters. In addition, ANFIS was proposed and its presentation is assessed with the assistance of expectation of water quality file utilizing a genuine informational index parameters. The present study was performed through MATLAB by using different types of ANFIS modelling like Subtractive Clustering (SC) and Grid Partition (GP) based on FIS for water quality index determination of surface water. Individual model was utilized to prepare, approve and test the list that was acquired from a few water quality parameters. Also, both models correlation coefficient value were compared to Pearson's product moment correlation coefficient which helped for identifying the best model. According to study, ANFIS-SC showed comparatively better performance than ANFIS-GP model for predicting the WQI of surface water and gave best correlation coefficient. Furthermore, sensitivity analysis of each station with respect to water quality index was performed where different types of models with different membership functions were fluctutated from existing water class. Among them, ANFIS-GP dsigmoid membership function was deviated largely from very poor water quality class which generally the highest existing water class. Other membership functions were laid in the tolerable limit between excellent and very poor. Since fuzzy framework is a decent expectation apparatus for loose and uncertainity data, the methodology would be the most fitting procedure for demonstrating the forecast of surface water quality.

Keywords: *Waste disposal site, surface water, water quality index, FIS, ANFIS, Khulna.*

1. INTRODUCTION

Water is viewed as one of the most bottomless items in nature yet in addition abuse one. Today surface water is most vulnerable against contamination because of its simple availability for transfer of poisons and wastewater (Puri, Meshram, Rana, & Yenkie, 2015). Overall, water quality is represented by complex human exercises and characteristic procedures including enduring disintegration, hydrological highlights, environmental change, precipitation, modern exercises, farming area use, sewage release, and the human abuse of water assets (Malvi, Nouri, Babael, & Nabizadeh, 2005). During the most recent decade, far reaching disintegration in water nature of inland oceanic frameworks has been accounted for because of quick improvement of ventures, agribusiness, and urban spread (Vie, Hilton-Taylor, Stuart, & Eds., 2009). Water quality assessment is a matter that indicates the consideration of administrative organizations on numerous occasions to shield different expected employments. In such manner, constant water quality observing is attempted in order to survey the water quality and applied adequate measures for its evaluation.

Water quality evaluation assumes a significant job in ecological administration and basic leadership and it gives a scientific premise to balanced use and assurance of water assets. Customary techniques barely introduce the non-linearity, subjectivity as well as multifaceted nature of the reason effect connections between factors and status of water quality, also there are not a for the most part acknowledged strategy up until now. A few strategies are typically utilized to assess the status of water quality, using fuzzy manufactured assessment (Liu, Zhou, An, Zhang, & Yang, 2010), matter component model, calculated bend model, trait acknowledgment model and ANN). The ANN technique is viewed as a conceivably helpful apparatus for demonstrating complex on-straight frameworks as well as has been broadly utilized for classification of water class as well as assessment (Zou & Wang, 2007).

New methods, for example, fuzzy logic as well as ANFIS have introduced as of late utilized as efficient elective apparatuses for displaying of complex water assets frameworks and generally utilized for forecasting. FL is a standard based framework comprising of three calculated parts, including (1) a standard base, containing a choice of fuzzy in the event that rules; (2) an information base, defining the function capacities utilized in the fuzzy guidelines; (3) a deduction framework, playing out the surmising methodology upon the principles to infer a yield (Zhang, 2009). FL models mainly focused on the utilization of theoretical in the framework analysis. This technique can be viewed as consistent models that utilization on the off chance that rules to set up subjective and numbering connections between factors. Their standard nature permits the utilization of data communicated as characteristic language code, use the model straightforward for prediction (Vernieuwe, Georgieva, Baets, & Verhoest, 2005). In any case, the fundamental issue with fuzzy logic with no precise methodology to define the participation work values, which can be foreordained by master information about displayed framework. The development of the fluffy principle requires the connotation of premises and results as fuzzy systems. Simultaneously, ANN can gain from info and yield combines and adjust to it in an intelligent way. So as to beat the issues, the ANFIS coordinates ANN and Fuzzy Logic was used by Jang (1993). ANFIS can possibly catch the benefits the techniques in a solitary system. ANFIS wipes out the fundamental issue in fluffy framework structure by effectively utilizing the learning capacity of ANN for programmed fluffy on the off chance that standard age and parameter streamlining (Nayak, Sudheer, Rangan, & Ramasastri, 2004). Since the idea of ANFIS was first presented in 1993 (Yan, Zou, & wang, 2010), it has effectively been demonstrated in many designing applications like precipitation runoff and continuous repository operation (Firat & Gungor, 2007).

In this manner the present investigation plans to build up the ANFIS model dependent on two different grouping techniques and measurably distinguish the best among the two. Also, another objective is to evaluate the best model which helps to identify the most touchy water quality parameter that can responsible an adjustment in the anticipated water quality. Also, sensitivity analysis was conducted for each model to know the variation of water quality class from existing value of WQI.

2. METHODOLOGY

In this study, several types of working steps were taken for collecting data and analyse the ANFIS model through MATLAB. These steps are divided into following categories which are describe elaborately. Before analyse WQI of surface water with ANFIS modelling, surface water quality parameters were measured in the laboratory and hence discussed in the following articles.

2.1 Study Area

Khulna is situated in the south-western region of the Bangladesh. The city is situated along the streams the Rupsha and the Bhairab. City Solid Waste Management has turned into an intense issue for Khulna city. The large amount of wastes in Khulna city are generated from areas like Houses, Road clearing, Industry, Mechanical and different sources. A study was performed in Rajbandh Landfill situated in Botiaghata Thana in Khulna city. Solid wastes of Khulna city are generally dumped in this location. Surface water samples were taken from several ponds of different location. Total 70 observations were taken from 14 stations shown in Figure 1. Overall, 5 samples were collected from each station in monthly based data collection.

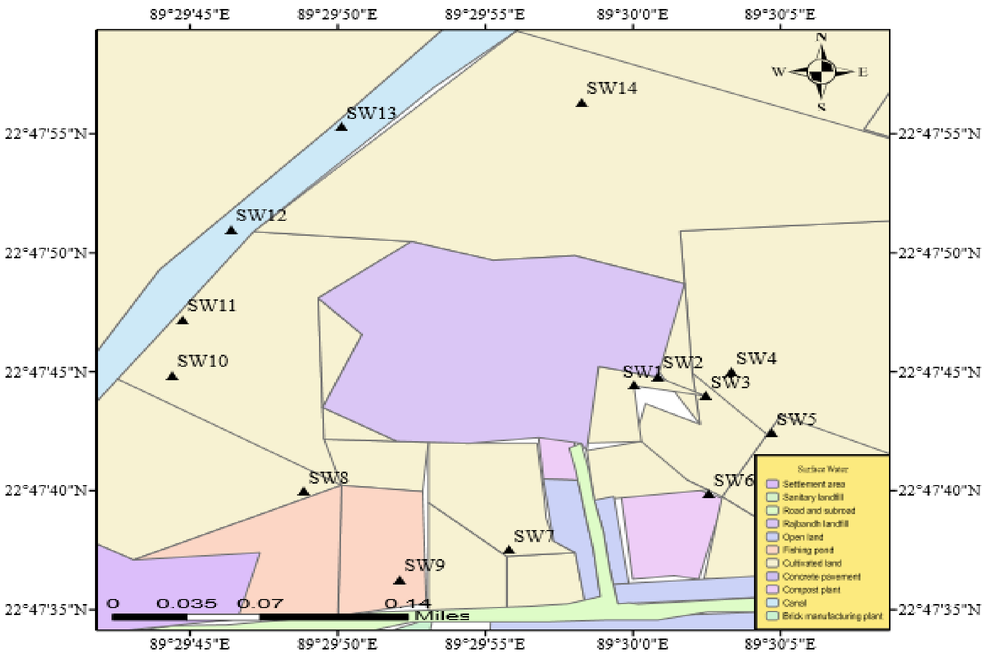

Figure-1: Location map showing surface water sampling from waste disposal site, Khulna

2.2 Water Quality Parameters

Several parameters can be used to determine the WQI for surface water. Some researchers (Puri, Meshram, Rana, & Yenkie, 2015) used the parameters of dissolved oxygen (DO) as well as biochemical oxygen demand (BOD) for calculating the surface WQI. But, these two parameters were not considered in the present study. Further research can be conducted with including these two parameters by using different fuzzy technique in future. In this research the parameters of pH, conductivity, chloride, sulphate, nitrate, phosphate and TDS were considered for determined the WQI. These 7 water quality parameters are generally identified for calculation of any surface water quality index. Following parameters are shown in Table 1, which shows the average value (among 5 Nos. sample) of each parameter of each station. Samples were taken monthly based at each station. After taken sample from study area, Parameters were determined from laboratory test through several tests according to each parameter. In case of conductivity and TDS parameters, the presented laboratory test value were largely deviated from realistic value of that study area. Due to the seasonal variation of sample collection, this may be happened.

Table-1: Mean concentration of parameters at each location around the selected disposal site

	Number of Stations													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
P^H	6.86	7	6.54	6.41	6.2	5.87	6.28	6.5	6.57	6.19	6.96	6.57	6.39	6.22
Conductivity	1413.2	1393.6	1762.6	1756.6	1621.93	1339.13	1295.73	1363.4	1092.2	1400.6	1707.18	1621.02	1299.11	1286.93
Chloride	61.99	71.14	65.05	74.99	67.6	79.85	69.09	83.91	70.74	86.73	73.19	88.49	76.37	89.53
Sulphate	108.91	98.08	107.6	92.53	11.67	91.07	90.2	54.2	57.93	65.2	108.77	100.32	103.56	90.38
Nitrate	0.46	0.08	0.28	0.1	0.19	0.11	0.14	0.11	0.12	0.11	0.11	0.11	0.11	0.10
Phosphate	0.43	0.38	2.5	1.40	2.01	1.23	1.71	1.13	1.49	1.08	1.32	1.05	1.21	1.03
TDS	2.1	1.84	1.91	1.97	1.82	2.11	1.79	2.24	1.77	2.38	1.75	2.53	1.74	2.66

2.3 Water Quality Index

Water quality represents physical, chemical and natural composition of water. WQI condenses various water quality information like Excellent, Good, Bad and so on, for answering to administrators as well as general population in reliable way. The WQI may be utilized like an apparatus in contrasting the water nature of various sources which give thought of the potential issues connected to water in a specific area. The records provide best approaches to convey the data on water quality patterns for the water quality administration (Boah , Twum , & Pelig-Ba , 2015). In this study, WQI was determined for surface water, where above parameters such as pH, conductivity, chloride, sulphate, nitrate, phosphate and TDS were used with their desirable limit of 8.5, 2000 µS/cm, 250 mg/L, 200 mg/L, 45 mg/L, 0.3 mg/L and 1000 mg/L respectively. The values of WQI were computed using weight factor (W_i) and quality rating (Q_i) of each parameter through the Equation 1 and Equation 2, respectively. The mathematical equation was used for determining the WQI, which is stated below with meaning. This equation consists of several steps which required for determining WQI in surface water.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

In above equation-1, W_i represents the relative weight and w_i denotes each parameter weight, also the number of parameters are indicated by n.

$$Qi = \frac{C_i}{S_i} \ x100 \tag{2}$$

In above rquation-2, Q_i denotes rating of the quality, C_i denotes the individual chemical parameter concentration present in the water sample (mg/L) and S_i represents the desirable limit (mg/L) of each parameter according to BIS 1998, except the limit unit in case of conductivity (µS/cm) and the unit less pH. In this study, finally the values of WQI were computed using the following Equation 3.

Water Quality Index (WQI) = $\sum_{i=1}^{n} WiQi$ (3)

2.4 Adaptive Neuro-Fuzzy Inference System

ANFIS consists of multilayer feed-forward system which utilizations learning calculations based on neural system as well as fuzzy rationale to outline information space (Sun & Jang, 1995). Jang proposed adaptive neuro-fuzzy inference system (ANFIS) to develop an information yield mapping dependent on the underlying given fuzzy framework and accessible info yield information combines by utilizing learning methods. This framework can accomplish an exceptionally non straight mapping and is better than normal direct strategies in creating nonlinear time arrangement. During the time spent mapping information space to a yield space, two ordinarily FIS are utilized in different applications. Two different frameworks are included in this like Mamdani framework as well as Sugeno derivation framework. The outcomes of the fuzzy principles for these two deduction models are different, and hence their conglomeration methodology additionally differ likewise. The Sugeno framework is, be that as it may, thought about more conservative than Mamdani's framework. Sugeno FIS provides outcome parameters in two different FIS system (Jang, Sun, & Mizutani, 1997).

2.4.1 Framework of ANFIS

Seven different layers are utilized to build this deduction system where individual layer contains a few hubs portrayed by the hub work. Versatile hubs, indicated by squares, parameter sets are customizable in these nodes which indicated by circles shown in Figure 2. The yield information taken from hubs in the past layers has a contribution to the existing current layer. Sugeno FIS is evaluated in the current examination.

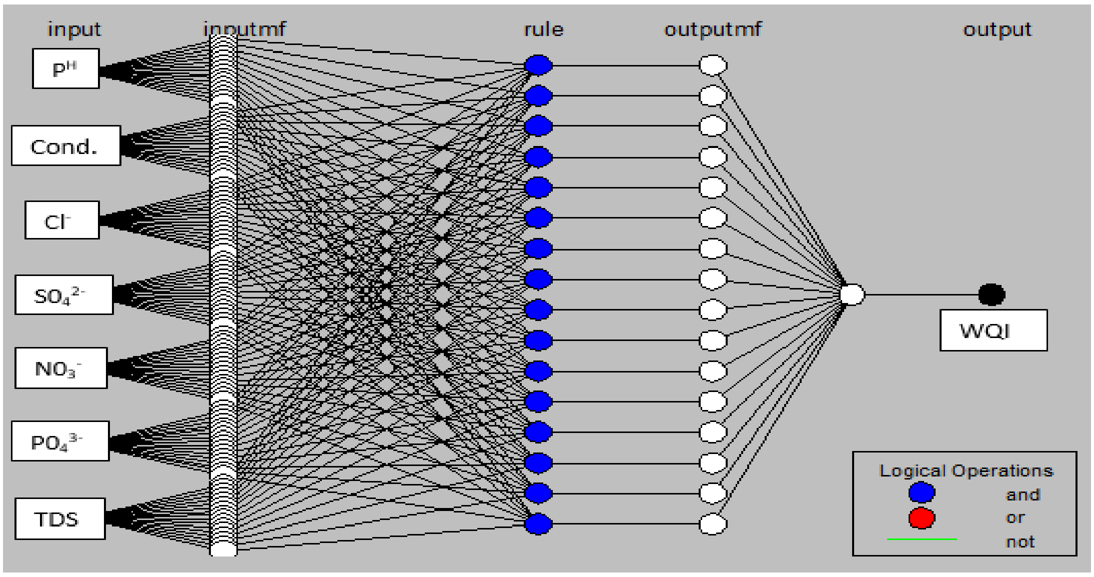

Figure-2: Framework of ANFIS utilised in this study

3. RESULTS AND DISCUSSION

In current study, for the determination of WQI with selected best technique of ANFIS, the following steps were taken which hence illustrated in the separate articles.

3.1 Model Development

For ANFIS modelling total 70 samples were taken from 14 stations. Two different fuzzy inference system was performed in this research for modelling shown in Figure 3. Subtractive-Clustering (SC) FIS was generated as well as Grid-Partition (GP) was performed. In case of SC ANFIS model, Gaussian membership function and In case of GP ANFIS model, several 8 membership functions were performed. GP mf's are triangular, trapezoidal, generalized bell, gaussian, two gaussian, pi, dsig and psig. In both ANFIS model, optimum method was taken backpropagation with epoch 10. Following parameters were developed during SC-ANFIS algorithm: Gaussian membership function, influence range (0.5), factor of squash (1.25), accepted ratio was 0.5 and rejected ratio was 0.15. Figure-3 reveals the output of each model and comparison between them with observed value. ANFIS-SC model was closely related with observed WQI and these two graphs were merged very closely. ANFIS-GP models consisted with eight different membership functions were deviated from observed value except dsigmoid membership

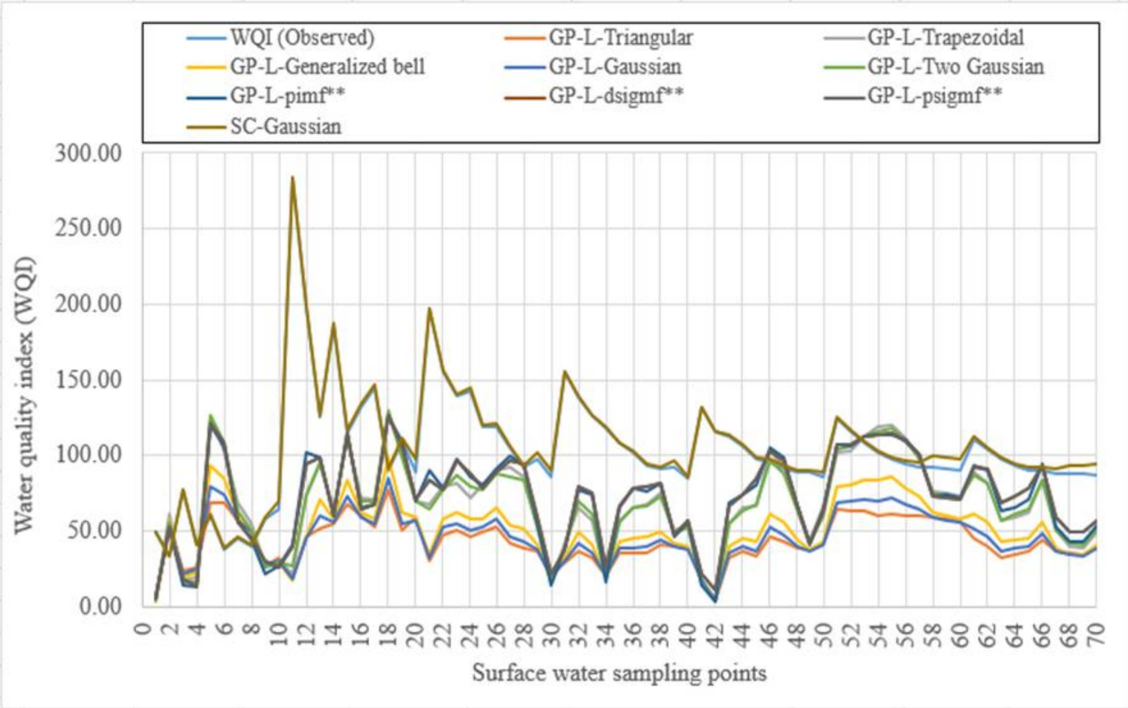

Figure 3: Comparison between Observed WQI and Predicted WQI by ANFIS-SC & ANFIS-GP (mf**= membership function)

3.2 Surface and Rule Viewer of ANFIS

Figure-4 represents the rule view of ANFIS-SC model by which predicted value was found. Each column from top left to right bottom shows the input value and last column in right side shows the output value of fuzzy inference system.

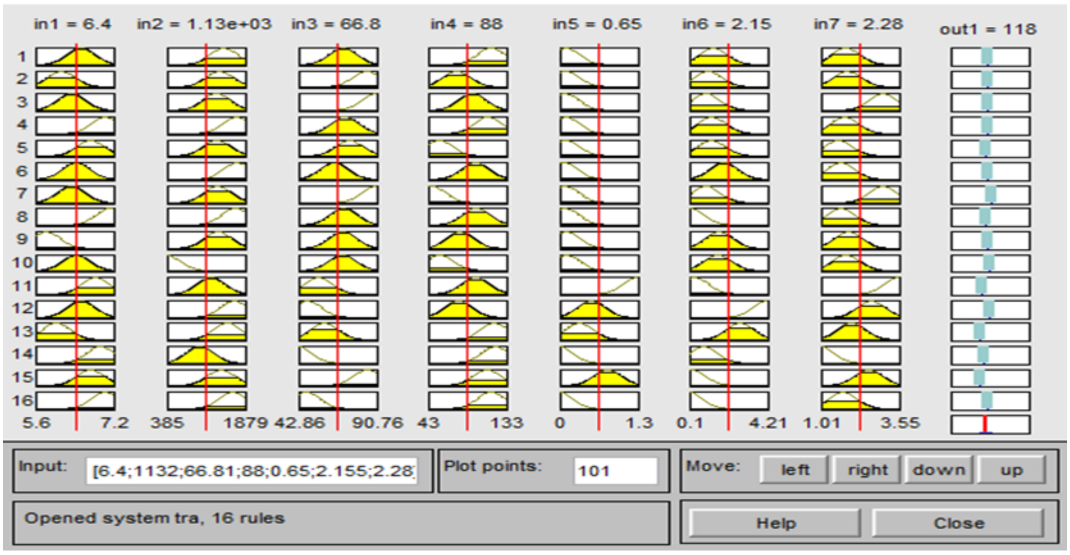

Figure-4: Rules view in ANFIS-SC model

Figure-5 shows the fit curve of ANFIS-SC algorithm. Among two different ANFIS modelling, ANFIS-SC showed best fit where correlation value (R=0.99866) was highest and RMSE (1.6807) was lowest. In terms of ANFIS-GP, value of ‘R’ was lower and RMSE value was higher than ANFIS-SC.

Figure-6 illustrates the surface viewers in ANFIS-SC model which represents the predicted value of WQI of surface water. For predicted value, input value was pH, conductivity, chloride, sulphate, nitrate, phosphates and TDS.

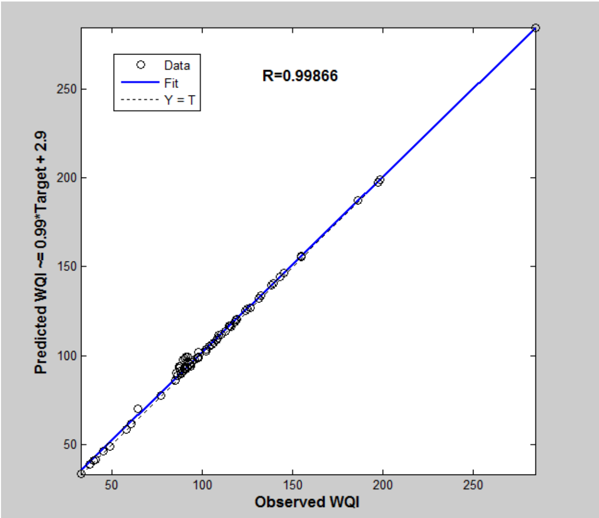

Figure-5: Best fit curve in ANFIS-SC model

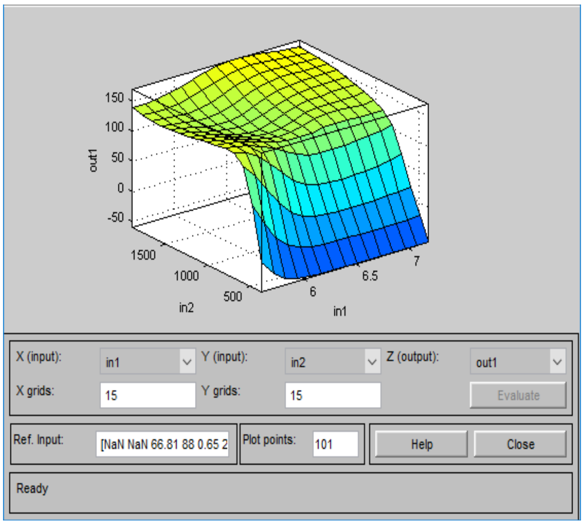

Figure-6: Surface view of ANFIS-SC

3.3 Sensitivity Analysis

Figure-7 represents the variation of water quality condition according to observed data and obtained data from ANFIS-SC and ANFIS-GP. Sensitivity analysis means the deviation of water quality index from existing water quality class. This analysis helps to know the variation of water quality in two different types of ANFIS modelling and observed value at the same station. According to Chatterji, Raziuddin (2002) and Brown (1972), water was classified into five (05) different classes with respect to water quality index. ANFIS-GP dsigmoid membership function largely deviated from other membership function and observed value. In case of Station 03 to 11, it indicated the sample water is not suitable for using in different purposes. Other analysis show the variation of water quality index which lies between excellent and very poor. Excellent water quality was found in station 01, 07, 08 and 09. Without station no 04 and 11, all analysis show the good water quality.

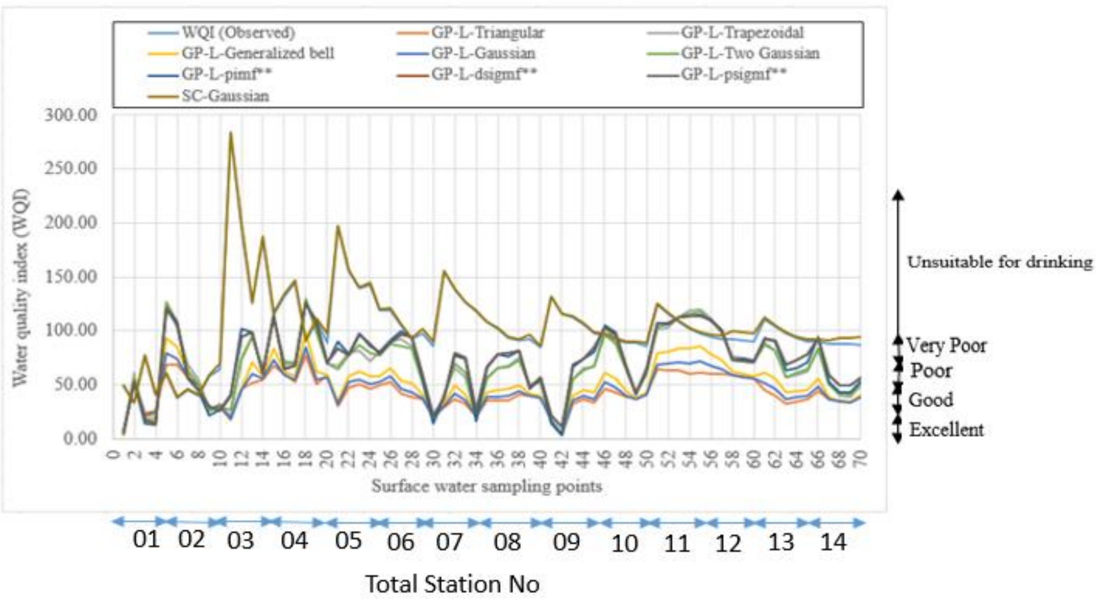

Figure-7: Sensitivity analysis of individual station with respect to Water Quality Index.

3.4 Model Verification

ANFIS models were verified with compare to the Pearson Product moment correlation coefficient value. From both ANFIS models, RMSE, MSE and R^2 were found. Table 2 shows the variation of RMSE, MSE and R^2 of different membership functions of two ANFIS modelling. This helps to compare the best fit according to Correlation value and RMSE. According to value of R^2, correlation is classified in Pearson's method (Table 3). From this classification, types of correlation can be identified which helped in validation of ANFIS-SC and ANFIS-GP modelling. Different types of correlation like very highly, highly, moderately, low and little was stated according to the magnitude of R^2 (Table 3).

Table-2: Water quality performance according to ANFIS-SC and ANFIS-GP

	SC-Gaussian	**GP-Triangular**	**GP-Trapezoidal**	**GP-Generalized Bell**	**GP-Gaussian**	**GP-Two Gaussian**	**GP-pi**	**GP-dsig**	**GP-psig**
RMSE	1.6807	8.8396	8.0131	8.5753	8.7420	8.0109	7.783	7.743	7.743
MSE	2.8249	78.1387	64.21	73.5365	76.4227	64.1755	60.57	59.95	59.95
R^2	0.9973	0.0107	0.0000156	0.0059	0.0074	0.00057	0.0179	0.0122	0.0122

Table-3: Pearson Product Moment Correlation Coefficient

Classification	**Magnitude of Correlation Coefficient (R^2)**
Very Highly Correlated	Between 0.82 and 0.99
Highly Correlated	Between 0.49 and 0.81
Moderately Correlated	Between 0.25 and 0.48
Low Correlation	Between 0.09 and 0.24
Little Correlation	Between 0.00 and 0.08

4. CONCLUSIONS

The validation of ANFIS model with eight membership functions for GP and SC algorithm was performed. Comparison of models gave the clear view that, ANFIS-SC models of Gaussian membership function was performed better and showed best fitting of regression model than that of ANFIS-GP. In case of ANFIS with SC and Gaussian membership function showed the highest R^2 value (0.9973) and lowest RMSE (1.6807) indicating very highly correlated according to Pearson correlation. This study express that fuzzy inference system (FIS) modelling with SC-ANFIS may be an effective way to deal with portrayal of water quality in terms of WQI. From sensitivity analysis of each model, ANFIS-GP dsigmoid membership function was deviated largely from existing water quality class which indicated the water quality is not suitable for different purposes. The other membership function of two different models were indicated the variation of water quality within the existing limit.

REFERENCES

Boah , D. K., Twum , S. B., & Pelig-Ba , K. B. (2015). Mathematical Computation of Water Quality Index of Vea Dam in Upper East Region of Ghana. Environmental Sciences, 11-16.

Firat, M., & Gungor, M. (2007). River flow estimation using adaptive neuro fuzzy inference system. Mathematics And Computers in Simulation, 87-96.

Jang, J. S., Sun, C. T., & Mizutani, E. (1997). Neuro-Fuzzy and Soft Computing—A Computational Ap-proach to Learning and Machine Intelligence. IEEE TRANSACTIONS ON AUTOMATIC CONTROL, 10.

Liu, L., Zhou, J., An, X., Zhang, Y., & Yang, L. (2010). Using fuzzy theory and information entropy for water quality assessment in three Gorges region, China. Expert Systems, Aplications, 4720.

Malvi, A., Nouri, J., Babael, A., & Nabizadeh, R. (2005). Agricultural activities impact on groundwater nitrate pollution. Int. Journal of Environmental Science and Technology, 45-46.

Nayak, P., Sudheer, K., Rangan, D., & Ramasastri, K. (2004). A neuro-fuzzy computing technique for modeling hydrological time serie. Journal of Hydrology, 52-66.

Puri, P., Meshram, S., Rana, D., & Yenkie, M. (2015). Application of water quality index (WQI) for the assessment of surface water quality. Europian J. of Experimental Biology, 37.

Sun, C. -T., & Jang, J. S. (1995). Neuro-fuzzy modeling and control. IEEE, 378-406.

Vernieuwe, H., Georgieva, O., Baets, B. D., & Verhoest, N. E. (2005). Comparison of data-driven Takagi–Sugeno models of rainfall–discharge dynamics. Journal of Hydrology, 173-186.

Vie, J., Hilton-Taylor, C., Stuart, S., & Eds. (2009). Wildlife in a Changing World: An Analysis of the 2008 IUCN Red List. Switzerland: IUCN, 2009.

Yan,H.,Zou,Z.,&wang,H.(2010).Adaptiveneurofuzzyinferencesystemforclassificationofwaterqualitystatus. Journal of Environmental Sciences 2010, 22(12) 1891–1896, 1891-1896.

Zhang, D. (2009). Matlab fuzzy system design. National Defense Industry Press, 37.

Zou, Z., & Wang, H. (2007). Application of BP modeling based on random samples to assessment on natural water quality. Environmental Engineering, 70.

RECYCLING PRACTICES OF ELECTRONIC WASTE IN KHULNA CITY, BANGLADESH

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ABSTRACT

The effective life of electronic devices is relatively short and decreasing as a result of rapid changes in technology, equipment features and capabilities. This creates a large waste stream of obsolete electronic equipments, electronic waste (E-waste). Rapid increase in the quantity of E-waste has become an emerging issue throughout the world. Although the recycling of E-waste management has been ignored by the local authorities, many waste collectors, shopkeepers, repairing technicians and dealers have been performing recycling activity as a source of income for a long time in Bangladesh. The aim of the study is to find out recycling practices of E-waste in Khulna city of Bangladesh. To achieve this goal, a number of field surveys and questionnaire surveys were performed. There are 127 shops in Khulna city which perform E-waste recycling in the form of recovery, reuse and repairing. Total 726 people in this city including E-waste pickers (Tokai), E-waste collectors (Feriwala) and E-waste recycling shop workers who are involved in E-waste recycling activities as their livelihood. The amount of recyclable E-waste in Khulna city was found 614 kg.day^{-1}. The study reveals that the items which form the major portion of E-waste in Khulna city are fan and motor (13.36%), iron, oven and rice cooker (5.37 %), refrigerator and air conditioner (37.13 %), TV, computer and laptop (36.16 %), mobile phone and battery (6.03 %), electric wire and bulb (2.44 %) and other electrical and electronic equipments (4.40 %). On the basis of the amount of E-waste, existing recycling programs and collection methods, a E-waste recycling pattern was developed to evaluate its generation (domestic), repairing, process of recycling practices, exporting and disposal. The study analyzed the income generation of the individuals involved in the whole process. The total amount of income from E-waste recycling in Khulna city was found 22,02,808 taka.month^{-1}. More willingness of E-waste recycling practices of the people in Khulna city can reduce the effects of heavy metals containing in E-waste and hence reduce soil pollution and can increase environmental, financial and economic develpoment of this city.

Keywords: *Electronic waste, Recycling practices, Recycling pattern, Income generation, Khulna.*

1. INTRODUCTION

1.1 Background

Solid waste can be defined as useless, unwanted and discarded matters coming from the production and consumption of materials by human and animal activities. Electrical and Electronic wastes have become a considerable part of solid waste. With the development of consumer-oriented electrical and electronic technologies, a large amount of electronic equipments have been sold to consumers. The useful life of these consumer electronic devices (CEDs) is relatively short, and decreasing as a result of rapid changes in equipment features and capabilities. This creates a large waste stream of obsolete electronic equipment (Kang H. Y. & Schoenung J. M., 2005). Any electrical or electronic devices which has reached their end of life and is destined to be recycled or dumped is considered as E-waste (Sajid M. et al., 2019). Previous studies indicate that the amount of generation of E-waste is almost 10% of the total amount of solid waste globally, but the growth rate is 2–3 times faster than other waste stream (Walden & J.L., 2012). E-wastes contains a significant amount of aseptic matters including heavy metals, inorganic pollutants and hazardous elements which has a large adverse effect on environment. Recycling of E-wastes (recovering, reuse and repairing) can reduce environment pollution as well as can be a source of income to the persons involved in this process. So recycling of E-wastes is beneficial from environmental, economical and social point of view.

1.2 Recycling of E-waste in Bangladesh

The recycling of E-waste management is mostly neglected by local authorities. For the generated E-wastes in the country, disposal is often done with other solid wastes without any treatment. These large quantities of E-wastes are resulting in environmental threat due to improper handling and disposal. In this country, there are little specific scope for E-waste management. But many people of the country directly or indirectly are related to E-waste recycling as a source of income. They are involved in E-waste recycling process as the forms of collecting or buying, repairing the E-wastes, recovering useful parts from the wastes, reusing them or selling them at a higher price than buying them.

1.3 Scenario of E-waste Recycling Practices in Khulna City

Khulna, the third largest city of Bangladesh, is located in the southern part of the country and is situated below the tropic of cancer, around the intersection of latitude 22.49_N and longitude 89.34_E. The area of Khulna city is 47 square km with a population 1.5 million (BBS, 2009). The total amount of solid waste generation in Khulna city is 520 tons/day (Waste Safe, 2005). As all kinds of electrical and electronic devices are available in this city, the amount of E-waste is also increasing day by day. The solid waste management in Khulna is performed by Khulna City Corporation (KCC). But there is no specific E-waste treatment plant in this city. But the recycling of E-waste is done by a considerable amount of People. A few portion of E-waste is recycled in Khulna city and rest of the recyclable E-wastes is sent to Dhaka, the capital of Bangladesh. Only precious gold such as gold, silver, aluminum, copper is separated in Khulna.

1.4 Study Aim

The objectives of the study are being to (i) study the existing recycling practices and collection methods of E-waste in Khulna city, (ii) determine the amount of E-waste and the types of E-waste recycled in Khulna city, (iii) compare these data with related previous studies, (iv) develop a recycling pattern to evaluate E-waste generation, process of recycling and disposal and (v) analyse the income generation of the individuals involved in the E-waste recycling process.

2. METHODOLOGY

The methodology adopted in this study is highlighted and hence discussed in the following articles.

2.1 Field Visit

In this study, reconnaissance suvey was performed all over Khulna city in order to get a clear concept about the E-waste recycling practices. The recycling dealers and repairing shops are found available in Shiromoni, Fulbari, Daulatpur, Khalishpur, Sheikhpara, Dakbangla, Sonadanga, Gallamari, Rupsa and Nirala. All the E-waste recycling practices are going on in these areas. These selected areas are indicated in the map of Khulna city in Fiure 1.

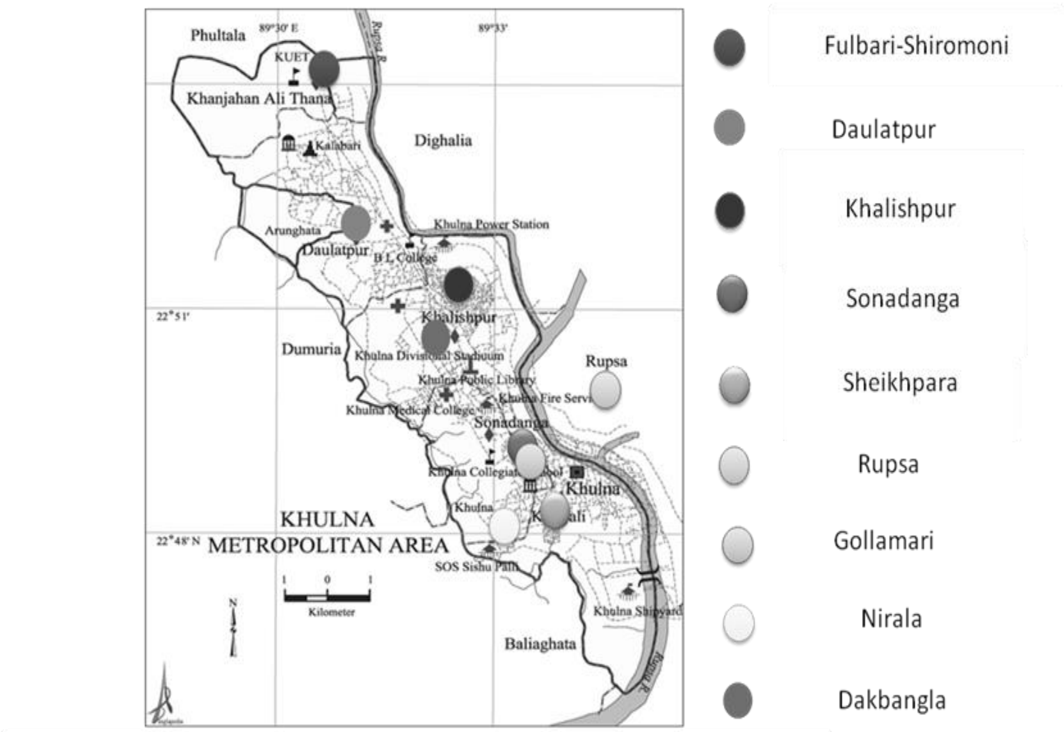

Figure 1: Selected Areas of Khulna city

2.2 Field Survey

Firstly, the location of Shiromoni, Fulbari, Daulatpur, Khalishpur, Sheikhpara, Dakbangla, Sonadanga, Gallamari, Rupsa and Nirala was identified through map. The characterstics, population and amount of households were collected. The E-waste recycling practices were studied in each area. The numer of recycling dealers and repairing shops was counted. The types of E-wastes which are being recycled, the pattern of practices of E-waste recycling were studied in those areas.

2.3 Questionnaire Survey for Data Collection

A several set of questionnaires was prepared for repairing shops, workers in the shops, waste ickers (locally named as Tokai), waste collectors (locally named as Feriwala) to obtain information about the ongoing waste recycling system. All data were collected in individual tabular form through questionnaire survey. The number of tokais, feriwalas, number of workers in each shop involved in E-waste recycling was counted. The shops were categorized as large, medium and small according to their size and E-waste recycling activities. The income generations of the individuals were also collected in taka month^{-1}. The amount of E-wastes generated for recycling in each shop was determined in kg.day^{-1}.

3. RESULT AND DISCUSSION

3.1 General

In this study, the characteristics of the selected areas Shiromoni, Fulbari, Daulatpur, Khalishpur, Sheikhpara, Dakbangla, Sonadanga, Gallamari, Rupsa and Nirala were observed by filed visiting. The types of E-waste recycled in individual areas were noticed. Some pictures of recyclable E-wastes in Khulna city are shown in Figure 2. The population and the number of households are collected from the papers of different organizations and government departments. All the collected data are shown in Table 1.

(a)

(b)

Figure 2: Recyclable E-wastes at (a) Dakbangla and (b) Sheikhpara in Khulna city

Table 1: A Description of Selected Areas

Location (i)	**Characteristics of Area** (ii)	**No. of House holds** (iii)	**Population** (iv)	**Practices of E-waste Recycling** (v)	**Types of E-Waste Recycled** (vi)
Fulbari-Shiromoni	Mainly low income households	1515	7575	Household E-waste repairing	TV, fan, motor, iron, oven, rice cooker etc.
Daulatpur	Located in city periphery, mainly pre urban	1463	7315	Household E-waste repairing	TV, refridgerator, iron, fan etc.
Khalishpur	Industrial area located along the river	3461	17805	E-waste repairing and sales	Electric bolb, electronic wires, fan, TV, Air conditioner etc.
Sheikhpara	It is mainly a recyclable waste market area	1577	7885	E-waste sales	Mobile phone. Battery, electric meter, clock, water heater, iron, remote, calculator etc.
Sonadanga	Planned housing in built up area with higher income households	1834	9170	Household E-waste repairing	TV, refridgerator, mobile phone, air conditioner, fan etc.
Gallamari	Central area. Traditionally middle class and educated professionals live here	2877	14385	Household E-waste repairing	TV, refridgerator, mobile phone, fan etc.
Rupsa	Mainly industrial and less residential area	3498	17490	Household E-waste repairing	TV, refridgerator, mobile phone, air conditioner, fan etc.
Nirala	Mainly residential area	2038	10190	Household E-waste repairing	TV, refridgerator, mobile phone, IPS, air conditioner, fan, iron etc.
Dakbangla	Mainly commercial area	1650	8250	Household and official E-waste repairing	Laptop, Desktop, TV, printer, mobile phone, air conditioner, refrigerator etc.

Note: Column (iii) and (iv) are collected from BBS (Bangladesh Bureau of Statistics) and column (ii), (v) and (vi) are collected from Field Survey.

3.2 Pattern of E-waste Recycling in Khulna

In this study, it was observed that the waste pickers locally known as Tokai primarily collect E-wastes with other solid wastes from domestic households and sell them to larger waste collectors locally named as Feriwala. They separate the easiest parts which is usable or recyclable and directly sell them to the consumers or to different markets of Khulna city. The shopkeepers whose business is related to E-waste recycling buy them. The recycling process is done by them in the form of recovery, repairing or reuse. Then they sell them to the consumers or to the dealers. The dealers further sell them to the related electronic companies mainly located at Dhaka the capital of Bangladesh. In each steps of this process, the non-recyclable parts of the E-wastes are gone for disposal. The overall pattern of E-waste recycling in Khulna city is shown in the flow-chart in Figure 3.

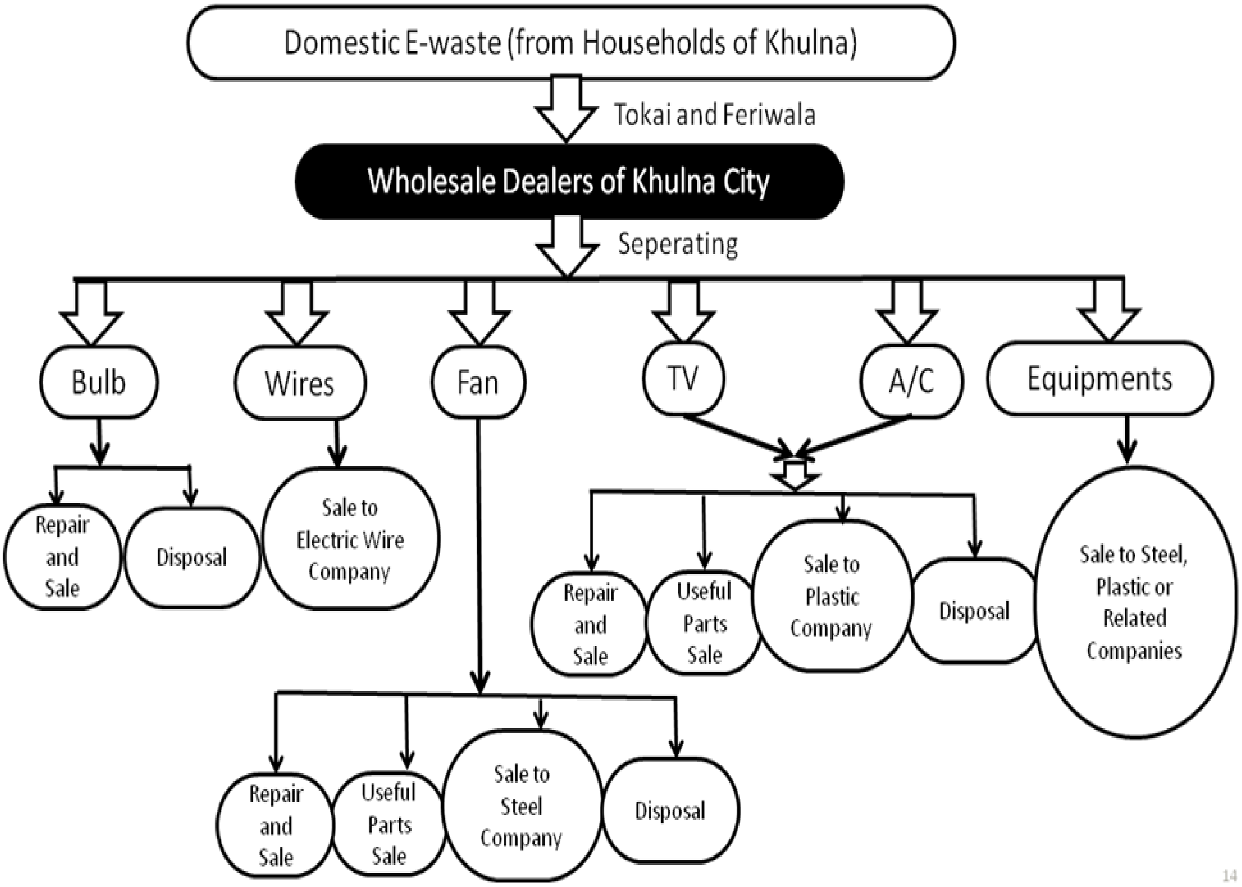

Figure 3: Flow-chart of E-waste Recycling Pattern in Khulna City

3.3 Number of Shops and Number of People Involved in E-wastes Recycling in Khulna City

The study reveals that several types of people such as Tokais, Feriwalas, recpairing shop workers and E-waste dealers are involved in E-waste recycling process in Khulna city which are discussed below.

3.3.1 Number of Shops and Number of Shop Workers Involved in E-waste Recycling

By performing field survey, the collected data for estimating the amount of shops and the amount of workers in the shops involved in E-waste recycling in Khulna city are given in Table 2.

Table 2: Number of Shops and Number of Workers in the Shops Involved in E-wastes Recycling in Khulna City

Location	Number of Shops			Total Number of Shops	Average Number of Workers (persons/ shop)			Total Number of Shop Workers in the Area
	Large Shops	Medium Shops	Small Shops		Large Shops	Medium Shops	Small Shops	
Sheikhpara	0	0	25	25	-	-	2	50
Dakbangla	0	7	18	25	-	4	2	68
Daulatpur	0	0	5	5	0	0	2	10
Fulbari-Shiromoni	0	0	8	8	-	-	2	16
Khalishpur	0	1	6	7	-	3	2	15
Sonadanga	3	5	10	19	8	5	2	69
Gallamari	1	2	6	10	7	4	2	27
Rupsa	1	2	4	9	7	3	2	21
Nirala	2	3	10	15	8	4	2	48
Other Places	1	2	5	8	8	5	2	28
Total				**127**				**354**

3.3.2 Total Number of People Involved in E-waste Recycling

The Total number of workers including Tokais, Feriwalas, E-waste recycling shop workers in different areas of Khulna City is shown in Table 3.

Table 3: Total Number of People Involved in E-wastes Recycling in Khulna City

Location	Number of E-waste Recycling Shop Workers	Number of Tokais	Number of Feriwalas	Total Number of People Involved
Sheikhpara	50	100	30	180
Dakbangla	68	50	18	136
Daulatpur	10	10	3	23
Fulbari-Shiromoni	16	8	2	26
Khalishpur	15	10	5	30
Sonadanga	69	20	7	96
Gallamari	27	15	5	47
Rupsa	21	12	4	37
Nirala	48	15	5	68
Other Places	28	50	5	83
Total				**726**

3.4 Daily Total Amount of Recyclable E-waste in Khulna City

In this study, it was found that different areas of Khulna city produce different amount of recyclable E-waste. Even the types of E-waste and their amount also varies from area to area. All the collected data and hence the total daily amount of recyclable E-waste in Khulna City are shown in Table 4.

Table 4: Daily Total Amount of Recyclable E-waste in Khulna City

Location	Fan and Motor (kg. Day^{-1})	Iron, Oven and Rice cooker (kg. Day^{-1})	Refrigerator and Air Conditioner (kg. Day^{-1})	Electrical Wire and Bulb (kg. Day^{-1})	Mobile Phone and Battery (kg. Day^{-1})	TV, Computer and Laptop (kg. Day^{-1})	Other devices (Remote, Clock, charger, Calculator etc.) kg. Day^{-1}	Total (kg. day^{-1})
Sheikhpara	10	5	-	5	5	-	10	35
Dakbangla	8	-	15	-	10	48	5	86
Daulatpur	6	3	10	-	-	14	-	33
Fulbari-Shiromoni	10	5	-	-	-	20	-	35
Khalishpur	5	-	10	5	-	10	2	32
Sonadanga	8	-	47	-	-	37	-	92
Gallamari	-	-	53	-	5	18	-	76
Rupsa	10	-	12	-	5	20	-	47
Nirala	15	10	46	-	2	30	5	78
Other Places	10	10	35	5	10	25	5	100
Total	**82**	**33**	**228**	**15**	**37**	**222**	**27**	**614**
Percentage (%)	**13.36**	**5.37**	**37.13**	**2.44**	**6.03**	**36.16**	**4.40**	

3.5 Comparison of Present Amount of Recyclable E-waste with Related Previous Study

From collected data of previous study done in Khulna city, daily amount of recyclable E-waste generated in Khulna city was 1877 kg.day^{-1} in 2013 (Ali M. H., 2013) and 368.94 kg.day^{-1} in 2017 (Nahar W., 2017). which are compared with present amount of Recyclable E-waste (614 kg.day^{-1}) in Figure 4.

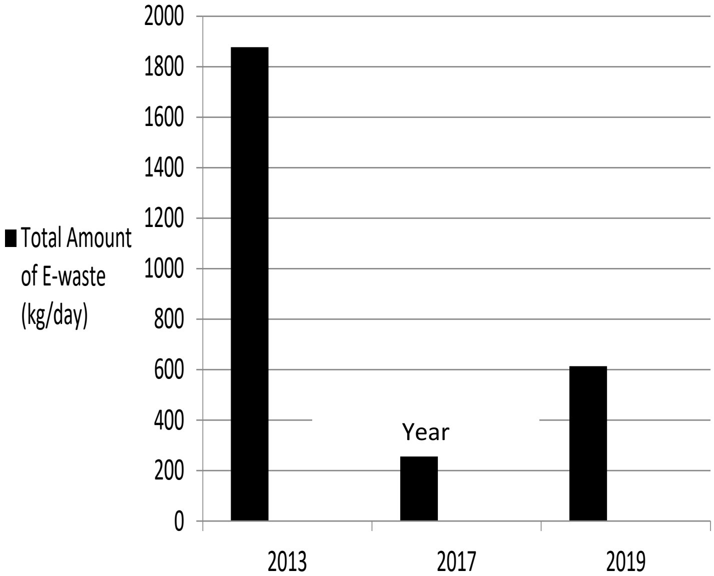

Figure 4: Comparison of Present Amount of Recyclable E-waste with Related Previous Study

3.6 Income Generation from E-waste Recycling in Khulna City

The profit generated from E-waste Recycling varies from shop to shop and person to person. The Feriwalas income more than the Tokais and the shop worker's income more than the Feriwalas. Similarly, big shops' income is more than the medium and small shops'. The total income generation from E-waste recycling was determined by multiplying their number with the approximate average income of the individuals collected form questionnaire survey. The amount was expressed in taka. month^{-1}. Total income generated from E-waste recycling is shown in Table 5.

Table 5: Income Generated from E-waste Recycling in Khulna City

Location	Number of E-waste Recycling Shop Workers	Avg. Income of Shop Workers (taka. person^{-1}. month^{-1})	Total Income of Shop Workers (taka. month^{-1})	Number of Tokais	Avg. Income of Tokais (taka. person^{-1}. month^{-1})	Total Income of Tokais (taka. month^{-1})	Number of Feriwalas	Avg. Income of Feriwalas (taka. person^{-1}. month^{-1})	Total Income of Tokais (taka. month^{-1})	Total (taka. month^{-1})
Sheikhpara	50	3935	196750	100	1700	170000	30	2850	85500	452250
Dakbangla	68	4328	294304	50	1680	84000	18	3050	54900	433204
Daulatpur	10	4125	41250	10	1500	15000	3	2680	8040	64290
Fulbari-Shiromoni	16	4107	65712	8	1600	12800	2	2700	5400	83912
Khalishpur	15	4116	61740	10	1450	14500	5	2650	13250	89490
Sonadanga	69	4376	301944	20	1600	32000	7	3100	21700	355644
Gallamari	27	4266	115182	15	1500	22500	5	3000	15000	152682
Rupsa	21	4188	87948	12	1480	17760	4	3000	12000	117708
Nirala	48	4293	205344	15	1550	23250	5	3050	15250	243844
Other Places	28	4278	119784	50	1500	75000	5	3000	15000	209784
Total			1489958			466810			246040	**2202808**

4. CONCLUSIONS

Recycling of E-waste is a important matter of concern in this modern era of electronics and technologies. In this study, the existing recycling practices and collection methods of E-waste in Khulna city were found out and an E-waste recycling pattern was developed. The characteristics of the selected areas (Shiromoni, Fulbari, Daulatpur, Khalishpur, Sheikhpara, Dakbangla, Sonadanga, Gallamari, Rupsa and Nirala) and the types of recyclable E-waste were collected by field survey. But the number of households and the population of each area were found different in different journals. So approximately the best data were selected. The number of E-waste recycling shops, the number of workers including Tokais, Feriwalas and E-waste recycling shop workers involved in the whole process of E-waste recycling were estimated in this study. The daily amount of recyclable E-waste was found out through questionnaire survey. Although correct data were tried to collect, it may slightly varies from the actual data. In comparision to previous studies, the amount of recyclable E-waste was reduced in 2017 than 2013 may be due to availability of all kinds of electrical and electronic devices in Khulna city and was increased in 2019 than 2017 may be due to increased population of this city. As the income generation from E-waste recycling practices varies from person to person, average income of the individuals was taken to determine the monthly total income generation from E-waste recycling practices in Khulna city. The willingness of E-waste recycling practices of the people in Khulna city can reduce the effects of heavy metals containing in E-waste and hence reduce soil pollution and can increase environmental, financial and economic develpoment of this city.

REFERENCES

Ali, M. H. (2013). Management and Recycling of Electronic Waste in Khulna City. B.Sc. Engineering Thesis, The Department of Civil Engineering; KUET, Khulna, Bangladesh.

Bari, Q. H., Hassan, K. M., & Haque, R. (2012). Scenario of solid waste reuse in Khulna city of Bangladesh. *Waste management*, *32*(12), 2526-2534.

BBS, 2009, Statistical Pocket Book of Bangladesh. Bangladesh Bureau of Statistics. p. 8.

Chi, X., Streicher-Porte, M., Wang, M. Y., & Reuter, M. A. (2011). Informal electronic waste recycling: a sector review with special focus on China. *Waste Management*, *31*(4), 731-742.

Kang, H. Y., & Schoenung, J. M. (2005). Electronic waste recycling: A review of US infrastructure and technology options. *Resources, Conservation and Recycling*, *45*(4), 368-400.

Moniruzzaman, S. M., Bari, Q. H., & Fukuhara, T. (2011). Recycling practices of solid waste in Khulna city, Bangladesh. *The Journal of Solid Waste Technology and Management*, *37*(1), 1-15.

Nahar, W. (2017). Electronic Waste Management in Khulna City. B.Sc. Engineering Thesis, The Department of Civil Engineering; KUET, Khulna, Bangladesh.

Nnorom, I. C., Ohakwe, J., & Osibanjo, O. (2009). Survey of willingness of residents to participate in electronic waste recycling in Nigeria–A case study of mobile phone recycling. *Journal of cleaner production*, *17*(18), 1629-1637.

Sajid, M., Syed, J. H., Iqbal, M., Abbas, Z., Hussain, I., & Baig, M. A. (2019). Assessing the generation, recycling and disposal practices of electronic/electrical-waste (E-Waste) from major cities in Pakistan. *Waste management*, *84*, 394-401.

Walden, J. L. (2012). Environmental Impacts Associated with Current Methods of Re-Use, Recycling and Reclamation of Personal Computers and Cell Phones.

Wang, B., Ren C., Dong, X., Zhang, B., & Wang, Z. (2019). Determinants shaping willingness towards on-line recycling behaviour: An empirical study of household e-waste recycling in China. *Resources, Conservation and Recycling*, *143*, 218-225.

Waste Safe (2005): Integrated Management and Safe Disposal of Municipal Solid Waste in Least Developed Asian Countries. M. Alamgir, C. McDonald, K.E. Roehl and A. Ahsan edited final report of Waste Safe, a feasibility study project under Asia Pro Eco Program at KUET, Bangladesh.

OCCURRENCE OF MICROPLASTICS AT SHIP BREAKING AND RECYCLING ZONE OF BANGLADESH

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ABSTRACT

Microplastic (MPs) has emerged as a global concern causing ubiquitous contamination of marine environment by tiny plastic particles. MPs are increasingly entering the food chain and subsequently into the human digestive system. Bangladesh is blamed for contributing MPS into the marine ecosystem through the Bay of Bengal. However, the country has not yet focused on this issue. On the other hand, Bangladesh is the global leader in open beaching ship breaking and recycling industry (SBRI) on the Sitakunda-Bhatiary shore of the Bay of Bengal. The role of SBRI in MP contamination of the Bay of Bengal is yet to be explored. This study evaluated the abundance, distribution, and characteristics of microplastics in the soils from SBRI. Samples were collected from 0-10, 10-20 and 20-30 cm depths at three zones viz., beaching, cutting and storage zones of five ship breaking yards (SBYs) and a control site at Kattali sea beach. MP fragments, between 0.3 to 5 mm, from the soil samples, were extracted following NOAA protocol for sediments. The fragments were analyzed under an optical microscope and by using ImageJ software and FTIR was used for the polymeric identity of the fragments. The study revealed an abundance of microplastics in the soils from SBYs with 217 MP particles per kg on an average compared to 127 MP particles per kg at the control site. Abundance varied among zones with respective ranges of 50-460, 80-410 and 70-330 for beaching, cutting and storage zones. Overall, the MP particles found in the ship breaking yard were mostly plastic fragments (45%) and fibers (40%). The respective ranges of plastic and polythene fragments were 10-260 and 10-50 pieces per kg of soil from SBYs compared to their respective values of 10 and 20-30 pieces in control. Fibers were the most abundant form of microplastic particles at beaching zone while at cutting and storage zones plastic fragments dominated. Microplastic particles from SBYs were mainly Transparent (22%) and Red & Black (10%) in color unlike particles in the control sample which were mostly Transparent or Grayish. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage zone. The second most abundant color was Black and Red respectively at beaching and cutting zones while it was Transparent and Gray at the storage zone. In terms of shape, 45% of microplastic particles were irregular shaped, 18% elongated, 17% rectangular without variations between SBYs and control samples. In terms of abundance, respective zone sequences of irregular shaped, elongated and rectangular particles were storage>beaching>cutting, cutting>storage>beaching and storage>cutting>beaching. Among the microplastic particles, ~71% were in the size range of 0.3 to 1 mm and about ~28% were in the range of 1- 1.70 mm in SBYs as in the control. Respective size ranges of plastic particles at beaching, cutting, and storage zones were 0.33-1.45, 0.3-1.81 and 0.3-2.54 mm. FTIR indicated presence of Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS) with PVC and PU occurring only in SBY samples. The result indicated elevated microplastic contamination of the coastal environment by SBRI with the exclusive contribution of PVC and PU. Therefore, SBYs should be directed to adopt MP control measures while breaking ships.

Keywords: *Microplastic, Ship breaking yards, Plastic pollution, Marine pollution.*

1. INTRODUCTION

Plastics in the environment are either macro- or micro-plastics based on their size (Barnes et al, 2009). There are varying opinions in classifying plastic fragments into microplastics, for example, less than 10mm diameter (Graham & Thompson, 2009), 2-6mm (Derraik, 2002), less than 2mm (Mark et al, 2010), smaller than 5.0 mm in size. Microplastic (MP) has become a global concern as exemplified by the UN environment's adoption of 'Beat Plastic Pollution' as the main theme of World Environment Day 2018. Unabated use of plastics all over the world at scale made MPs ubiquitous especially in the marine environment leading to damages of the marine ecology. In 2017, globally almost 350 million tonnes of plastics entered economic flow which was around 15 million tonnes higher than in 2016 (PlasticsEurope, 2018). About 15-31% of MPs in the oceans are primary MPs from laundering of synthetic clothes (35% of primary microplastics); abrasion of tires through driving (28%); intentionally added microplastics in personal care products, for example, microbeads in facial scrubs (2%) while 69-81% are secondary MPs (European Parliament, 2018).

As the MPs are increasing, in recent years MPs were extracted from sediment cores collected in Japan, Thailand, Malaysia, and South Africa. Variety of polymers, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terphthalates (PET), polyethylene-polypropylene copolymer (PEP) and polyacrylates (PAK) were identified in the sediment. Most of the microplastics which size were in the range of 315 lm–1 mm. The abundance of microplastics in surface sediment varied from 100 pieces/kg-dry sediment in a core collected in the Gulf of Thailand to 1900 pieces/kg-dry sediment in a core collected in a canal in Tokyo Bay (Matsuguma et al., 2017). MPs have been extensively detected in sea, freshwater, land environment and organisms (He et al., 2018). Polypropylene, nylon, PVC MPs were found in Belgian beaches (Claessens et al, 2011) in the Belgian beaches and estuarine and subtidal sediments around Plymouth, UK (Thompson et al., 2004). PS and PMMA acrylic fibres MPs are accumulating in marine habitats (Mark et al., 2011). PE, PP, PS, Nylon, PVA, and acrylonitrile butadiene styrene (ABS) have been recently identified in Singapore's coastal environment (Ng & Obbard, 2006).

Ship Breaking and Recycling Industry (SBRI) is a hugely profitable industry with a great environmental cost and Bangladesh has recently become the ship breaker in the world surpassing India in terms of gross tonnage (Express, 2018). Shipbreaking activities in Bangladesh are concentrated in Sitakund (Bhatiary to Barwalia), just north of Chittagong city on the Bay of Bengal. And most of the activities are performed in open beach sediment. Hazardous waste coming from the ship breaking yard includes asbestos, oil pollutants, persistent organic pollutants, Polycyclic Aromatic Hydrocarbons (PAHs), Polyvinyl Chloride (PVC), PCBs (Polychlorinated Biphenyls) and electrical equipment (Hossain & Islam, 2006; Jobaid et al, 2014) may easily contaminate the soil. MP fragments were found in a ship-breaking yard in the Arabian sea (Reddy et al, 2006). They found PU, nylon, PS, polyester, and glass wool in extracts from sediments which are normally used in the construction of ships and the making of associated components such as insulating materials, fabrics, packaging, etc. Therefore, during the ship dismantling process at Alang-Sosiaya (Reddy et al., 2006). Tiwari and her colleagues (2019) found Microplastic concentrations in beach sands were varied from 45 ± 12 MP kg^{-1} to 220 ± 50 MP kg^{-1} of dry sand of Indian coast (Tiwari et al, 2019). In an Indian ship-breaking yard, the highest concentration of microplastic was 89 mg kg^{-1}, whereas, in UK beach, the microplastic concentration was 9 kg^{-1}. Though many aspects of pollution from SBRI have been performed - the role of SBRI in MP pollution is yet to be investigated. This study addressed this research gap by analysing MPs in samples of soils from SBRI.

2. METHODOLOGY

2.1 Study Area

Soil samples were collected from five Ship Breaking Yards (SBYs) in Bhatiary, Chittagong, Bangladesh on May 2018. A control sample was collected from Kattoli Sea Beach which was not affected by ship breaking activities and is located in a similar geography compared to SBYs. In each yard, samples were taken from three zones – Beaching zone, Cutting zone and Storage zone. At each zone, the samples were taken from three depths *viz.*, 0-10 cm, 10-20 cm and 20-30 cm. For the analysis, the samples from three depths were made into a composite sample.

Table 1: GPS locations of soil samples collected from SBYs

Yard	Zone	Latitude	Longitude
1	Beaching	22.43522	91.73264
	Cutting	22.4352	91.73308
	Storage	22.43531	91.73344
2	Beaching	22.46905	91.71942
	Cutting	22.46926	91.71972
	Storage	22.46914	91.72024
3	Beaching	22.47972	91.71319
	Cutting	22.4798	91.7134
	Storage	22.47981	91.71373
4	Beaching	22.48392	91.71123
	Cutting	22.48402	91.71147
	Storage	22.48407	91.71198
5	Beaching	22.5169	91.68879
	Cutting	22.51702	91.68885
	Storage	22.51729	91.68891
Control	Beaching	22.35087	91.75723
	Cutting	22.35088	91.75782
	Storage	22.35085	91.7586

2.2 Materials and Methods

This separation of MPs from the soil matrix was done following adapted National Oceanic and Atmospheric Administration (NOAA) protocol for quantifying synthetic particles in waters and sediments. According to NOAA, this method can be used for the analysis of plastic debris include hard plastics, soft plastics (e.g., foams), films, line, fibres, and sheet in bed sediments. Moreover, this method is applicable for the determination of many common plastics including polyethylene (0.91-0.97 g/mL), polypropylene (0.94 g/mL), polyvinyl chloride (1.4 g/mL), and polystyrene (1.05 g/mL) (Masura et al, 2015). In this study, 0.3-5mm size plastic fragments were considered as microplastics. In brief, the samples were weighted and 100g of the samples were dried at 105°C for overnight. Then the dried soils were crashed using morter and pastle and sieved through a 5-mm metal sieve to discard the particles larger than 5-mm. Finally, the samples were subjected to density separation in 5M NaCl (aq.) solution in a beaker overnight to isolate the plastic debris through flotation. The floating solids were separated from the denser undigested mineral components using a density separator and transferred through a custom 0.3-mm sieve.

MPs that were collected on the 0.3-mm sieve were subjected to wet peroxide oxidation (WPO) after drying by using 20ml 30% Hydrogen peroxide (H_2O_2) in the presence of a 20ml 0.05M Fe(II) catalyst to digest organic matter. In this process, the plastic debris remains unaltered. Then the WPO mixture was again subjected to density separation in 5M NaCl to isolate the plastic debris through flotation. The floating solids were collected in a petri dish and dried at 60°C for 10-15 minutes or until the sample dryness. An optical microscope with 10X lens was used to take images of MPS to determine their sizes, shapes and colours beside other parameters. ImageJ software was used to determine the shape, length, area and perimeter of the microplastic particles. Fourier-Transform Infrared Spectroscopy (FTIR) was used to confirm the polymeric identity of the microplastic particles. The working flow chart is given below:

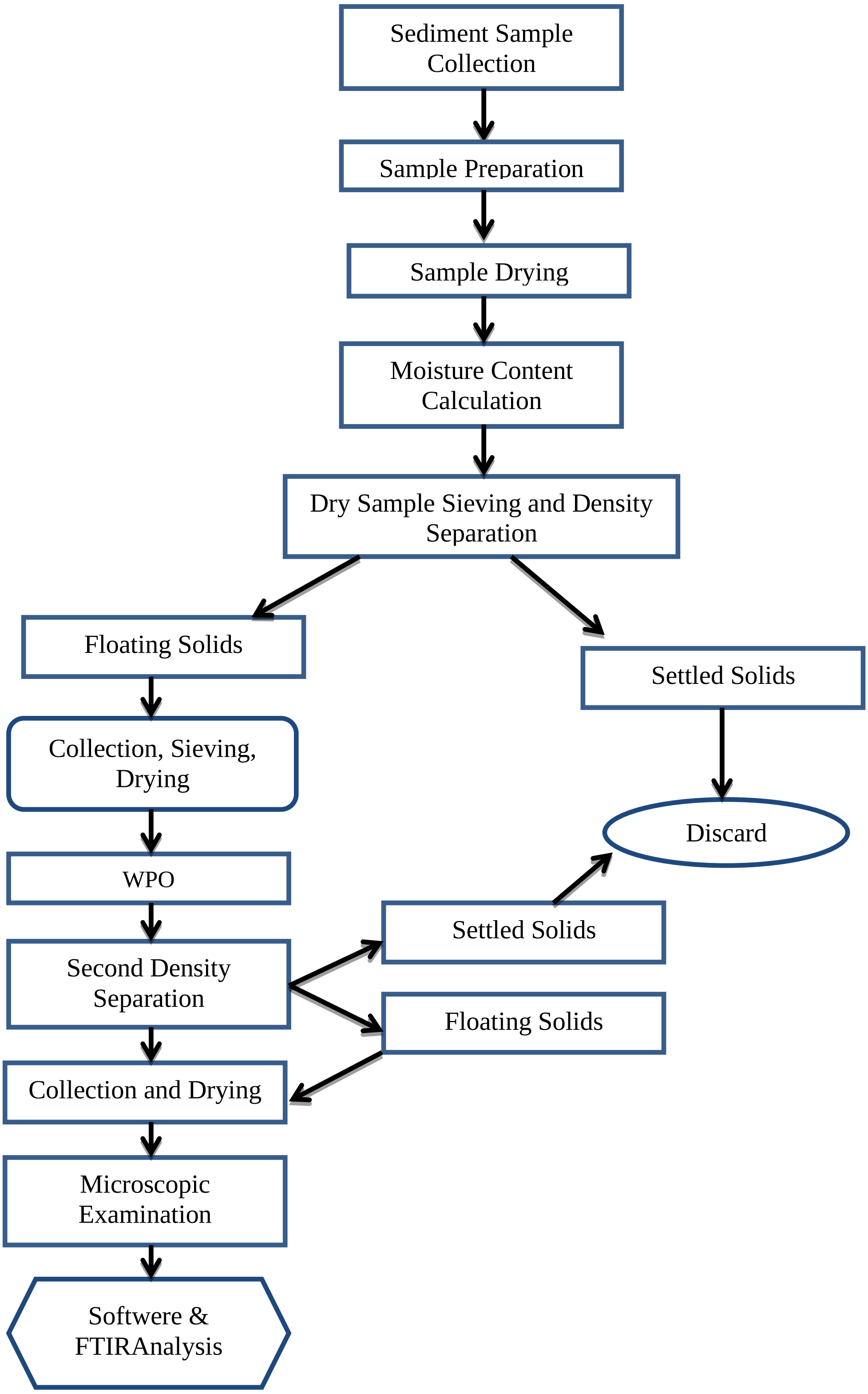


Figure 1: Flow Diagram of Working Process

3. RESULTS AND DISCUSSION

3.1 Number of Microplastics

MPs were found in all the SBY samples. The total number of microplastics particles in SBY samples was around 217 MP particles per kg compared to 127 in control indicating significant enrichment of microplastic in the SBYs. The number of particles varied among Beaching, Cutting and Storage zones (Figure 3.1) and the respective ranges were 50-460, 80-410 and 70- 330. In the control site the range was 80-160. In Belgian coastal waters total MPs count was as high as 390 particles per kg dry sediment (Claessens et al., 2011). Beijiang River littoral zone showed 178±69 to 544±107 MPs particles per kg sediment (Wang et al., 2016). In Indian coast, MPs concentrations in beach sands varied from 45±12 to 220±50 MP per kg sand (Tiwari et al., 2019). At Changjiang Estuary in China the mean MP concentration was 121±9 particles per kg (Peng et al., 2017). Compared to these reports, SBYs seems to substantially contribute in MPs enrichment in beach soil which may ultimately find their ways into the global oceanic circulation through the Bay of Bengal.

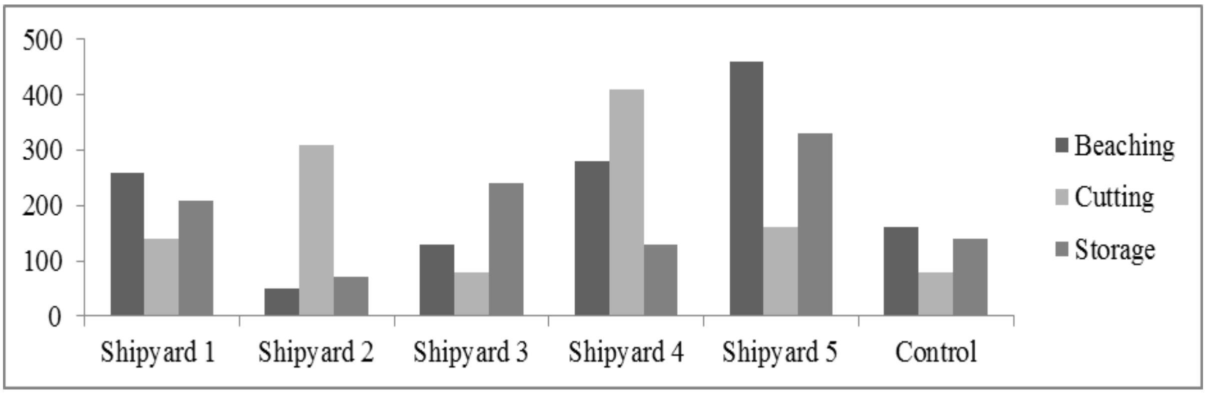


Figure 2: Total Number of Microplastics (Per Kg Soil)

3.2 Types of Microplastics

Several forms of MPs were found in soil samples from ship breaking. Plastic fragments, Polythene fragments, Pellets, Foams, and Fibers were the main forms. Plastic fragments and fibres were the most abundant form. Overall, the number of plastic fragments varied from 10-260 pieces, polythene fragments varied from 10-60 pieces, foam 10-50 pieces and fibre 10-340 pieces per kg soil in SBY. But in the control the number of plastic fragments is around 10 pieces, Polythene fragments varied from 20-30 pieces, foam 10-20 pieces and fibre 30-120 pieces per kg soil. In the Beaching zone, fibres were most abundant followed by plastic fragments whereas in the Cutting zone and Storage zone, plastic fragments were the most abundant form followed by fibres. In the beaching zone, fibers > plastic fragments > polythene fragments > foams. In the cutting zone, plastic fragments > fiber > foam > polythene whereas it is plastic fragments and foams > polythene and fiber in the control. In the storage zone, plastic fragments > fiber > polythene > foam whereas it is fiber > polythene and foam > plastic fragments in the control. In contrast, it was fiber > polythene > plastic and foam in the control.

At a glance, 1450 out of 3260 (~45%) of total microplastics found in SBY were Plastic fragments, 40% (1310 out of 3260) was Fibers, 9% (300 out of 3260) was Polythene fragments and 6% (200 out of 3260) was Foams (Figure 3.3a). On the other hand, 63% was fibers, 18% was Polythene fragments, 11% was Foams and 8% was Plastic fragments in the control (Figure 3.3b). In the beaching zone, around 46% of total microplastics was Fibers, 41% was Plastic fragments, ~10% was Polythene, and ~3% was Foam. In the cutting zone, around 45% was Plastic fragments, ~42% was Fibers, ~7% was Foam and ~5% was Polythene fragments. And in the storage zone, ~48% was Plastic fragments, ~32% was Fibers, ~12% was Polythene fragments and ~8% was Foams.

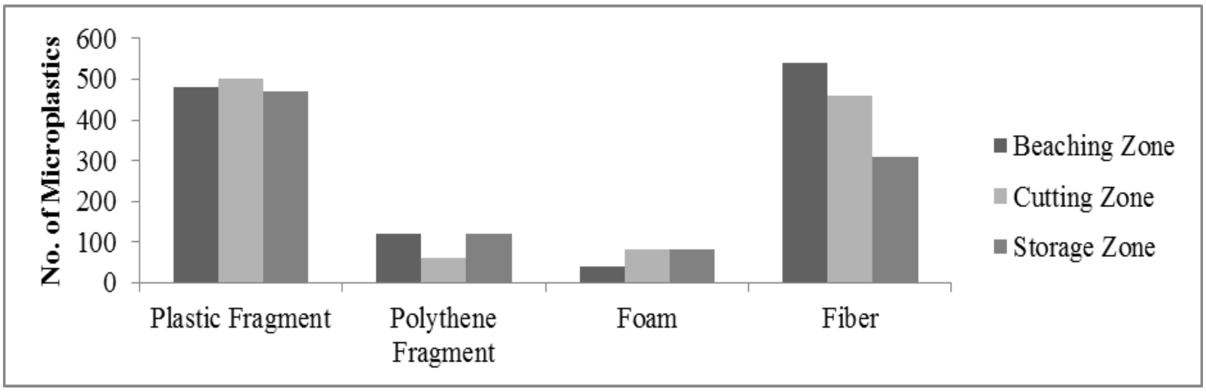
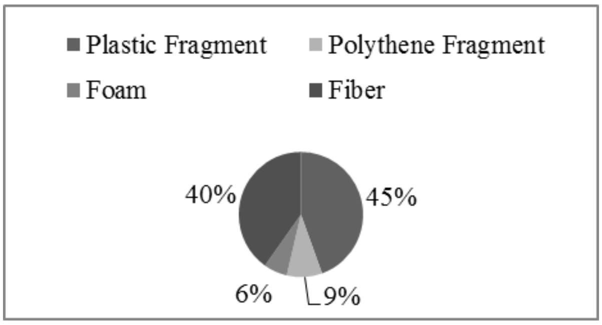


Figure 3: Types of Microplastics in different zones

In the Channel of Bizarte in Northern Tunisia the dominant shape of microplastic was fibre (88.88%) (Abidli et al, 2017). In Browne coastal areas, the proportions of polyester and acrylic fibres used in clothing were dominant (Browne et al., 2011). In the pelagic zone and sedimentary habitats, plastic fragments and fibres were accumulated (Thompson et al., 2004). In Belgian harbours, Polypropylene, nylon, polyvinyl alcohol Fibres were the most common types of particles found (Claessens et al., 2011). On the southeast coast of Shanghai fiber (93%) were the most abundant types. Comparison with these sites clearly indicated unique characteristic of SBYs in terms of forms of MPs released.



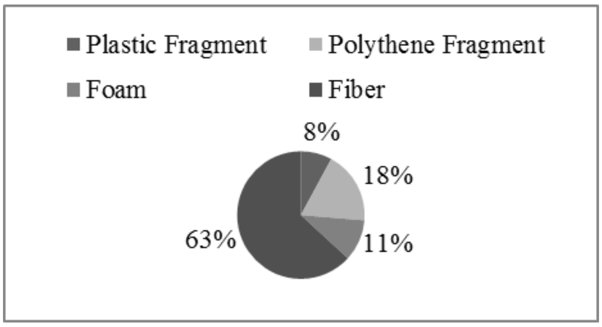


Figure 4 (a): Abundance of Microplastics in SBY (b) Abundance of Microplastics in Control

3.3 Color

In this study, Transparent microplastic particles were the most abundant both in ship-breaking yard and control samples. In the SBY the color abundance varies from Transparent > Red > Black > Green > Gray > Grayish > Yellow > Reddish > Blue > Brownish > Brown > Bluish > Golden > White > Greenish. On the other hand, in the control the color abundance varies from Transparent > Grayish > Reddish > Greenish > White, Green, Blue > Yellow. Black, Red, Reddish, Blue, Bluish, Yellow color particles were not found in the control. In SBY around 22% microplastics were transparent compared to around 47% in the control. About 10% of particles were Black, Red and Green in the SBY whereas 16% was Greyish and 11% was Reddish in the control. Black particles were absent in the control indicating less permanence of microplastics in the soil of control. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage. However, the second most abundant color of microplastic particles was Black, Red respectively at beaching, cutting zone while it was Transparent and Grey at storage zones. In the Beaching zone, the abundance of microplastics by color was Transparent (25%) > Black (19%) > Grayish (12%) > Red, Yellow (~8%) > Blue, Green, Brownish (~5%) > Reddish, Gray, Golden, White (~3%) > Bluish (2%). In the Cutting zone the sequence was Transparent (24%) > Red (15%) > Reddish (14%) > Yellow (8%) > Blue, Green, Gray (~6%) > Brown, Grayish (~5%) > Black (4%), Bluish (2%), Golden (1%). And in the Storage zone the sequence was Green (18%) > Transparent and Gray (16%) > Black and Red (~7%) > Blue and Yellow (~6%) > Brown and Grayish (~5%) > Brownish (4%) > Bluish (3%) > Reddish and Greenish (~2%) > Golden (1%).

In the Channel of Bizarte in Northern Tunisia microplastic color were white blue green red and black (Abidli et al., 2017). At a Brazilian beach, plastic pellets/nibs were mainly white or pearly, bluish/greenish and brownish (Spengler et al., 2008).

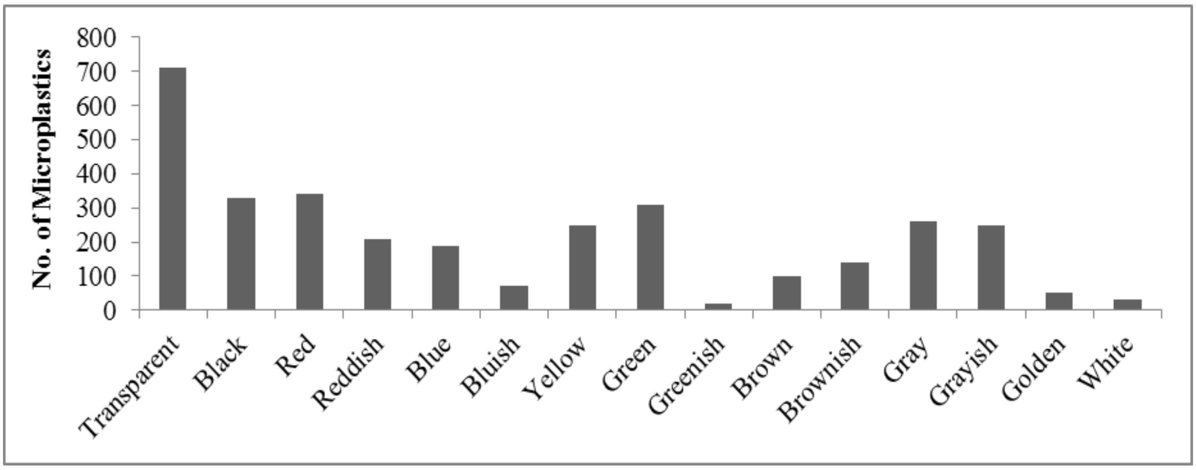


Figure 5: Total Color abundance in SBY

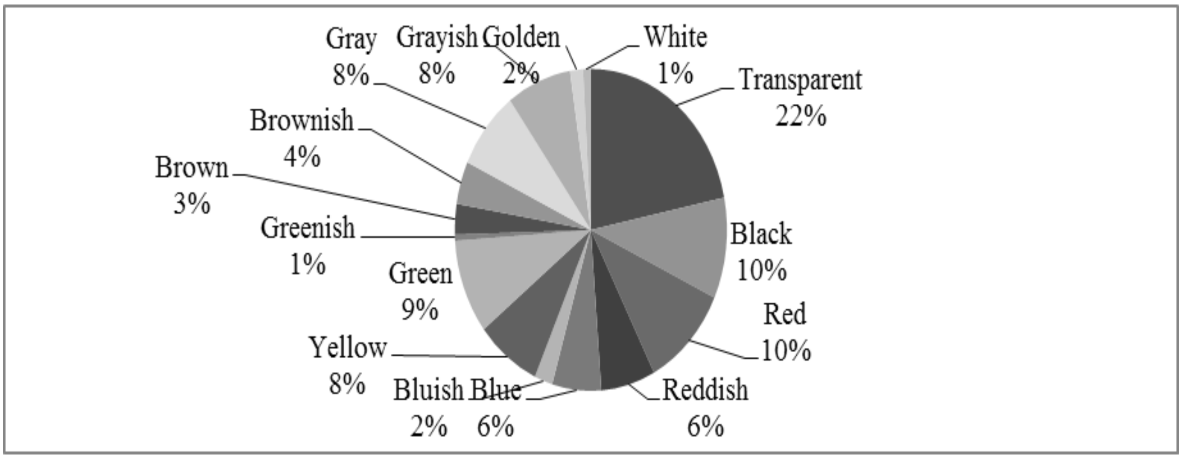


Figure 6: Total Color Percentage in SBY

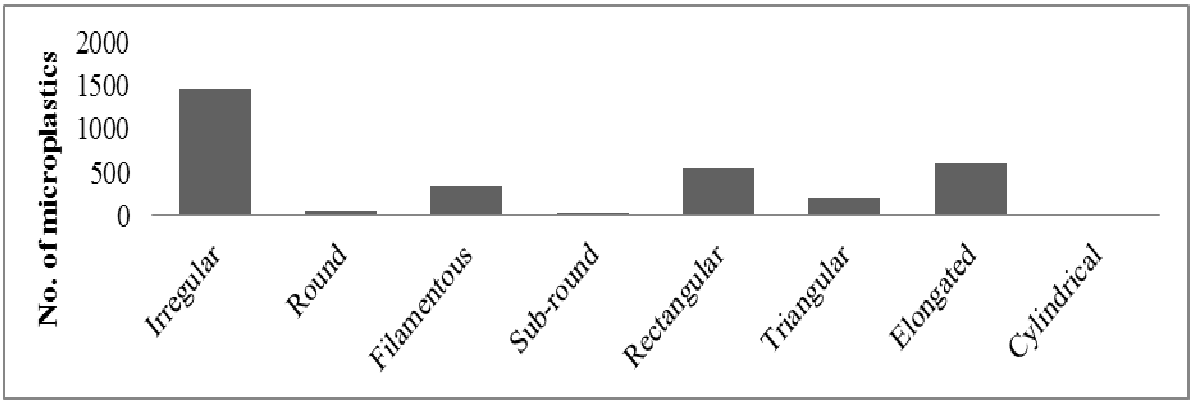


Figure 7: Total Shape-wise distribution of microplastics in SBY

3.4 Shape

Most of the microplastics were irregularly shaped followed by elongated shape both in SBY and control. In the SBY soil the abundance of microplastics on the basis of their shapes were as follows: Irregular > Elongated > Rectangular > Filamentous > Triangular > Round > Sub- round > Cylindrical. It was Irregular > Elongated > Rectangular > Filamentous > Sub- round in the control. Round, Triangular and Cylindrical shape particles were absent in the control.

Among the particles occurred in SBY soils, around 45% were irregularly shaped, ~18% elongated, ~17% rectangular, ~10% filamentous, ~6% triangular, ~2% round and ~1% in cylindrical and sub-round shape. On the other hand, in the control 47% was irregular in shape, ~26% elongated, ~13% rectangular, ~11% filamentous, ~3% sub- round.

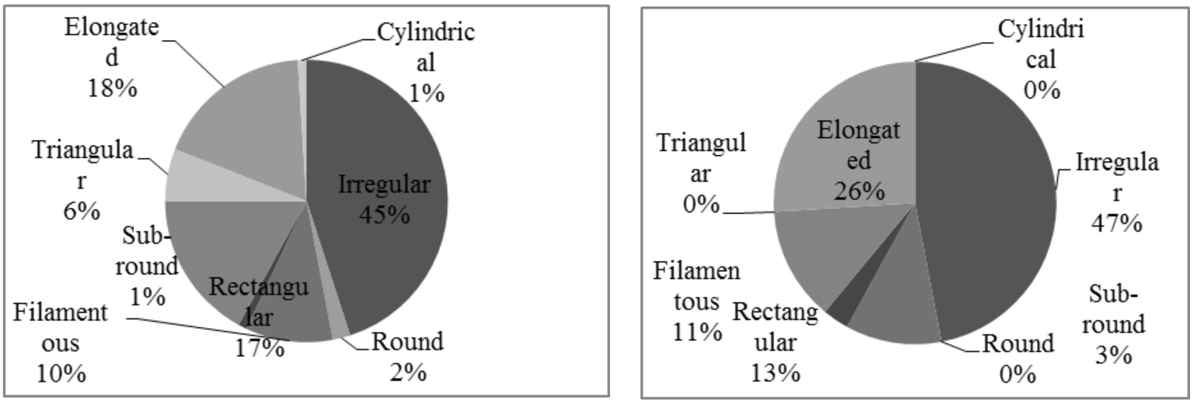


Figure 8: Shape-wise distribution of microplastics in SBY and Control

In the Beaching zone shape-wise distribution of microplastics was as follows Irregular (48%) > Filamentous (16%) > Elongated (14%) > Rectangular (13%) > Triangular (7%) > Round (2%). Sub-round and cylindrical shaped was not found here. In the Cutting zone shape-wise distribution of microplastics was as follows Irregular (35%) > Elongated (25%) > Rectangular (18%) > Filamentous (10%) > Triangular (6%) > Sub- round (3%) > Round (2%) and Cylindrical (1%). And in the storage zone, Irregular (53%) > Rectangular (19%) > Elongated (15%) > Triangular (5%) > Filamentous (4%) > Sub- round, Round and Cylindrical (1%) particles were found.

3.5 Size

Around 71% particles' size was in the range of 0.3 to 1mm, around 28% was in the range of 1-1.7mm, and around 1% was in the range of 1.7- 2.4mm and 2.4- 3.1mm. No particles > 2.54mm were found. On the other hand, around 76% of particles showed sizes is in the range of 0.3 to 1mm, around 24% was between 1- 1.7mm. In control all particles were below 1.7mm in size. Respective size ranges for Beaching, Cutting and Storage zones were 0.33-1.45 mm, 0.3-1.81 mm and 0.3-2.54 mm.

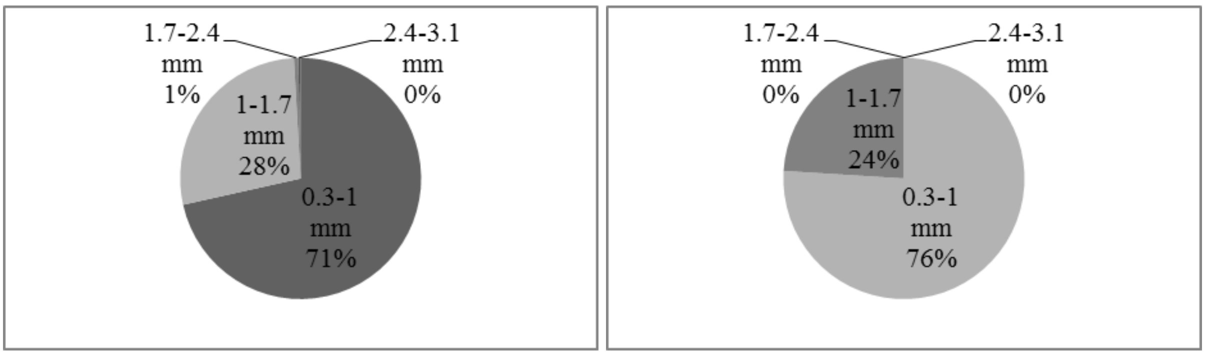


Figure 9: Size-wise distribution of microplastics in SBY (left one) & Control (right one)

3.6 FTIR Analysis

FTIR identified the microplastic particles as Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS). Among these particles Polyvinylchloride (PVC) and Polyurethane (PU) were found only in the ship breaking yard indicating characteristic enrichment of SBYs soil by ship breaking activities. In Nordeerney, PP, polyethylene, PET, PVC, PS and PA were identified (Dekiff et al, 2014).

4. CONCLUSIONS

Microplastic is a relatively new issue and it is a matter of concern all over the world. Though Bangladesh is one of the vulnerable countries, there is a dearth of studies on this issue specially in context of Ship Breaking and Recycling Industries (SBRI). This study aimed to find the contribution of SBRI on MP enrichment of beach sediment for the first time by following NOAA protocol. This study revealed high abundance of microplastics in the sediments from SBYs in Bangladesh with ~ 217 MP particles per kg of soil from SBYs on an average compared to 127 particles per kg at the control site. The abundance of MP particles varied among the zones with respective ranges of 50-460, 80-410 and 70-330 for beaching, cutting and storage zones. Overall, the particles found in the SBYs were mostly plastic fragments (45%) and fibers (40%). The respective ranges of plastic and polythene fragments were 10-260 and 10-50 pieces per kg of soil from SBYs compared to their respective values of 10 and 20-30 pieces in control. At beaching zone fibers were the most abundant form of microplastic particles. In contrast, at cutting and storage zones plastic fragments dominated. Microplastic particles from SBYs were mainly Transparent (22%) and Red & Black (10%) in color unlike particles in the control sample which were mostly Transparent or Grayish. Transparent particles were most abundant in the beaching and cutting zones and Green in the storage. However, the second most abundant color of microplastic particles was Black, Red respectively at beaching, cutting zone while it was Transparent and Gray at storage zones. Shapewise, 45% of microplastic particles had an irregular shape, 18% were elongated, 17% rectangular and it was almost similar between SBYs and control samples. In terms of abundance, respective zone sequences of irregular shaped, elongated and rectangular particles were storage>beaching>cutting, cutting>storage>beaching and storage>cutting>beaching. Among the microplastic particles, ~71% were in the size range of 0.3 to 1 mm and about ~28% were in the range of 1- 1.70 mm in the SBY. This is almost the same in the control. Respective size ranges of plastic particles at beaching, cutting and storage zones were 0.33-1.45, 0.3-1.81 and 0.3-2.54 mm. The analyzed particles were identified as Polyethylene (PE), Polyethylene terephthalate (PET), Polypropylene (PP), Polyvinylchloride (PVC), Polyurethane (PU), Polystyrene (PS). Among these particles Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard. Therefore, the described microplastic fragments originated both from sea sediments and directly from the ship-breaking activities at the site. The comparison between control and ship breaking yard samples reveals the contribution of ship breaking in microplastic contamination. As Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard so their source should be identified including their concentration. And their impact should be identified including the counter measure. Though the study deals with a limited number of samples, it may provide baseline information about the distribution, types, colours, shapes, area coverage, the perimeter of microplastics of the soils of ship breaking yard, Bangladesh. As Polyvinylchloride (PVC) and Polyurethane (PU) found only in the ship breaking yard and were absent in control, care must be taken during ship breaking while handling the materials which may contains these plastics.

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REFERENCES

Abidli, S., Toumi, H., Lahbib, Y., & El Menif, N. (2017). The First Evaluation of Microplastics in Sediments from the Complex Lagoon-Channel of Bizerte (Northern Tunisia). https://doi.org/10.1007/s11270-017-3439-9

Barnes, D. K. A., Francois, G., C., T. R., & Morton, B. (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Browne, M. A., Galloway, T. S., & Thompson, R. C. (2010). Spatial Patterns of Plastic Debris along Estuarine Shorelines. Environmental Science & Technology, 44(9), 3404–3409. https://doi.org/10.1021/es903784e

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. Environmental Science & Technology, 45(21), 9175–9179. https://doi.org/10.1021/es201811s

Claessens, M., De Meester, S., Van Landuyt, L., Clerck, K., & Janssen, C. (2011). Occurrence and distribution of microplastics in marine sediments along the Belgian coast. 62. https://doi.org/10.1016/j.marpolbul.2011.06.030

Dekiff, J. H., Remy, D., Klasmeier, J., & Fries, E. (2014). Occurrence and spatial distribution of microplastics in sediments from Norderney. 186C. https://doi.org/10.1016/j.envpol.2013.11.019

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. Marine Pollution Bulletin, 44(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

European Parliament. (2018, November 22). Microplastics: Sources, effects and solutions. Retrieved February 20, 2019, from European Parliament website: http://www.europarl.europa.eu/news/en/headlines/society/20181116STO19217/microplastics-sources-effects-and-solutions

Express, T. F. (2018, July 12). Challenges before ship-breaking industry. The Financial Express. Retrieved from https://www.thefinancialexpress.com.bd/editorial/challenges-before-ship-breaking-industry-1531411490

Graham, E. R., & Thompson, J. T. (2009). Deposit- and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. Journal of Experimental Marine Biology and Ecology, 368(1), 22–29. https://doi.org/10.1016/j.jembe.2008.09.007

He, D., Luo, Y., Lu, S., Liu, M., Song, Y., & Lei, L. (2018). Microplastics in soils: Analytical methods, pollution characteristics and ecological risks. TrAC Trends in Analytical Chemistry, 109, 163–172. https://doi.org/10.1016/j.trac.2018.10.006

Hossain, Md. M., & Islam, M. (2006). Ship Breaking Activities and its Impact on the Coastal Zone of Chittagong, Bangladesh: Towards Sustainable Management.

Jobaid, Md. I., Khan, M. M., Haque, A. K. M. K., & Shawon, I. A. (2014). Ship Recycling and Its Environmental Impact: A Brief Overview of Bangladesh (Vol. 16). https://doi.org/10.9790/487X-161013137

Masura, J., Baker, J., Foster, G., and Arthur, C. (2015). Laboratory Methods for the Analysis of Microplastics inthe Marine Environment: Recommendations for quantifying synthetic particles inwaters and sediments. National Oceanic and Atmospheric Administration.

Matsuguma, Y., Takada, H., Kumata, H., Kanke, H., Sakurai, S., Suzuki, T. and Newman, B. (2017). Microplastics in Sediment Cores from Asia and Africa as Indicators of Temporal Trends in Plastic Pollution (Vol. 73). https://doi.org/10.1007/s00244-017-0414-9

Ng, K. L., and Obbard, J. (2006). Prevalence of microplastics in Singapore's coastal marine environment. 52. https://doi.org/10.1016/j.marpolbul.2005.11.017

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., and Li, D. (2017). Microplastics in sediments of the Changjiang Estuary, China (Vol. 225). https://doi.org/10.1016/j.envpol.2016.12.064

PlasticsEurope. (2018). Plastics- the Facts 2018: An analysis of European plastics production, demand and waste data. Retrieved from www.plasticseurope.org

Reddy, M. S., Basha, S., Adimurthy, S., & Ramachandraiah, G. (2006). Description of the small plastics fragments in marine sediments along the Alang-Sosiya ship-breaking yard, India. Estuarine, Coastal and Shelf Science, 3–4(68), 656–660. https://doi.org/10.1016/j.ecss.2006.03.018

Spengler, A., Silva-Cavalcanti, J. S., Ivar do Sul, J. A., Araújo, M. C. B., Costa, M. F., & Tourinho, P. S. (2008). Microplastics on the strandline: Snapshot of a Brazilian beach.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., and Russell, A. E. (2004). Lost at Sea: Where Is All the Plastic? Science, 304(5672), 838–838. https://doi.org/10.1126/science.1094559

Tiwari, M., Rathod, T. D., Ajmal, P. Y., Bhangare, R. C., and Sahu, S. K. (2019). Distribution and characterization of microplastics in beach sand from three different Indian coastal environments. Marine Pollution Bulletin, 140, 262–273. https://doi.org/10.1016/j.marpolbul.2019.01.055

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q., and Cai, L. (2016). Microplastics in the surface sediments from the Beijiang River littoral zone: Composition, abundance, surface textures and interaction with heavy metals. 171. https://doi.org/10.1016/j.chemosphere.2016.12.074

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MATERIAL FLOW ACCOUNTING OF ALUMINUM IN BANGLADESH WITH SPECIAL EMPHASIS ON CIVIL ENGINEERING SECTOR

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ABSTRACT

Aluminum (Al) is one of the most used materials in any economy. Accordingly, in the booming economy of Bangladesh, Al sector has become a flourishing industry fueled mainly by its heightened demand as a civil construction material and its uses in making electrical wires, kitchen utensils, and range of other household and industrial products by both public and private sectors. Rapid industrial and infrastructural development has elevated the consumption of all construction materials including Aluminum. On the other hand, as the world is thriving to attain sustainable development goals - the sustainability of material consumption has become a core concern due to the material criticality fueled by natural resources depletion owing to thier over-exploitation and the environmental burdens associated with the life cycles of materials uses. In reent time, to measure the sustainability of material, a number of tools and indicators has been developed including Material Flow Analysis (MFA) whcih can calculate resource consumption efficiency (RCE) and resource recycling efficiency (RRE) of an industrial entity, a region or a country beside helping to assess the environmental footprint and waste management situation associated with a specific material. Bangladesh needs to adopt MFA as a tool to design and monitor its sustainability in material use by conducting MFAs of major materials to make her development pursuits resource efficient. Accrdoingly, we have conducted an MFA of Al in the economy of Bangladesh. The temporal scope of the study was 2015 fiscal and the spatial boundary was the geographic boundary of Bangladesh. The aim was to quantify inflows, hidden flows, outflows, emissions, stocks related to Al besides calculating the input-output efficiency of Al based on publicly available data from Journal articles, UN's Commodity Trade Statistics database, World Bank databases, Bangladesh statistical bureau databases, different published reports and newspaper articles and expert opinions by using spreadsheet and STAN software. The study revealed that the country consumes 1.07 kg of Al per capita for the year 2015. Transport sector consumed the highest share of Al (30%) folllowed by packaging (29%). Building and construction sector is becoming a major consumer that accounted for 13% of the country's total requirements for Al in 2015. Bangladesh imported 109.16 thousand MT of Al in predominantly as unwrought Al (65%) and semi-products (25%) while the country exported 552.50 MT of Al in the form of different goods which indicates a sharp rise in on-the-use and scrap Al-stock in the country. Al was imported mainly from Singapore (36%), Malayasia (18%), India (15%), China (13%) and South Korea (8%) indicating need for diversification of Al sourcing to remain immune to geopolitical changes. Respective values of the Domestic Material Input (DMI), Domestic Processed output (DPO), Resource Consumption Efficiency (RCE) and Resource Recycling Efficiency (RRC) for Al in the economy of Bangladesh in 2015 were 136472 MT, 111679 MT, 1.526467 million USD/MT and 0.3177795 compared to 52490 thousand MT, 13451 thousand MT, 0.21079 million USD/MT and 0.13711 for China. The higher RCE and RRC of our economy compared to China was due to the use of processed Al and finished products which will change as we go for more Al casting industries. Hence, the policy makers should adopt measures to keep these indicators higher by devising appropriate policy measures to attain SDGs 9 and 12.

Keywords: *Aluminum, MFA, Material Flow Analysis, MFA indicators, Bangladesh.*

1. INTRODUCTION

Industrial ecology has emerged as a paradigm for environmentally sound development and is characterized by minimal physical exchanges with the environment, with internal material loops being driven by renewable energy flows (Bonnin et al. 2013; Maung et al. 2017; Buchner et al. 2015; Buchner et al. 2014). However, the industrial metabolism is over-loading the environment with waste and emissions in many respects (Rauch 2009; Bringezu and Moriguchi 2018; Sevigne-Itoiz et al. 2014). For that skyrocketed, sharpening and growing demand trends shifted from geological reserves to large in-use stocks of metals in society (Maung et al. 2017; Sujauddin et al. 2017; Hatayama et al. 2007).

Non-ferrous metals are acting as a vital functioning component of nature, humans and the modern society and always present all around us (Bertram et al. 2017; Chen, Shi, and Qian 2010). Aluminum(Al) is the most widely used nonferrous metals, and its applications in construction, transportation, electrical engineering and consumer goods like packaging have significantly flourished in the last decades (Liu and Müller 2012; Rauch 2009; Chen and Graedel 2012; Dahlström and Ekins 2007). Moreover, Al is stronger and tougher than plastic and lighter than steel that’s why Apple uses predominantly Al parts replacing plastic and steel in its iPhones, iPADs and MacBooks. Experts predict that the average Al content in a car will increase by 60% by 2025 (Bonnin et al. 2013; Ciacci et al. 2013; Menzie et al. 2010). Al is also theoretically 100% recyclable with no loss of its natural properties (Bertram, Martchek, and Rombach 2009; Qiang et al. 2014). The largest portion of Al stock is in U.S. (28%), China (15%), Japan (7%), and Germany (6%) and so on. Major sectors which consume Al like building and construction (40%) and transportation (27%) globally (Liu and Muller 2013). According to (Cullen and Allwood 2013), demand for Al in final products has increased 30-fold since 1950 to 45 million tonnes per year, with forecasts predicting this exceptional growth to continue so that demand will reach 2−3 times today’s levels by 2050 (Rauch 2009).

The depletion of nonrenewable resources and the availability of alternative raw materials are of great concern in the metallurgical industry, as in other base material industries (Koscielski, Rogowsky, & Laney-Cummings, 2010). Consequently, the use of Material Flow Analysis (MFA) gains increasing importance to companies operating in those regions where primary raw materials are limited/absent or dependent on expensive energy (Lovik, Modaresi, & Müller, 2014; Passarini, Ciacci, Nuss, & Manfredi, 2018). MFA has been defined as a systematic assessment of materials within a system defined in space and time (Brunner and Rechberger 2016; Hatayama et al. 2007). In a MFA study, a target material is characterized in terms of flows, processes and stocks of that material and overall environmental impact of that material within a predefined region and timeframe (Brunner and Rechberger 2016; Gloser et al. 2013). The purpose of MFA is to look for the potentials and measures of resource conservation and environment protection, and encouraging industrial system to meet the requirements of sustainable development (Muller et al. 2014; Spatari et al. 2002). Substance flow cycles can provide a picture of resource uses and losses through a geographic region, allowing us to evaluate regional resource management and estimate gross environmental impacts (Graedel et al. 2004; Guo and Song 2008; Spatari et al. 2002). This research performs a dynamic material stock and flow analysis of Al in Bangladesh (Daigo et al. 2009; Spatari et al. 2005). As the wrld is sought to achieve Sustainable Development Goals (SDGs), we need to enhance our material consumption efficiency which is more important for rapidly growing economies like Bangladesh. However, an MFA of Al has not yet been conducted in Bangladesh, primarily because of poorly kept and inaccessible statistics, both public and private. In this study, our aim is to conduct the first MFA of Al in Bangladesh to find the flow parameters and calcualte the efficiency indicators for making policy comments.

2. MATERIALS AND METHODS

2.1 Definition of System Boundary

In an MFA, a target material is characterized in terms of flows, processes and stocks of that material and overall environmental impacts of that material within a predefined region and timeframe (Brunner and Rechberger 2016; Ding, Yang, and Liu 2016; Moriguchi and Hashimoto 2016). In the current study the spatial system boundary was the geographical border of Bangladesh, while the temporal boundary was the year 2015. Because there is no operating Al-mine in Bangladesh, imports are the main inputs. Figure 1 shows every Al flow and stock that were determined, including imports and exports, losses into the environment as wastes and emissions etc.

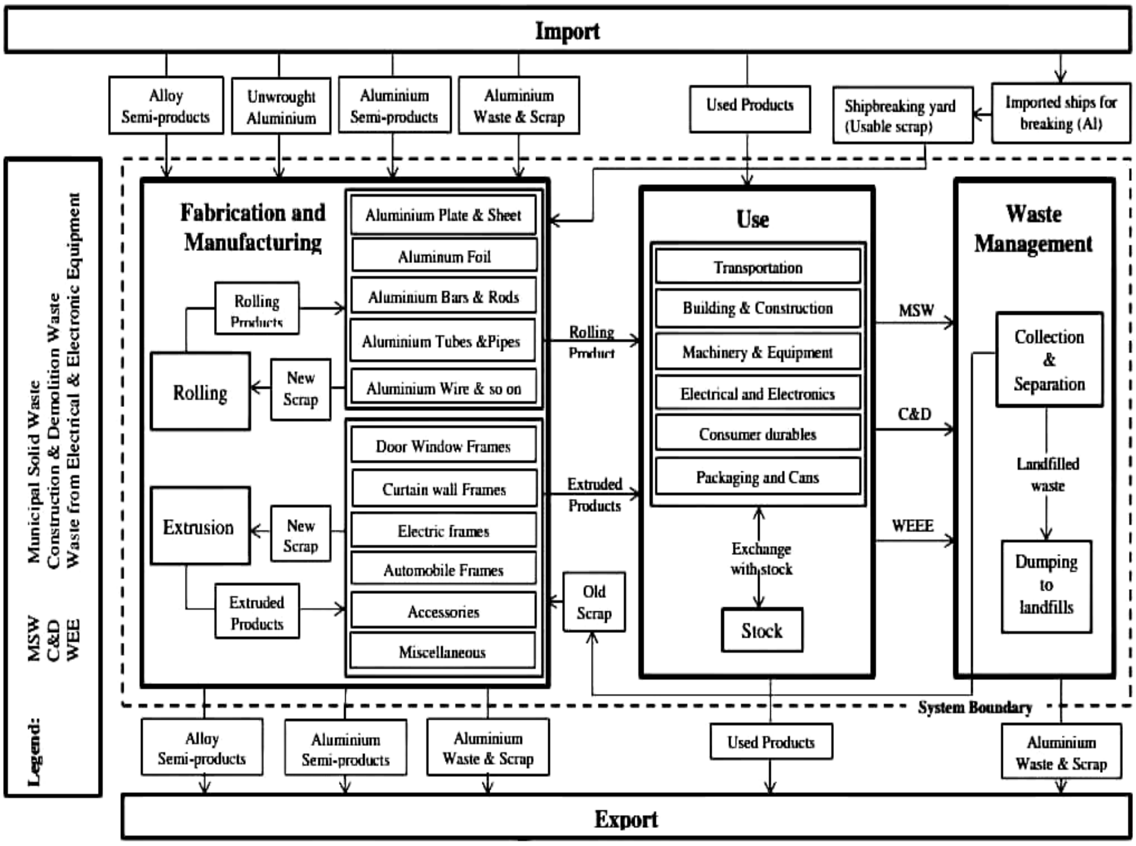

Figure 1: System boundary for MFA of Aluminum in Bangladesh for 2015

2.2 Flows and Stock Estimation

The system under study concerned only material flows. The calculation of both stocks and flows, which was then based only on the principle of mass conservation is performed by Eq. (1) (Bonnin et al. 2013).

$$I + P = C + \triangle S + E + \textit{Loss through emission} \quad (1)$$

Here, I is imports, P is production, C is consumption, S is stock and E is export flows.

2.3 Data Collections

The actual data collection from each individual stage is preferred. However, it was not feasible due to the large scope of the present study. Data were collected various international databases as shown in Table 1, namely UN Comtrade (UN Comtrade 2018), the World Bank (World Bank 2017), World Integrated Trade Solution and some local database mainly Statistical yearbook by Bangladesh Bureau of Statistics (Statistical Yearbook 2017). As, local data were not available over a continuous time range, we prioritize international data sources for analysis. However, UNComtrade data were unavailable for import and export in 2014 for which we relied on the local databases for these instances (see Table 1 for details). Noteworthy to mention that data were obtained and analyzed utilizing both UN Comtrade and World Bank, at the initial phase of data collection, however because a similar trend in both datasets, we decided to continue with UN data for final calculation.

Table 1: Year wise data sources used for analysis

	2006-2013	**2014**	**2015**
Import	(UN Comtrade 2018)	(Statistical Yearbook 2017)	(UN Comtrade 2018)
Export	(UN Comtrade 2018)	(Statistical Yearbook 2017)	(UN Comtrade 2018)

2.4 Dealing with Data Uncertainties

Data uncertainties arise from various reasons as methods of data collection are different and statistical integrity of data collection is not the same in all cases. Another uncertainty arose from unclear definition of system boundary. To deal with the above-mentioned uncertainties in this study we tried to follow some consistent data sources and made some rules prior to selection of data.

In the case of UNComtrade, export and import data varied when Bangladesh was the reporter and other countries were partners and vice versa. To deal with this, the data of World Integrated Trade Solution Database was used for more accuracy. Again, in case of UNComtrade data was available for 2006 to 2013 and for 2015. But there is no data available for the year 2014. Hence, data was used from Statistical Year Book Bangladesh, 2017 to fill the gap for 2014.

2.5 Data Calculations

2.5.1 Fabrication and Manufacturing

Sources of import and export data are shown in Table 1. There was no data on the allocation of either Al-based products in different categories of finished products manufactured in Bangladesh. It was assumed as shown in Table 2 that the products are manufactured with the same ratios as they are imported.

Table 2: Ratio of different category of Al-based products

Aluminum	**Ratio**	**Reference**
Extruded products	0.5	Personal interview
Rolling products	0.2	Personal interview

2.5.2 Use

Aluminum industry is a flourishing sector in our growing economy fueled mainly by its heightened demand as a civil construction material and its use to make electrical wire, kitchen utensils, and other products by both public and private sectors (Erbel 2018; Nakajima et al. 2007). India's per capita Al-consumption was used under the consideration that GDP per capita Bangladesh is quite similar with GDP per capita in India and that both countries have similar kind of infrastructure and life standards.

2.5.3 Waste Management

From the use sector different types of waste flows entered into the waste management process stream. For calculating the waste flow, the following data given in Table 3 were used.

Table 3: Aluminum compositions in different types of wastes

Year	Waste types	Weight of waste (MT)	Al in waste (%)	Al (MT)	Reference
2015	MSW	2920000	0.434	12673	(Alamgir and Ahsan 2007)
2015	WEEE	1240000	7	86800	(Statista 2018)
2015	C & D	224000000	0.02	44800	Personal Interview

2.6 Tools and Software Used for Analysis

All the Calculations and graphs were prepared using Microsoft Excel 2010. Computation and steps are implemented by using the STAN (version 2.6.801) which is an opensource software widely used in MFA (Cencic and Rechberger 2008).

3. RESULTS AND DISCUSSION

3.1 Trend of Aluminium import and export in Bangladesh from 2006 to 2015

An aspect of MFA is to estimate the inflow of concerned material from outside the geographic boundary of a country in the form of import. Figure 2 shows year wise import of Al in Bangladesh for the year 2006 to 2015 which indicated that in 2014 the import volume was the highest 141.74 thousand metric tons. The trend shows increasing imports with GDP growth since 2010.

As UN Comtrade database was used for import data, it might be low or high from the actual data. However, the figure reflects that import has been increasing over time with increasing GDP in Bangladesh. This will continue with the increase due to increasing consumption of Al in different sectors in Bangladesh. In contrast, the export of Al from Bangladesh is still quite low but it is increasing over time. Export insignificantly increases after 2013 than the previous years and was the highest in 2015 (552.50 metric tons).

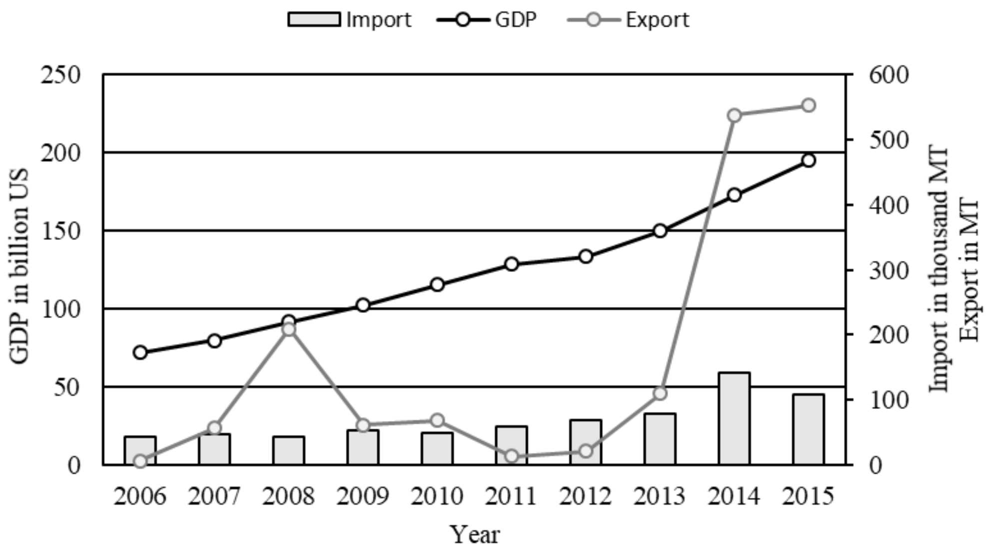

Figure 2: Year wise import and export of Aluminum in Bangladesh

3.2 Aluminum flows into fabrication and manufacturing process

Imported Al was the only inflow into Bangladesh unwrought Al, Al-semi-products, alloy semi-products, Al waste and scrap and others. Figure 3 shows an increasing trend for all types of imported aluminium in Bangladesh from 2011 to 2015. Of the total imported amount, about two-thirds of Al imported as unwrought Al and entered the inflow of fabrication and manufacturing process. Al flows into fabrication and manufacturing process increases over time and the highest value for unwrought Al, Al semi-products, alloy semi-products, Al waste and scrap were 72.70, 21.61, 7.04 and 5.23 thousand MT respectively.

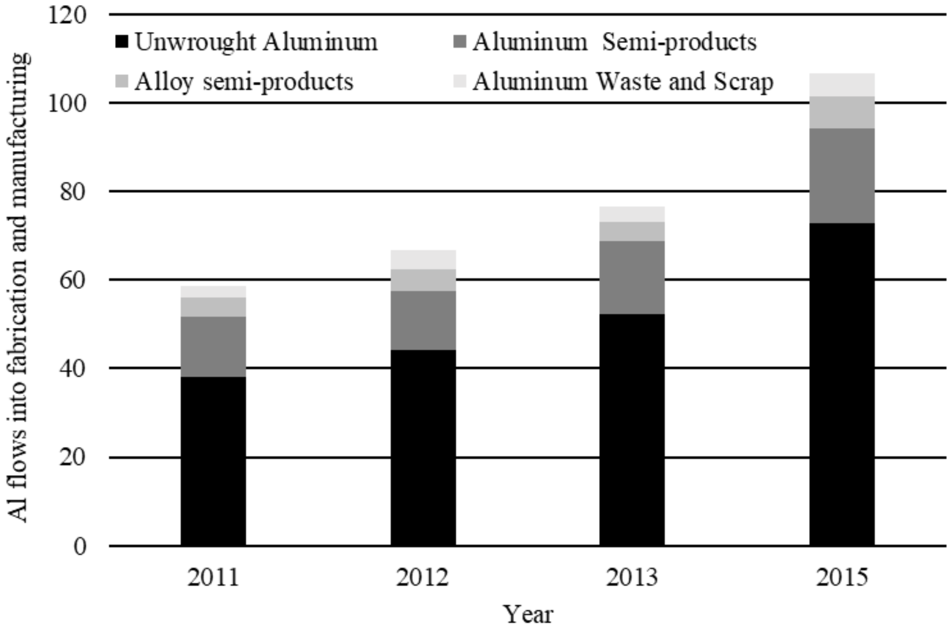

Figure 3: Category wise Aluminium flows into Fabrication and Manufacturing

3.3 Aluminum flows into different end-use sectors of society in Bangladesh

Figure 4 illustrates that the consumption pattern of Al in Bangladesh is different from the global consumption pattern. The demand for the Al industry has been predominantly from the transport sector accounting for 30 % of the total Al demand followed by packaging sector (29%)and building and construction sector (13%), electrical and engineering sector (8%) while 11% is consumed by consumer goods and others. Total domestic consumption was about 172 thousand metric tons in 2015.

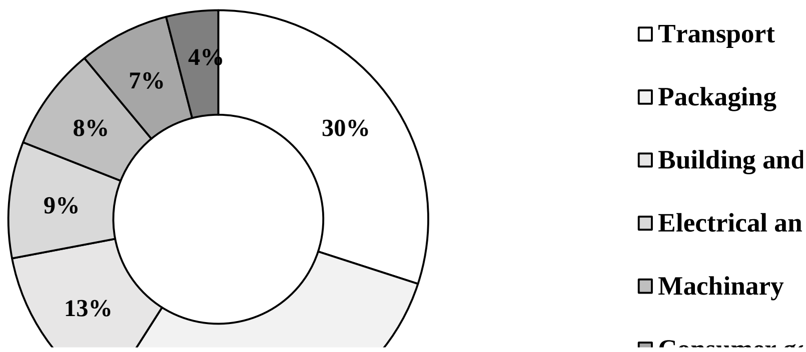

Figure 4: Aluminium usages by end-use sectors in Bangladesh

3.4 Top Aluminium sources for Bangladesh (2015)

Figure 5 represents that Bangladesh imported higher amount of Al form Singapore (36%) followed by Malaysia (18%), India (18%) and China (15%). Small amounts are imported from UAE and South Korea.

3.5 MFA of Aluminium in Bangladesh 2015

MFA of Al is shown in Figure 6. About 106622 metric tons of unwrought Al, Al semi- products, alloy semi-products and Al waste and scrap imported from different countries entered into the fabrication and manufacturing process. From ship breaking 29900 metric tons of Al scrap entered as inputs.

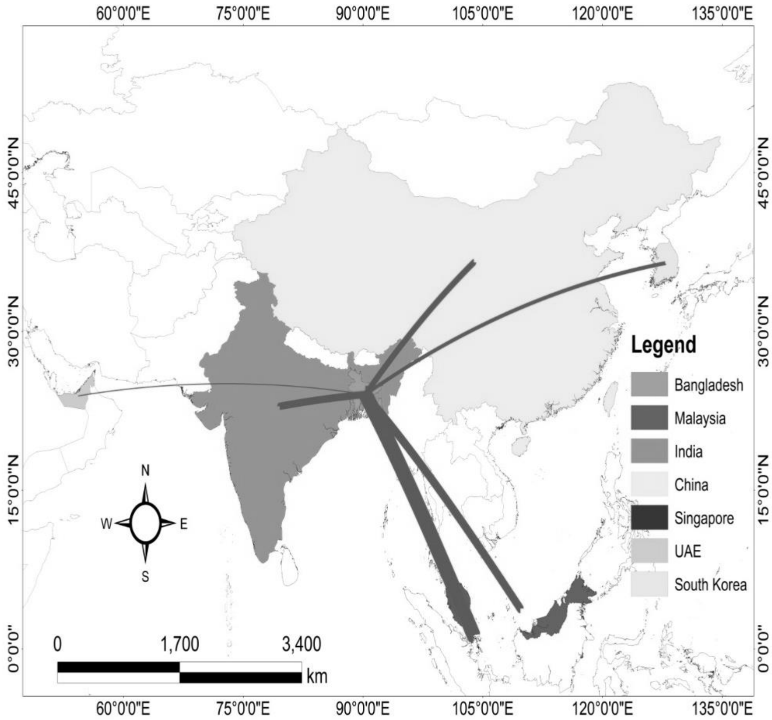

Figure 5: Aluminium supplier countries in Bangladesh for the year 2015

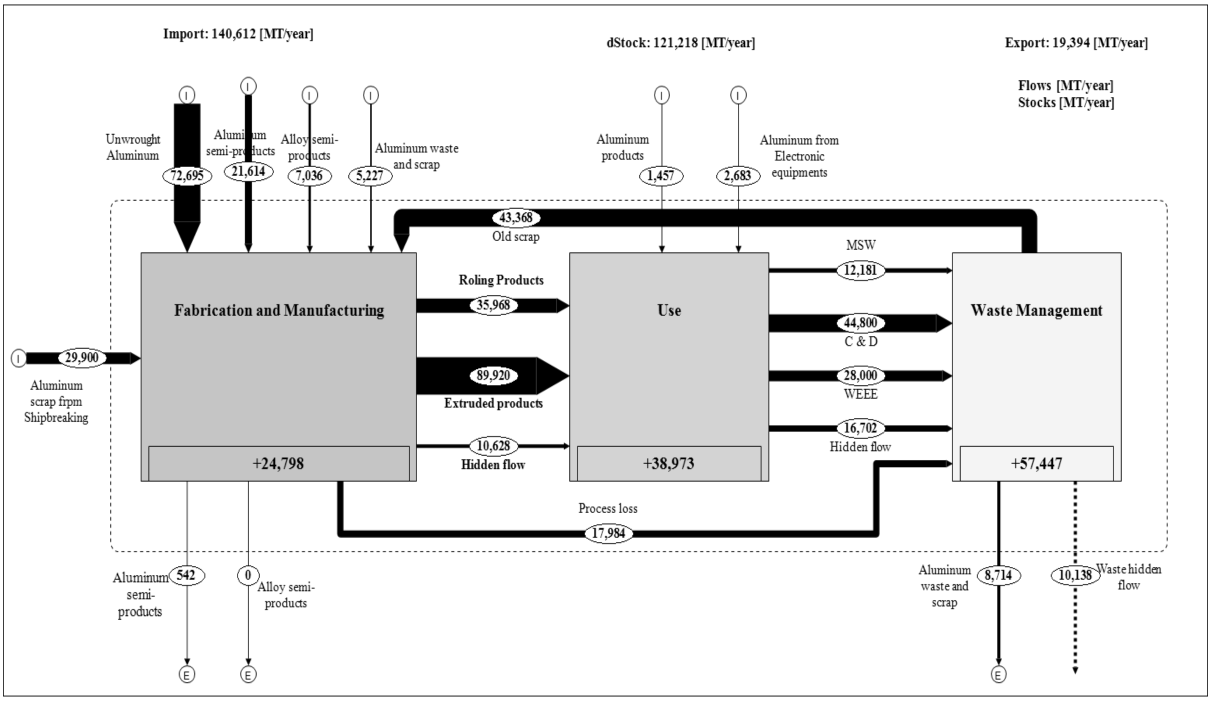

Figure 6: Material Flow Analysis of Aluminum in Bangladesh, 2015

Al and alloy products were outputs from fabrication and manufacturing. There is no data on their allocation; hence it was assumed that the products were manufactured at the same ratio as they were used. System loss of 10% from the fabrication process was added to the waste management process. About 125888 metric tons of rolling and extruded products entered use stage along with 2683 metric tons of electrical equipment. Substantial amount of MSW (12181 metric tons), Electrical waste (28000 metric ton) and construction waste (44800 metric ton) were generated of which 43368 metric tons were recycled into the system. Al waste and scrap were exported from waste management process. There was some hidden flow through different processes which were calculated. After all data input into three processes, the STAN software calculated the stock at every process.

Fabrication and manufacturing stock were 24789 metric tons which means after the production process some material remains in the system which can be further used as a raw material. In-use stocks were 38973 metric tons which means people don't bother about the huge generation of waste at every stage. Waste management stock 57447 metric tons means disposed in dumping station. Al waste and scrap were also exported from waste flow. Combining all the sub-processes, the total amount of imported Al was 140612 MT/year and the total exported amount was 19394 MT/year. The total calculated stock amount was 121218 MT/year.

3.6 MFA indicators for Aluminium in Bangladesh

Table 4 illustrates the MFA indicators for the MFA of Al in Bangladesh. Resource consumption efficiency indicates a significant amount of waste from the flow of material being unutilized that ultimately lowers the efficiency, but it is also related with the unavailability of data that how much waste had been recycled in 2015. Resource consumption efficiency in 2015 was 1.526467 million USD/MT and resource efficiency of material extraction was 0.274571. The total calculated stock amount was 121218 MT/year which can be used to reduce the pressure on ferrous metal.

Table 4: MFA indicators for Aluminium in Bangladesh

Type	Indicator	Definition	2015	Unit
Input	Direct Material Input (DMI)	Domestic raw material + Imports in MT	136472	MT
	Total Material Requirement (TMR)	DMI + HF* in MT	163802	MT
Output	Domestic Processed Output (DPO)	Emissions + waste in MT	111679	MT
	Total Domestic Output (TDO)	DPO + relevant HF in MT	121817	MT
Efficiency	Resource Consumption Efficiency (RCE)	GDP/DMI	1.526467	Million USD/MT
	Resource Recycle Efficiency (RRE)	Recycling waste/DMI	0.3177795	Ratio
	Resource Efficiency of material extraction	Unused/used= HF/DMI	0.2745471	Ratio

4. CONCLUSIONS

Rapid industrial and infrastructural development has raised the consumption of all construction materials including Al. On the other hand, the sustainability of material use has become a critical concern due to the material criticality fueled by natural resources depletion and the environmental burdens associated with the life cycle of material uses. The resulting MFA of Al in Bangladesh for 2015 showed the major flows related to Al by considering the geographic boundary of Bangladesh as the system boundary. As a developing country, the total consumption of Al in Bangladesh was low amounting to 172.48 thousand metric tons in 2015. Transport sector was the largest end user of Al accounting for 30% of the total Al demand. MFA indicators has been calculated for the year 2015 which showed a resource consumption efficiency of $1.526467*10^{-3}$ billion \$/MT and resource efficiency of material extraction is 0.2745471. The total calculated stock amount was 121218 MT/year. Flow of Al within the system boundary has also been produced for 2015 which can be used as a baseline in any future studies related to Al use in Bangladesh considering industrial ecology perspective for sustainable development of this industrial sector to attain sustainable development goals (SDGs) 9 and 12.

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REFERENCES

Alamgir, M, and A Ahsan. 2007. 'Municipal solid waste and recovery potential: Bangladesh perspective', *Journal of Environmental Health Science and Engineering*, 4: 67-76.

Bertram, M, S Ramkumar, H Rechberger, G Rombach, C Bayliss, Kenneth J Martchek, DB Muller, and G Liu. 2017. 'A regionally-linked, dynamic material flow modelling tool for rolled, extruded and cast aluminium products', *Resources, Conservation and Recycling* 125: 48-69.

Bertram, Marlen, Kenneth J Martchek, and Georg Rombach. 2009. 'Material flow analysis in the aluminum industry', *Journal of Industrial Ecology*, 13: 650-54.

Bonnin, Marie, Catherine Azzaro-Pantel, Luc Pibouleau, Serge Domenech, and Jacques Villeneuve. 2013. 'Development and validation of a dynamic material flow analysis model for French copper cycle', *Chemical Engineering Research* 91: 1390-402.

Bringezu, Stefan, and Yuichi Moriguchi. 2018. 'Material flow analysis.' in, *Green Accounting* (Routledge).

Brunner, Paul H, and Helmut Rechberger. 2016. *Handbook of material flow analysis: for environmental, resource, and waste engineers* (CRC press).

Buchner, Hanno, David Laner, Helmut Rechberger, and Johann Fellner. 2014. 'In-depth analysis of aluminum flows in Austria as a basis to increase resource efficiency', *Resources, Conservation and Recycling* 93: 112-23.

Buchner, Hanno, David Laner, Helmut Rechberger, and Johann Fellner. 2015. 'Dynamic material flow modeling: an effort to calibrate and validate aluminum stocks and flows in Austria', *Environmental science and technology* 49: 5546-54.

Cencic, Oliver, and Helmut Rechberger. 2008. 'Material flow analysis with software STAN', *Journal of Environmental Engineering and Management* 18: 3.

Chen, Wei-Qiang, and Thomas Graedel. 2012. 'Dynamic analysis of aluminum stocks and flows in the United States: 1900–2009', *Ecological Economics*, 81: 92-102.

Chen, Weiqiang, Lei Shi, and Yi Qian. 2010. 'Substance flow analysis of aluminium in mainland China for 2001, 2004 and 2007: Exploring its initial sources, eventual sinks and the pathways linking them', *Resources, Conservation and Recycling* 54: 557-70.

Ciacci, Luca, Weiqiang Chen, Fabrizio Passarini, Matthew Eckelman, Ivano Vassura, and Luciano Morselli. 2013. 'Historical evolution of anthropogenic aluminum stocks and flows in Italy', *Resources, Conservation and Recycling* 72: 1-8.

Cullen, Jonathan M, and Julian M Allwood. 2013. 'Mapping the global flow of aluminum: From liquid aluminum to end-use goods', *Environmental Science and Technology*, 47: 3057-64.

Dahlström, Kristina, and Paul Ekins. 2007. 'Combining economic and environmental dimensions: Value chain analysis of UK aluminium flows', *Resources, conservation and recycling* 51: 541-60.

Daigo, Ichiro, Susumu Hashimoto, Yasunari Matsuno, and Yoshihiro Adachi. 2009. 'Material stocks and flows accounting for copper and copper-based alloys in Japan', *Resources, Conservation & Recycling* 53: 208-17.

Ding, Ning, Jianxin Yang, and Jingru Liu. 2016. 'Substance flow analysis of aluminum industry in mainland China', *Journal of Cleaner Production* 133: 1167-80.

Erbel, Hans Joachim. 2018. "Demand for Aluminium is growing worldwide." In *13th World Trade Fair & Conference*.

Gloser, Simon, Marcel Soulier, Luis Tercero Espinoza, and Martin Faulstich. 2013. "Using dynamic stock and flow models for global and regional material and substance flow analysis in the field of industrial ecology: the example of a global copper flow model." In *Proceedings of the 31st International Conference of the System Dynamics Society*. Cambridge, MA.

Graedel, Thomas E, D Van Beers, Marlen Bertram, Kensuke Fuse, Robert B Gordon, A Gritsinin, A Kapur, RJ Klee, RJ Lifset, and L Memon. 2004. 'Multilevel cycle of anthropogenic copper', *Environmental Science and Technology*, 38: 1242-52.

Guo, Xueyi, and Yu Song. 2008. 'Substance flow analysis of copper in China', *Resources, Conservation & Recycling* 52: 874-82.

Hatayama, Hiroki, Hiroyuki Yamada, Ichiro Daigo, Yasunari Matsuno, and Yoshihiro Adachi. 2007. 'Dynamic substance flow analysis of aluminum and its alloying elements', *Materials transactions*: 0708200173-73.

Liu, Gang, and Daniel Muller. 2013. 'Centennial evolution of aluminum in-use stocks on our aluminized planet', *Environmental Science and Technology*, 47: 4882-88.

Liu, Gang, and Daniel B Müller. 2012. 'Addressing sustainability in the aluminum industry: a critical review of life cycle assessments', *Journal of Cleaner Production*, 35: 108-17.

Maung, Kyaw Nyunt, Tomoharu Yoshida, Gang Liu, Cherry Myo Lwin, Daniel B Muller, and Seiji Hashimoto. 2017. 'Assessment of secondary aluminum reserves of nations', *Resources, conservation and Recycling*, 126: 34-41.

Menzie, WD, JJ Barry, DI Bleiwas, EL Bray, TG Goonan, and Grecia Matos. 2010. "The global flow of aluminum from 2006 through 2025." In.: US Geological Survey.

Moriguchi, Yuichi, and Seiji Hashimoto. 2016. 'Material flow analysis and waste management.' in, *Taking stock of industrial ecology* (Springer, Cham).

Muller, Esther, Lorenz M Hilty, Rolf Widmer, Mathias Schluep, and Martin Faulstich. 2014. 'Modeling metal stocks and flows: A review of dynamic material flow analysis methods', *Environmental science and technology* 48: 2102-13.

Nakajima, Kenichi, Hirotake Osuga, Kazuyo Yokoyama, and Tetsuya Nagasaka. 2007. 'Material flow analysis of aluminum dross and environmental assessment for its recycling process', *Materials transactions*, 48: 2219-24.

Qiang, YUE, He-ming Wang, Zhong-wu Lu, and Sheng-ke Zhi. 2014. 'Analysis of anthropogenic aluminum cycle in China', *Transactions of Nonferrous Metals Society of China* 24: 1134-44.

Rauch, Jason N 2009. 'Global mapping of Al, Cu, Fe, and Zn in-use stocks and in-ground resources', *Proceedings of the National Academy of Sciences*, 106: 18920-25.

Sevigne-Itoiz, Eva, Carles M Gasol, Joan Rieradevall, and Xavier Gabarrell. 2014. 'Environmental consequences of recycling aluminum old scrap in a global market', *Resources, Conservation and Recycling* 89: 94-103.

Spatari, S, M Bertram, Robert B Gordon, K Henderson, and TE Graedel. 2005. 'Twentieth century copper stocks and flows in North America: A dynamic analysis', *Ecological Economics* 54: 37-51.

Spatari, Sabrina, Marlen Bertram, Kensuke Fuse, Thomas E Graedel, and Heinz Rechberger. 2002. 'The contemporary European copper cycle: 1 year stocks and flows', *Ecological Economics*, 42: 27-42.

Statista, 2018. 2018. "Chemical and Resources: Mining, Metals and Minerals." In, edited by The Statistical portal.

Statistical Yearbook, 2017. Retrieved from https://www.google.com/search?q=statistical+yearbook+2017&oq=statistical+year&aqs=chrome.4.69i57j0l5.6859j0j7&sourceid=chrome&ie=UTF-8

Sujauddin, Mohammad, Ryu Koide, Takahiro Komatsu, Mohammad Mosharraf Hossain, Chiharu Tokoro, and Shinsuke

Murakami. 2017. 'Ship breaking and the steel industry in Bangladesh: a material flow perspective', *Journal of Industrial Ecology*, 21: 191-203.

UN Comtrade, 2018. 2018. Retrieved from https://comtrade.un.org/data/2018

World Bank, 2017. Retrieved from http://pubdocs.worldbank.org/en/908481507403754670/Annual-Report-2017-WBG.pdf

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PRESENCE OF MICROPLASTIC PARTICLES IN EDIBLE SALTS IN BANGLADESH

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ABSTRACT

Ubiquitous contamination of the marine environment by microplastic is a global environmental disaster. Occurrence of microplastics in human excreta indicates their entry into the human food chain indicating the urgent need to explore candidate foods and food additives for microplastic contamination from public health perspective. The number of publications on microplastics contamination of various matrices is on a rise globally unlike in Bangladesh where it has yet to get attention. This study aimed to address this gap by evaluating the occurrence of microplastic in edible salts – the most common food additives in the country. Salt is traditionally produced by solar drying of microplastic contaminated sea water without refinement. Hence, the occurrence of microplastic is highly probable in raw sea salts which may gradually decrease under different intensities of refinement. In this study, raw salt samples (21) were collected from salt farms in Cox's Bazar and refined salt samples (8) were collected from local salt refineries while super refined salt samples (3) were collected from the market. Microplastics extraction was based on NOAA protocol that combined density separation technique with wet peroxide oxidation to remove any non-plastic floating particles. Isolated microplastic particles (MPP) were then observed under a microscope, photographed and analyzed by image analysis software to get their size, shape and, type color. Raw (unrefined) salt contained 2105 MPP/kg compared to 283 MPP/kg in refined salts. In contrast, super refined salt contained only 4 MPP in 5 kg. Unlike most other studies which focus on 0.33-5mm MPPs - this study has also looked for smaller particles, as smaller particles are more harmful to health. Worrisomely, minute MPPs, as small as 0.058mm, were the most dominant in salt. The results indicate a high level of microplastic contamination in raw salts and arrested the need to make mass people aware about the microplastic contamination in refined soil and to promote the use of super-refined salt for human consumption.

Keywords: *Microplastics, Sea salt, Salt, Bangladesh, Salt refining.*

1. INTRODUCTION

Plastics are predominantly synthetic organic polymers of high molecular mass, most commonly derived from petrochemicals. When other materials became scarce during World War II, researchers looked to synthetic polymers to fill the gaps, as they being synthetic their stock depends on the hands of producers, and are also easy and cheap to make, not saying requiring a very short time comparing to any natural alternatives. Until very recent times, typically the fate of the product after the end initial lifetime not considered in designing a plastic or its product. This resulted in huge amount of plastic debris, which by dint of the very properties that made them noble material have become a burden on the environment, pervading all the spheres. Plastic marine debris has been an environmental concern for decades. Despite the increased international attention, the build-up of these materials in the environment is considered problematic due to an increasing global plastic production and the continuing improper disposal of plastic waste. These mismanaged discarded plastics; going through different media gets shredded and fragmented repeatedly by various weathering agents like the mechanical forces exerted by wave action, the influence of UV radiation, the oxidative properties of the atmosphere and hydrolytic properties of seawater etc. and gets converted to smaller particles (Carson, Colbert, Kaylor, & McDermid, 2011). Microplastics are plastic particles smaller than 5.0 mm in size(Arthur, Baker, & Bamford, 2008). Particles< 5 mm, are of especial concern mainly due to their long environmental persistence, small size, high surface/volume ratio, and their capability of entry into the cells and induce adverse effects(Iñiguez, Conesa, & Fullana, 2017). There are two main ways microplastics are formed and enter a body of water: primary and secondary microplastics. Primary microplastics consist of plastic material, which are, from the very production stage, are micro, for example, micro beads used in personal care products such as face scrubs. Secondary microplastic introductions occur when larger plastic items enter a beach or ocean and undergo mechanical, photo (oxidative) or biological degradation. This degradation breaks the larger pieces into progressively smaller plastic fragments which eventually become undetectable to the naked eye. Owing to their size, Microplastics have totally different properties and hazards, compared to plastics in general. It has been stressed that more investigation is needed to understand the impacts of microplastics on marine organisms and food web (Wright, Thompson, & Galloway, 2013). Furthermore, marine microplastics are far more difficult to trace back to its origin than macro-debris, which presents an additional obstacle in managing this type of pollution. Very recently microplastics have been found in human excreta, which indicate their entrance in out digestive tracts, through edibles (Liebmann, Bucsics, Königshofer, & Köppel, 2018). Since these are not our target intake, hence we may conclude that our intakes have been contaminated by micro plastics. Microplastics have the capacity to translocate across living cells to the lymphatic and circulatory system in humans and other mammals, possibly via the intestine (Rieux et al., 2005). Provided that they are considered non-degradable, Microplastics have the potential to bioaccumulate in secondary organs, with possible impacts in the immune system and cell health (Smith, Love, Rochman, & Neff, 2018). Moreover, these particles can adsorb and concentrate high levels of hydrophobic organic contaminants (HOCs) (e.g., PAHs, organochlorine pesticides and polychlorinated biphenyls), metals (e.g., cadmium, lead, selenium, chromium), non-metals, and additives/monomers (e.g., bisphenol- A, polybrominated diphenyl ethers, nonylphenols and octylphenol) (Smith et al., 2018) The question that will than arise is what items do carry these contaminants to our guts. Fish are known to ingest microplastic, making them a potential vector of toxic chemicals through food chains and into human diets. Due to typically high concentrations of microplastic along urbanized coasts, there is a need for more research in these areas to quantify and assess the extent of microplastic ingestion by fishes and other marine biota specially the species humans consume. Similarly, since dehydration of near coast sea-water is the main mode of salt production, so, the status of microplastics contamination salt, which is consumed by everyone have become essential to investigate (Kim, Lee, Kim, & Kim, 2018). In all, the objectives of this study were to evaluate microplastic contamination in salt, to characterize the microplastics available in salt samples and to check the impact of salt refinement on microplastic removal.

2. METHODOLOGY

2.1. Sample Collection

Raw salt samples were collected from field as well as during transporting to the milling area of Islampur. Raw salt collected were from Mognama, Ilishia, Kutubdia, Khutakhali, Gumatali, Moheshkhali, and Badarkhali, as well as a batch of imported salt, and a batch of wash salt, (which is obtained in the milling area, by drying the brine that have been discarded after being repeatedly used for refining). Salt refineries of Cox's Bazar are all located in the Islampur industrial area under Eidgah upazilla and sample were collected from 8 of 24 operational mills, and samples were collected. Since most of the mills at a time process salts of one batch entirely, so a total 8 batches of refined salts were collected. Packed refined and super refined salts were collected from the market.

2.2. Laboratory Analysis

The laboratory processing of any microplastics study is isolation and separation from the matrix. In this study, the protocol developed by NOAA for microplastics study was adopted. According to the NOAA protocol, microplastics are plastic particles that can stand oxidation by a standard Hydrogen peroxide solution, and shows floatation in a 5M NaCl solution. The usual size range of microplastics in most studies is between 5-0.33mm, however, in this study, all plastics <5mm are considered.

First the collected salts are sundried to remove moisture. Then 20gm of each sample was dissolved in previously prepared 5M brine, made by dissolving super-refined table salt, vacuum filtered to remove any particles present. After thorough mixing in a magnetic stirrer, it was let to rest, so that the heavy undissolved particles to settle down. Then the top portion containing any floating debris was removed. Equal amount of 30%H2O2 solution, (lab grade) was mixed, along with acidified Fe(II) solution (0.05 M) (Prepared by adding 7.5 g of FeSO4.7H20 to 500 mL of water and 3 mL of concentrated sulfuric acid) catalyst. It was again placed on the magnetic stirrer at 600c until a fume was seen. After cooling the mixture, again density separation was done, and top portion was pipetted out on a petri dish, and dried and observed under an Omron Microscope with 10X zooming.

Images were taken and analyzed using image processing software, and the physical characters of the particles identified as plastics under microscope or the image was recorded.

3. RESULTS

Characterization was done based on physical appearance, as photographed under the microscope. The size, shape, type and color of the objects were the parameters observed. The shapes found commonly were angular, bar-shaped, elongated, oval, irregular and round. All the obtained particles were classified on the basis of their appearance into plastic dust, filaments, foam, broken plastic fragment and polythene fragment. Only 4 particles were found in 5kg of super refined salt, which suggests that the process of super refining practically removes any microplastics from the salt. Accounting for the very minimal abundance, super refined salt is included under the refined category in this study.

3.1 Particles Distribution

The percentage ratio of the particles as they fall under several categories of different parameters was found to be as follows:

3.1.1 Distribution of Different Types

Microplastics from both refined and unrefined samples were categorized as dust, filament, foam, broken fragment and shredded polythene fragments, based on their appearance under microscope. The distributions of both the types are shown in the figure 1. In unrefined salt, fragment was found to be most dominant, followed by dust. The order of dominance was found to be fragment, dust, filament, foam and finally polythene in raw salt. Fragment was most dominant, in refined salt, too. The order of the other types was dust, polythene, filament and foam.

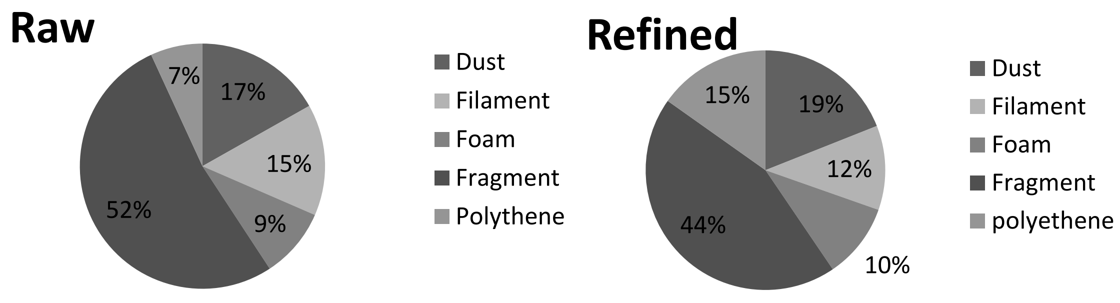


Figure 1: Distribution of plastic types in raw and refined salt

3.1.2 Distribution of Different Colors

In raw salt, black plastic particles were found to be most dominant (24%). The abundance of other colors was in the following order: brown, transparent, orange, red, yellow, ash, greenish, blackish, green, brownish, white and blue. Black was also found to be the dominant color in refined salt. The other colors, was sorted as orange brown, green, red, ash, white, yellow, blue and transparent.

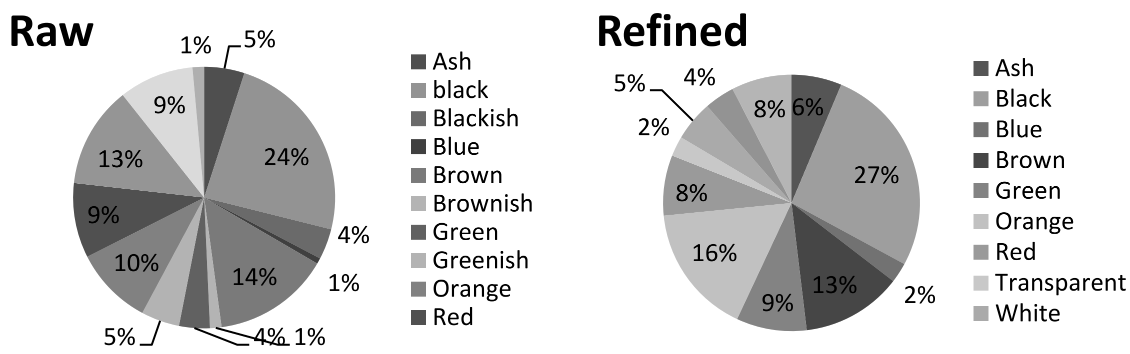


Figure 2: Color distribution of microplastic in raw and refined salt

3.1.3 Distribution of Different Shapes

The order of dominance of shapes of plastic fragments, found in raw salt was Irregular>Elongated>Angular>Bar>Round>Oval. In refined salt, the order of the shapes were Irregular>Elongated>Angular>Bar>Round>Oval>others. Thus the shape distribution of plastics in refined and unrefined salts was found to be same, indicating that the refining process works irrespective of shapes of particles.

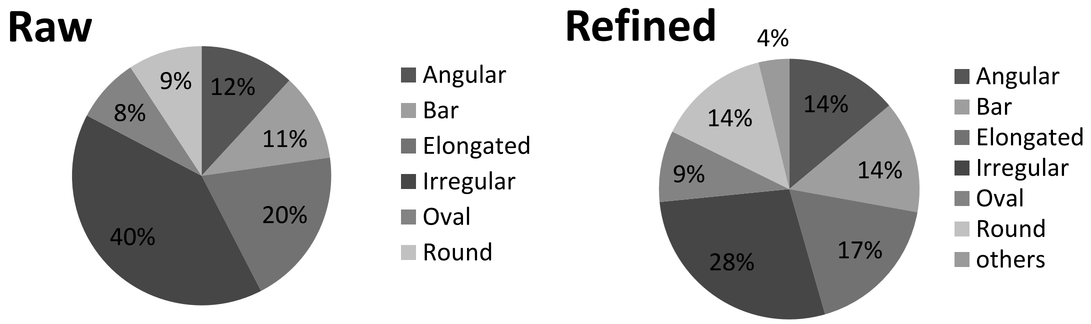


Figure 3: Distribution of shapes of microplastics in raw and refined salt

3.1.4 Distribution of Different Sizes

From the figure, it is apparent that very small particles, below 0.33mm, which are often ignored from microplastics studies, including Eerkes-Medrano, Thompson, & Aldridge, 2015; Kim et al., 2018; Lam et al., 2018 etc. are the most dominant in raw sea salt. Hence care should be taken for these too, as these are also not our target intakes. The share of other size ranges were 0.33-1mm>1-2mm>2-3mm>3-4mm> 4-5mm, i.e abundance reduces as size increases. In refined salt, as we can see from the above figure 4.8, the most dominant was the particles of very small size (<0.33mm), followed by the next 2 groups, covering particles of 0.33-1 mm and 1-2mm respectively. It is however notable, that the larger particles of size above 2mm was not significantly present at all, which might be the effect of refining.

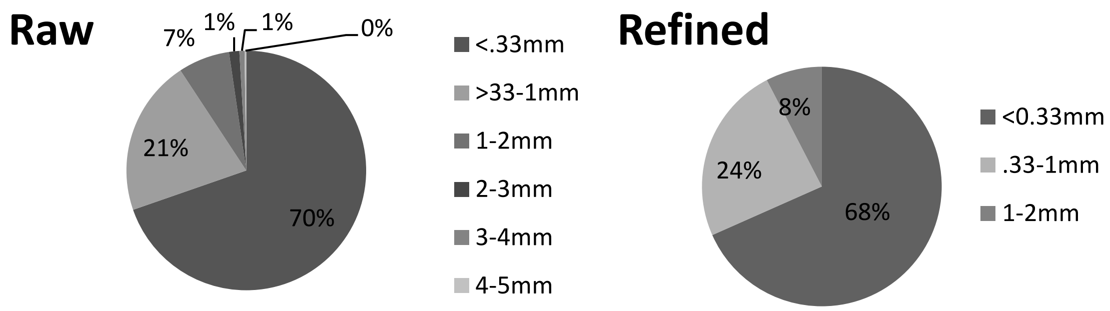
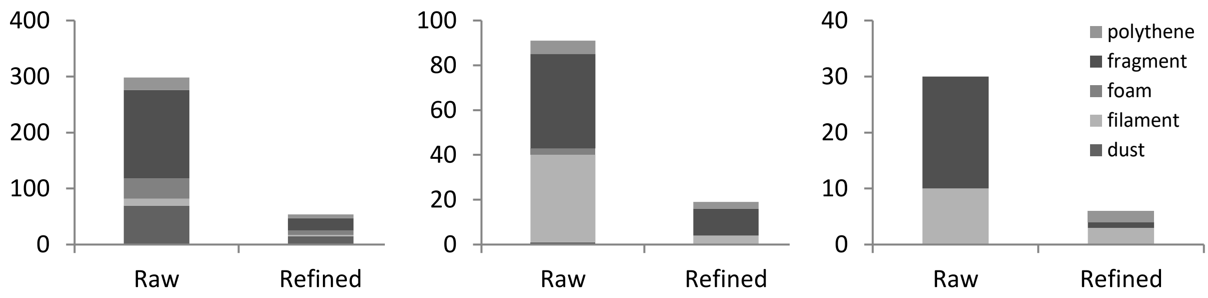


Figure 4: Distribution of size of microplastics in raw and refined salt

3.2 Particles Association

3.2.1 Association of Size and Type

Figure 5 shows, is the abundance of different types of particles from various classes. It is significant that in raw salt filaments of size between 0.33 and 1mm are as abundant as fragments of the same category, which is the dominant type. Apart from the figure, only 1 fragment particle of size class 4-5mm was found in raw salt.



Size class <0.33mm Size class 0.33-1mm Size class 1-2mm

Figure 5: Size-wise distribution of types of particles in raw and refined salt

3.2.2 Association of Shape and Type

Figure 6 shows us a complete comparative picture among raw and refined salt, along with types variation. As can be seen from this graph, the abundance of microplastic greatly varies between raw and refined salt. In both the types, fragments are dominant, and irregular shaped fragments are most abundant. Filaments are another dominant type in raw salt, but not in refined salt.

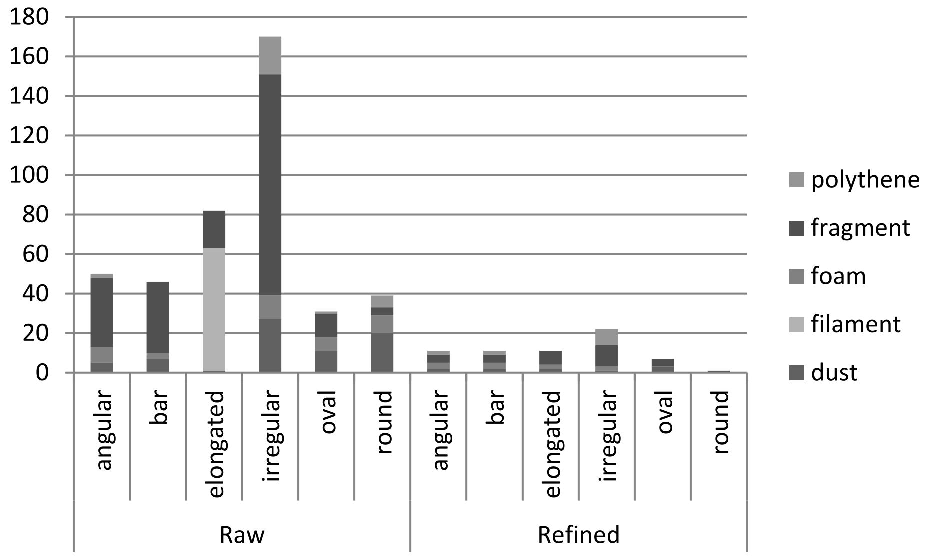


Figure 6: Shape-wise distribution of types of particles in raw and refined salt

3.2.3 Association of Size and Shape

Irregular particles are most dominant in both raw and refined salt, however the abundance varies significantly. Besides, the abundance varies with size, larger particles being less frequent. Especially in refined salt, larger particles are very few, suggesting the refining process can remove bigger particles more efficiently.

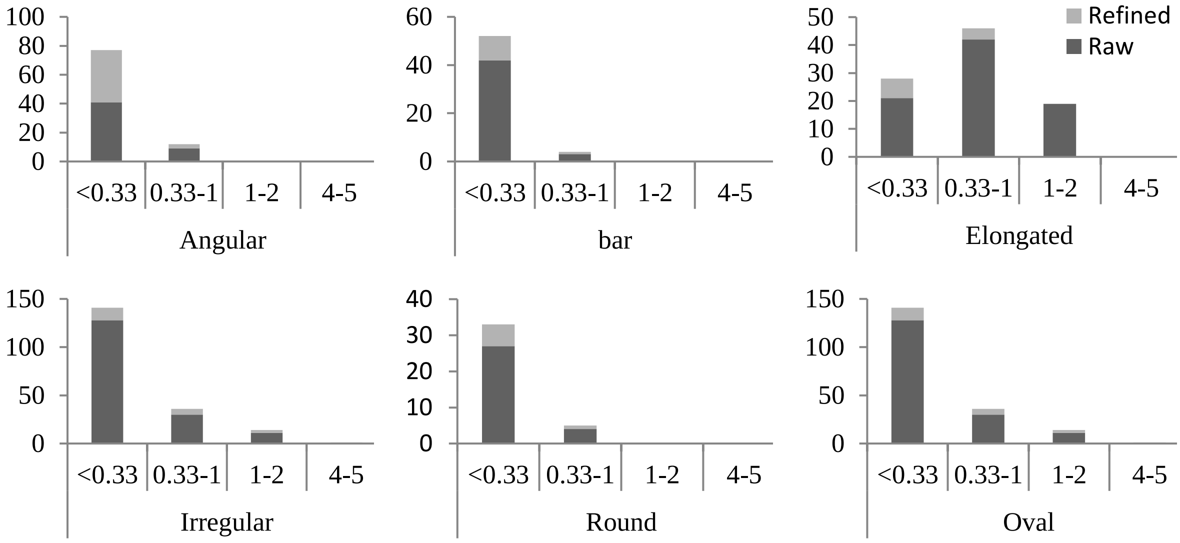


Figure 7: Distribution of Size of particles, according to shape

3.3 Distribution of Particles in Raw and Refined Salt (Sorting According to Color)

Like figure 6, figure 8 also displays the large variation of microplastics abundance in refined and raw salt. Black particles are dominant in both the types followed by brown and transparent in raw, and orange and brown in refined salt.

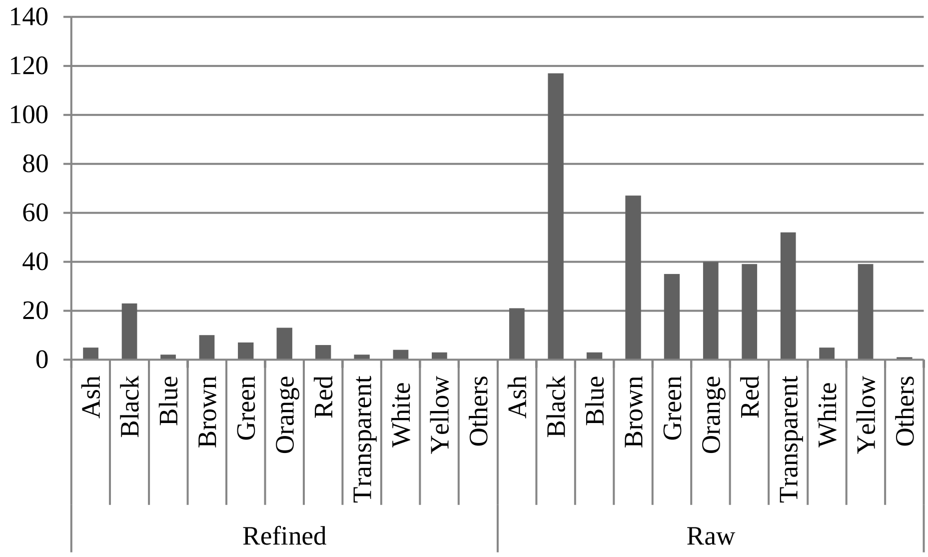


Figure 8: Distribution of Particles of various colors in Raw and Refined salt.

3.4 Discussion

Similar studies have been conducted around the world looking into salts from various places, and the findings altogether shows a wide deviation range. The presence of MPs in 15 brands of commercial salt in Chinese supermarkets was found in a study conducted, during October and November 2014. MPs were present in all of the samples analyzed. Higher concentrations of MPs were found (550–681 particles/kg) in sea salts than the other salt types(Yang et al., 2015rios). Another study analyzed eight commercial sea salt brands from India. They found MPs in all samples with concentrations ranging from 56 to 103 particles/kg (Seth & Shriwastav, 2018). The presence of MPs analyzed in 21 Spanish salt samples from different locations in the country. MPs were found in all of the analyzed samples. In sea salt samples, the concentrations ranged from 50 to 280 particles/kg (Iñiguez et al., 2017). The findings of the present study is almost in line with this one, reporting 283 particles/kg refined salt. However, in raw salt, the figure is as high as 2105/kg. Another research, studying 11 salt brands from Italy and Croatia, found that, all the sampled lots contained MPs. The concentrations of MPs ranged from 22 to 594 particles/kg in Italian brands, which again confirms the validity of our finding, and from 13,500 to 19,800 particles in per kg Croatian salt. According to this study, the concentrations recorded in their work could be related to an overestimation, given the proximity of sea salt production sites to highly populated urban settlements and the water received from polluted rivers (Renzi & Blašković, 2018).

In another study, investigation of the presence and concentration of MPs in 17 different brands of salt, from eight countries (Australia, France, Iran, Japan, Malaysia, New Zeeland, Portugal, and South Africa). MPs were present in 88% of the salts. In the contaminated samples, the concentrations of the particles ranged from zero in French sea salt to 10 particles/kg in Portuguese sea salt (Karami et al., 2017) The concentration of MPs assessed in sea, rock and lake salts from Turkey. MPs were present in 100% of the salts analyzed. MP concentration ranged from 16 to 84 particles/kg in sea salts (Gündoğdu, 2018).In another study, MPs also quantified in 12 salt brands from different world regions (Atlantic Ocean, Celtic Sea, Himalayan region, Mediterranean Sea, Mexico, North Sea, Pacific Ocean, Sicilian Sea, USA, and Utah Salt Lake). MPs were present in all of the salts analyzed. The concentrations of MPs found ranged from 47 to 806 particle/kg being fibers the most frequent plastic type in their samples and not particles (Kosuth, Mason, & Wattenberg, 2018).

4. CONCLUSION

This study was the first time in Bangladesh to look into microplastics contamination scenario in salts of Bangladesh. The abundance and distribution of microplastics in salt, along with their physical characterization was studied. It was found that the abundance varied largely between refined and unrefined salt. Considering physical characteristics, black colored particles was found to dominate in both the types, also irregular shaped ones if we consider the shape. As it was seen that the dominant size range in both the salt types were below 0.33mm, it should be focused in further studies, especially in similar consumable media, as plastics are assumed to have toxic effects conveying other toxic substances within our body(Rios, Moore, & Jones, 2007). Besides refining process should be developed, to eliminate the hazards of microplastics contamination through salt. Unlike the other possible food items, salt is universally consumed by all, and have no exception. So it should be considered seriously.

REFERENCES

Arthur, C., Baker, J., & Bamford, H. (2008). *Proceedings of the international research workshop on the occurrence, effects, and fate of microplastic marine debris*. Silver Spring, MD 20910: NOAA.

Carson, H. S., Colbert, S. L., Kaylor, M. J., & McDermid, K. J. (2011). Small plastic debris changes water movement and heat transfer through beach sediments. *Marine Pollution Bulletin*, *62*(8), 1708–1713. https://doi.org/10.1016/j.marpolbul.2011.05.032

Eerkes-Medrano, D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*, *75*, 63–82. https://doi.org/10.1016/j.watres.2015.02.012

Gündoğdu, S. (2018). Contamination of table salts from Turkey with microplastics. *Food Additives & Contaminants: Part A*, *35*(5), 1006–1014. https://doi.org/10.1080/19440049.2018.1447694

Iñiguez, M. E., Conesa, J. A., & Fullana, A. (2017). Microplastics in Spanish Table Salt. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-09128-x

Karami, A., Golieskardi, A., Choo, C. K., Larat, V., Galloway, T. S., & Salamatinia, B. (2017). The presence of microplastics in commercial salts from different countries. *Scientific Reports*, *7*(46173), 1–9.

Kim, J.-S., Lee, H.-J., Kim, S.-K., & Kim, H.-J. (2018). Global Pattern of Microplastics (MPs) in Commercial Food-Grade Salts: Sea Salt as an Indicator of Seawater MP Pollution. *Environmental Science & Technology*, *52*(21), 12819–12828. https://doi.org/10.1021/acs.est.8b04180

Kosuth, M., Mason, S. A., & Wattenberg, E. V. (2018). Anthropogenic contamination of tap water, beer, and sea salt. *PLOS ONE*, *13*(4), e0194970. https://doi.org/10.1371/journal.pone.0194970

Lam, C.-S., Ramanathan, S., Carbery, M., Gray, K., Vanka, K. S., Maurin, C., … Palanisami, T. (2018). A Comprehensive Analysis of Plastics and Microplastic Legislation Worldwide. *Water, Air, & Soil Pollution*, *229*(11). https://doi.org/10.1007/s11270-018-4002-z

Liebmann, B., Bucsics, T., Königshofer, P., & Köppel, S. (2018, October 28). *Assessment of microplastic concentrations in human stool final results of a prospective study*. Presented at the Conference on Nano and microplastics in technical and freshwater systems, Monte Verità, Ascona, Switzerland.

Renzi, M., & Blašković, A. (2018). Litter & microplastics features in table salts from marine origin: Italian versus Croatian brands. *Marine Pollution Bulletin*, (135), 62–68.

Rieux, A. des, Ragnarsson, E. G. E., Gullberg, E., Pr´eat, V., Schneider, Y.-J., & Artursson, P. (2005). Transport of nanoparticles across an in vitro model of the human intestinal follicle associated epithelium. *European Journal of Pharmaceutical Sciences*, (25), 455–465.

Rios, L. M., Moore, C., & Jones, P. R. (2007). Persistent organic pollutants carried by synthetic polymers in the ocean environment. *Marine Pollution Bulletin*, *54*(8), 1230–1237. https://doi.org/10.1016/j.marpolbul.2007.03.022

Seth, C. K., & Shriwastav1, A. (2018). Contamination of Indian sea salts with microplastics and a potential prevention strategy. *Environmental Science and Pollution Research*.

Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in Seafood and the Implications for Human Health. *Current Environmental Health Reports*.

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, (178), 483–492.
Yang, D., Shi, H., Li, L., Li, J., Jabeen, K., & Kolandhasamy, P. (2015). Microplastic Pollution in Table Salts from China. *Environmental Science & Technology*, *49*(22), 13622–13627. https://doi.org/10.1021/acs.est.5b03163

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COMMUTER EXPOSURE TO AIR POLLUTANTS IN KHULNA RAILWAY STATION DUE TO THE INFLUENCE OF LOCOMOTIVES

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ABSTRACT

Particulate matter (PM) emitted by the burning of diesel fuel has become an egregious air pollutant. It originates from the engine of the rail transport in available forms. Besides, emissions of SO_2 and NO_2 are the most significant pollutants and the constant exposure of these will lead our way to various chronic diseases. In instances of extended publicity to excessive CO concentrations, obtuseness, scolding, and loss of life would show up. For that reason, a detailed investigation was conducted for 8 hours on three different dates to quantify the exposure to size-segregated particulate matter ($PM_{2.5}$, PM_{10}), total suspended particle (TSP) and gaseous pollutants (SO_2, NO_2, CO) from locomotives in the Khulna Railway Station. The average concentrations of $PM_{2.5}$ and PM_{10} were found 26 μg/m^3 and 50 μg/m^3 respectively. The values of SO_2, NO_2, CO were also measured to be 193 μg/m^3, 44 μg/m^3, 1754 μg/m^3. Furthermore, the current work explores the routine mean degrees of total suspended particles were 77 μg/m^3 in comparison with the standard limiting magnituds. Though it was observed increment of values at the arrival and departure time of the train, the average value lies in the considerable range. Enormous air quality index (AQI) values in the platform suggested that the air around the platform is much more polluted due to the emission of diesel particulate matter (DPM) than Khulna air. According to our investigated data the air quality lies in the moderate zone for Khulna Railway Station. Correlation analysis showed a weak association between the concentration of PM at ground level and background air. It is revealing that the ground PM concentration was less influenced by the ambient air (r^2= 0.45). The study of setting up the Instrument on two different altitudes has found that a smaller value of PM fraction shows that freight rails emit heavier fragments into the wind. It had been observed that commuters were exposed to a noticeably greater degree of $PM_{2.5}$ than PM_{10} when traveling from Khulna railway station. This practice indicates that the volume enhancement of air pollutants linearly associated to the diesel rail visitors concentration and future increment in rail traffic will amplify the rate of PM_{10} and residents residing near the railway station, may additionally experience extraordinary carcinogenic illnesses.

Keywords: *Particulate matter, Gaseous pollutants, Diesel emissions, Air quality, Railway station.*

1. INTRODUCTION

Clean air is a fundamental requirement for human health and environmental resources. However, the air is continuously being contaminated with different types of air pollutants. Every year millions of people are dying due to “air pollution”. This act of forcing the air is causing a great change to the standard chemical composition. Short term and long-time period exposure to accelerated degrees of PM have been sharply associated with the enhancement of respiratory and cardiovascular illnesses as well as carcinogenic hassles(Star, March 06, 2019). Particulate matter (PM) or particulates or commonly known as “floating dust” are emitted directly into the atmosphere creating a complex mixture in the air. Sources of particulate matter are commonly associated with anthropogenic or by the air itself. $PM_{2.5}$ (<2.5 microns in diameter) and PM_{10} (2.5 to <10 microns in diameter) are the most hazardous forms of airborne particles having the ability to penetrate deep into the lungs without being unfiltered. Generally, the coarser (PM_{10}) particles tend to settle down quickly due to gravity force making the lighter and finer ($PM_{2.5}$) more dangerous.

Rapid construction activities, combustion of fossil fuel and other biomass directly emitting toxic suspended particles and gaseous pollutants in the air of developing countries (Annadanam & Kota, 2019). Bangladesh, being the most densely-populated nation in the global, has been competing with air pollution for long and country's capital, frequently demands its position among the most polluted cities in global indices. “At a country level, weighted by population, Bangladesh arises as to the most country,” stated the 2018 World Air Quality Report (Star, March 06, 2019). To protect human health and environment, all coarse ($PM_{2.5}$) and fine (PM_{10}) particulate sources should be pointed out. In that circumstance, traffic is one of the prime mentioned source categories.

Bangladesh is a developing country, railways serve as the safest and cheapest mode of transport. Most of people prefer to use railways for reaching their destination. However, diesel-powered trains create a momentous blow on air quality. In Khulna, Bangladesh almost all rail locomotives are powered with diesel gas and rail tracks are located in busy city corridors. Thousands of people are traveling daily using this railway to reach their desired destination. Intercity trains, Mail trains, and International trains are moving from the Khulna railway daily. it is essential to put more concern on it. But in this regard, they are unwisely exhausting the diesel particulate matters (DPM) and other pollutants in the air. This is causing a serious threat to the health of commuters. Most of the people in these areas are finding themselves associated with different allergic sinusitis and asthma.

On the other hand, SO_2, NO_2, CO emitted from locomotives are associating with direct radioactive forcing and increasing the overall surface temperature. Emissions of NO_2 and CO are the most significant pollutants contributing to the formation of ground ozone that produces smog to the atmosphere and the constant exposure of these are obvious that we can’t see with our open eyes and will lead our way to various chronic diseases.

In Seattle and exclusive urban areas, DPM is the most vital “air toxic” in the metropolitan location and offers greater than 80% of the chance for most cancers from airborne air poisons (Jaffe et al., 2014). In addition to DPM emissions, freight trains carrying different goods and emitting more coarser, finer particles into the air than passenger trains (Jaffe et al., 2014). The emission of air particulates into the air based on abrasion losses of wheels, poorer curving behaviour and, tread brakes (Fridell, Ferm, & Ekberg, 2010). Wear particles cannot be measured easily by just measuring particle concentrations. Airflow during the measurement time should be analysed perfectly to get that answer. But it is impossible to be done without having detailed knowledge of airflow as the air changes the magnitude and direction quite rapidly before, during and after the passage of time.

For that reason, a detailed investigation was conducted to quantify the exposure to size-segregated particulate matter ($PM_{2.5}$, PM_{10}), total suspended particle (TSP) and gaseous pollutants (SO_2, NO_2, CO) from locomotives in the Khulna Railway Station. The main aim was to evaluate the concentration of PM2.5, PM10, and gaseous pollutants to observe the air quality of Khulna railway station through Air Quality Indexing (AQI) and colour scheme. To convey the health implications of air quality and forecasting air pollution level the Site AQI was to find for a specific period to different air pollutants. On the other hand, the study was directed to assess the contribution of the background air upon the Khulna railway air.

2. METHODOLOGY

2.1 Sampling locations

For PM and Gaseous pollutant concentration assessment, The Khulna railway, shown in Fig. 1, was sampled during 24 hours (8 hours/day) sampling period.

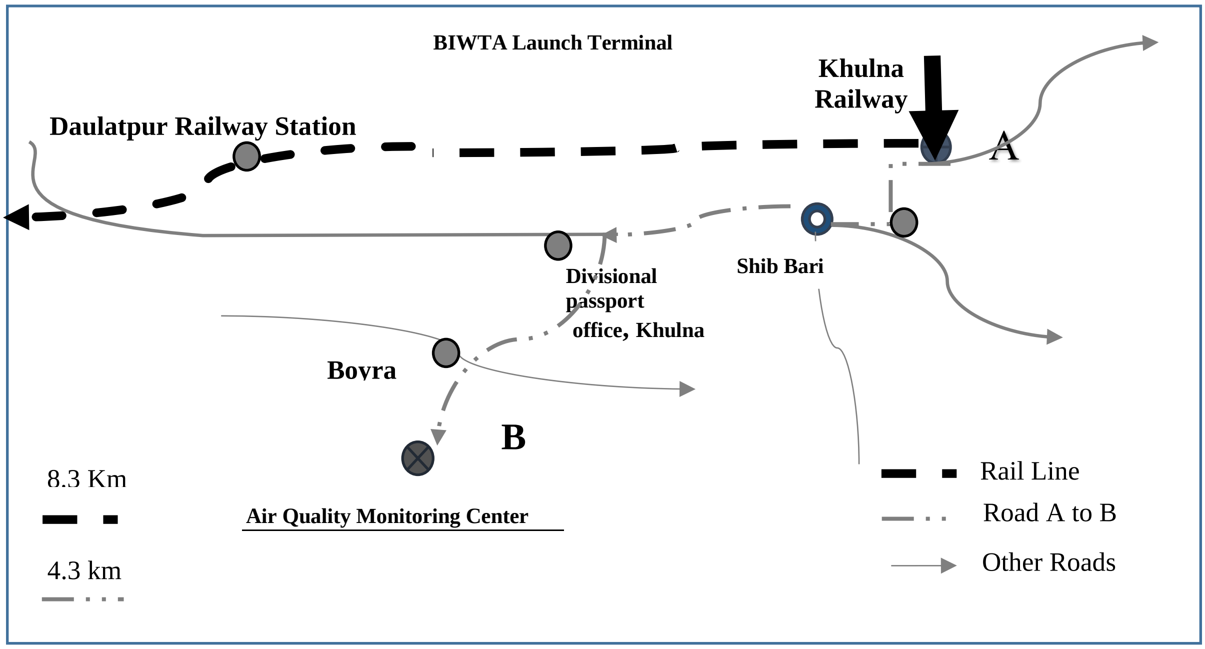

Figure 1: Plan signifying the selected railway station (ground level platform) and adjacent air quality monitoring station where particles were collected for pollutant concentration assessment.

On three specific dates, quantity calculations on train emissions were accomplished at two different sites in Khulna, Bangladesh. The first site was located near the platform of Khulna railway (22.8224ºN, 89.5583ºE) which is the main station of Khulna city and links to Jessore railway station and other different ends of the country. Two distinctive situations are very substantial large concerning railway traffic. On is the scenario in the environment of railway stations, where trains were gradually decreasing speed or accelerating and crossing track switches. The other one is when the train is passing or traveling at a less or more constant speed (Gehrig et al., 2007). In this study, the first situation was covered by the first site. The instruments were set up on the ground platform which is nearly 15 meters from the busy rail tracks. For the different height of the instrument set up the data was measured. The rail tracks are adjoining to the edges of Bhairab River and additionally connected with urban corridors. The second situation is covered by another site about 4 km away from Khulna's main station at Khulna. It is a continuous air monitoring station from where the PM data and gas data are calculated.

2.2 Monitoring Instruments and Sampling campaigns

During this campaign, a laser particle counter (handheld 3016) was used for data sampling of size-segregated PM. It can detect 6 particle sizes simultaneously in the range of 0.3um-25um. This instrument reports PM mass concentration in 6 different sizes of concentrations: 0.3 $\mu g/m^3$, 0.5 $\mu g/m^3$, 1.0 $\mu g/m^3$, 2.5 $\mu g/m^3$, 5 $\mu g/m^3$, 10 $\mu g/m^3$. Then collected data needs to be calibrated using coefficients. Then using an Excel data sheet, it indicates PM mass concentration in 4 different size concentrations: PM_1, $PM_{2.5}$, PM_{10} and Total suspended particle (TSP). The instrument was set to collect six different size-segregated data every minute.

The sampling campaign was carried out on 22 June, 01 and 02 August 2019 from 9 AM to 5 PM. On the ground platform, the sampling introduced to collect both PM_{10} and $PM_{2.5}$ data. Sampling from inside the train was not associated with the study. The instrument was set up at the level of 4 feet from the ground on 22 June. But the elevation was changed and set to 7 feet from the ground level. The fixed air quality station recorded the overall Khulna data at the same time. The fixed air station was located near the Khulna railway. The air station data provided valuable information about the background data of the Khulna railway. Besides, the concentration of gaseous pollutants was collected using the Environmental test meter. The instrument showed the concentration of gaseous data every minute and the data was sampled using two different probes. One was used to collect the SO_2 and another one is used to read NO_2 particles efficiently. This technique of sampling had been effectively performed in many research to inspect the degree of air pollutants in the Urban air.

On the other hand, the fixed air quality station set up their instrument at the elevation of 20 feet to collect the size-segregated particulates and other gaseous pollutants perfectly. XR premium work station V6.4.37 is used to collect the air samples. This also gives readings of every minute both for PM and gaseous pollutants. Besides monitoring of PM, fundamental meteorological data was observed as well, along with temperature (^{0}C), ambient humidity (%RH).

2.3 Quality assurance of PM measurement

It had been seen the difference in measurement values between light scattering assessment scheme, particle counting method and other schemes applied in the air quality fixed monitoring sites (Mohsen, Ahmed, & Zhou, 2018). Therefore, a correction factor was typically ascertained and applied to attain correct measurements from the scattering scheme. To justify the degree of precision for the cumulated data of the specified area of Khulna railway station and from the fixed station a regression model is performed. The main thought was to find the relation between the collected samples from the two sites at the same time. The relation was constructed to find the requirement of any correction factor. The calibration of data samples was done for more accuracy. During the campaign, the collection of data was done in two different elevations for the site so that the PM dust samples that flow with the wind velocity can be detected through the instrument.

2.4 Analytical method

The average concentration of PM standards and the gaseous pollutants were averaged for every hour based on the railway microenvironments alongside with the magnitudes from the fixed monitoring station to illustrate the measurement of the surrounding environment. A regression analysis (based on the least square method) was done to differentiate the values of specified area pollutants concentration to the background pollutant concentration.
For reporting daily air quality of the Khulna station and conveying health implications of the commuters indexing was done. It is known as Air quality index (AQI). The different countries set natural (AQGs) depending upon their technical feasibility, economic consideration, and political & social factors. The pollution level was ascertained using Eq. (1) and consequences were interpreted by the approved Air Quality Index (AQI) for Bangladesh categorization given in table 1.

$$AQI\ pollutant = \frac{Conecentration\ of\ pollutant}{Standard\ concetration\ value} \times 100 \qquad (1)$$

Where pollutant data reading was found from hourly average or daily average value in ug/m^3 both for two different sites and standard readings are the corresponding value the air pollutants that are fixed for a specific area location. The highest AQI for any criteria pollutant is known as site AQI or simply AQI of that day of that specific site. So the AQI proportional to health risk. As the AQI increases denote more air pollutants are getting mixed into the air and showing more health risks for sensitive groups.

Table 1: Approved Air Quality Index (AQI) for Bangladesh for making the comparison of pollutants affecting air quality and sorting out site AQI.

Air Quality Index (AQI) Values	**Levels of Health Concern**	**Colors**
When the AQI is in this limit:		
0 to 50	Good	Green
51 to 100	Moderate	Yellow Green
101 to 150	Caution	Yellow
151 to 200	Unhealthy	Orange
201 to 300	Very Unhealthy	Red
301 to 500	Extremely Unhealthy	Purple

3. RESULTS AND DISCUSSION

3.1 PM and gaseous pollutant concentrations at ground level of the rail station

The gaseous pollutant data from the platform were transferred to an Excel sheet and analysed using Excel to determine the average concentration of the pollutants. Pollutant chemicals show a significant change in concentrations with time. The analysed graph displayed that gaseous pollutants undergo a great change in value due to the passage of a train. The data obtained over 24 hours of sampling in three different days are shown in the (figure 2) illustrating average concentration magnitudes of PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2 from railway microenvironments.

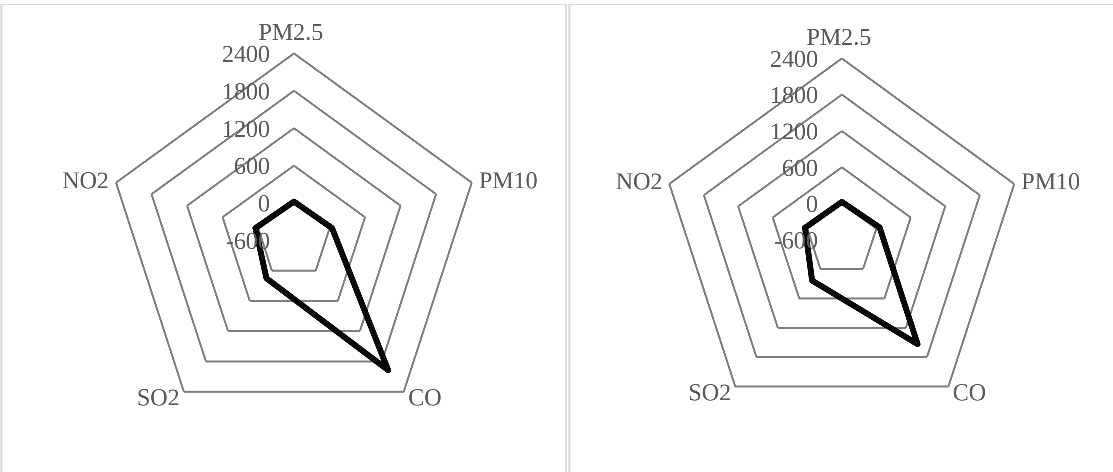

Figure 2: Multi variables ($PM_{2.5}$, PM_{10}, SO_2, NO_2, CO) of radar showing the daily average concentrations of the five criteria pollutants.

Measurements of PM2.5 and PM10 for the first situation shows that the average values are 26 µg/m3 and 50 µg/m3 respectfully of that site. But the value changes every day as it depends on wind blow and other parameters. The readings of PM2.5 vary from 11 µg/m3 to a value of 96 µg/m3. It has been investigated that this maximum value obtains during loading or unloading operation or both occur simultaneously of a passenger train. Due to the movements of the diesel-powered vehicle near the rail lines caused an additional effect on the value (Gangwar & Sharma, 2016). Wind flow at the direct of the instrument to catch more pollutants can be another reason. But as there was not any reading of air magnitude and the direction it couldn't be explained explicitly. The value of PM10 for the site also varied from 18 µg/m3 to 243 µg/m3. The construction site near the railway, abrasion of train wheels with rails were detected to be the probable cause of distributing larger particles or metals into the air and increasing the value of PM10. The average value of SO2, CO, NO2 are 193 µg/m3, 1754 µg/m3, and 44 µg/m3. All the average values of the pollutants lie below the standard limit. But the maximum value for a specific train event went beyond that standard limit. During the rain, the concentrations of the pollutant went down gradually with time. The lesser value of the total suspended particle in the air was the main reason for that.

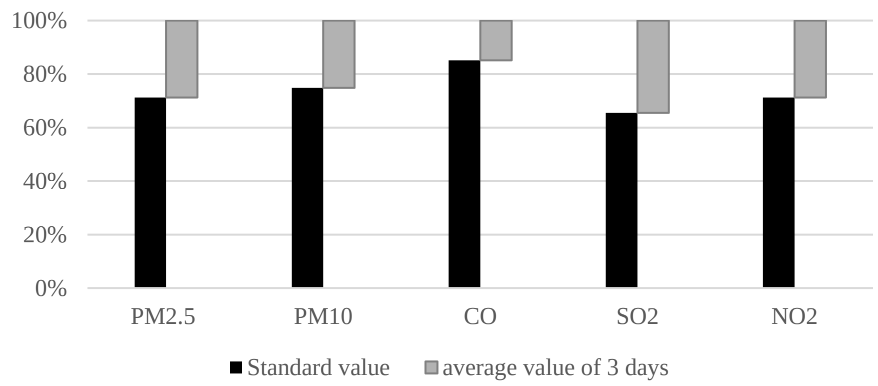

Figure 3: Showing the average concentrations of pollution levels to their standard limits.

Another important investigation was done to measure the fine particle proportion by considering the ratio between $PM_{2.5}$ and PM_{10}. The ratio for the site between $PM_{2.5}$ and PM_{10} was 0.65 where it was 0.50 for the other observation. The enormous portion of the lighter particle is directed towards more health complications.

But inside the train, the fraction or pollutant level of PM works differently. The effects (inside the train) were designated through the Los Angeles research (inside the trains), displaying that commuters were revealed to minor degrees of fine particles while anticipating on the metro systems by a factor of 6% (Cha, Olofsson, Gustafsson, & Johansson, 2018). For considering the degrees of air pollution a character undergoes, accounts that to be taken of how lengthy they are in connection with the microenvironment pollutants. It is essential to build a variety among the term concentration, exposure and respiratory deposition dose (RDDs) (Gupta & Elumalai, 2019). From the 24 hours reading, it has seen that commuters are revealed to an especially greater degree of $PM_{2.5}$ than PM_{10} when traveling from Khulna railway station.

3.2 Site AQI or AQI analysis

The AQI is done for five major criteria pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO, NO_2). The AQI is founded using (equation 1). For a single pollutant, the hourly average concentration was used to find the Hourly AQI. For all the pollutants the hourly AQI is obtained and plotted against time. So total AQI was analysed for every criterion pollutant from 8 hours of data. The highest AQI was found for a single criteria pollutant denoted the site AQI or daily AQI for that specific site (Qiu et al., 2017). From (figure 4) and (figure5) The site AQI for 22 June, 01 August were 72 and 70 respectively. The AQI for August 02 was measured 66. The background site AQI form the air station for 22 June, 01 and 02 were 27, 42 and 48 respectively.

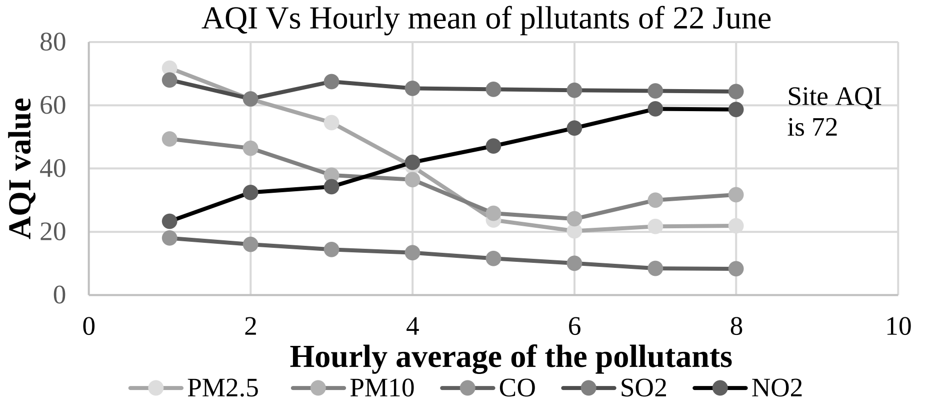

Figure 4: Showing hourly pollution level and the Site AQI of 22 June.

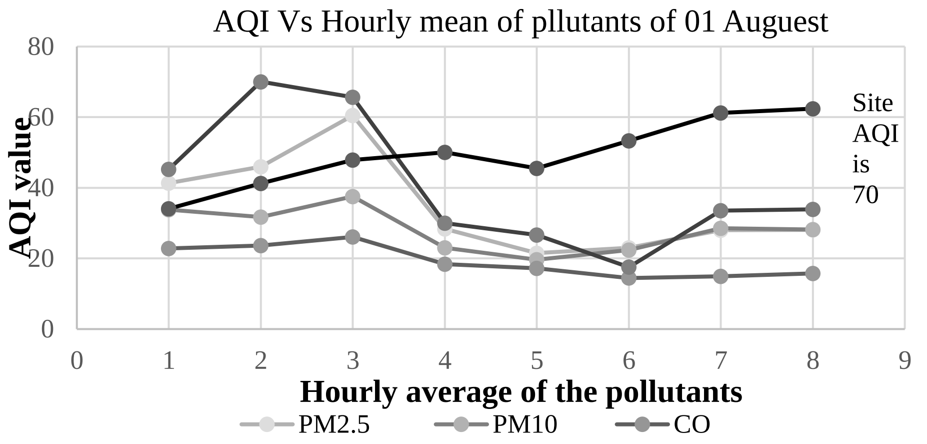

Figure 5: Showing hourly pollution level and the Site AQI of 01 August.

Using (Table 1) and from the AQI, it is noticeable that the railway air is in the moderate zone having a yellow green colour This value is acceptable and can cause moderate health problems for little sensitive people. On the other hand, the air station AQI lies in the Good air quality zone and denoting Green colour. The quality of air is satisfactory with absolutely no health concern.

3.3 Differentiate between PM concentration from Khulna railway and background air

Correlation analysis is carried out to evaluate the impact on the adjacent sources on PM_{10} and $PM_{2.5}$ in the Khulna railway. This impact degree can be several based on adjacent conditions. In (figure6), the PM_{10} data from the platform are plotted against the PM_{10} data from the Air quality station. The correlation showed a weak association as the value of (r^2) = 0.45, exposing little influence from the adjacent air to the railway air. It also signifies that the cause or source of moderate air quality in the rail station lies in the railway station.

Emission from the diesel locomotive is denoted as the primary cause of air pollution in the rail station. But the frisking of the passengers at the last moment of leaving the train from the station created a great change in PM value. It is found that the freshly settled dust is again started floating in the ambient air of the Khulna railway for the hastening of passengers to catch the train. The overflow of air due to the weather itself caused extra particulates to add into the air of that specific situation.

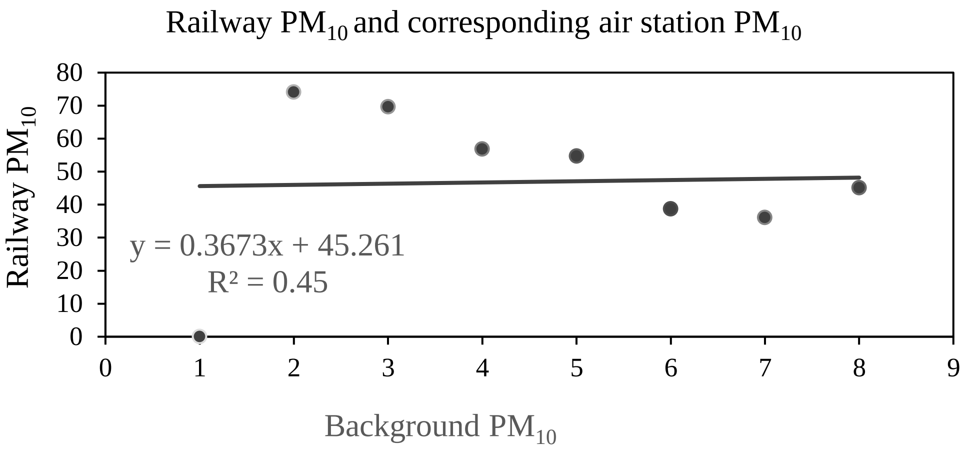

Figure 6: Showing the correlation between railway and background PM_{10}

3.4 Differentiation of PM from Khulna rail with international railway systems

Table 2: Different levels of $PM_{2.5}$ and PM_{10} were obtained from global railway systems.

Location	Measurement environment	PM_{10} Mean	$PM_{2.5}$ Mean	References
Seoul, Korea	On platform/ground level	123.0	115.6	(Park & Ha, 2008)
Prague, Czech Republic	On platform	214.8	115.6	(Cusack et al., 2015)
Sydney, Australia	On platform/ ground level	20.1	16.7	(Mohsen et al., 2018)
Taipei, Taiwan	On platform/ ground level	44.0	33.0	(Cheng, Lin, & Liu, 2008)
Los Angeles, USA	On platform/ ground level	38.0	29.0	Kam, Cheung, Daher, and Sioutas (2011)
Naples, Italy	On platform/ ground level	16.0	10.0	(Cartenì, Cascetta, & Campana, 2015)
Bangladesh	On platform/ ground level	50.3	26.26	Current study

From Table (2) It is acquired that the exposure level of PM in the developed countries lies in a lower magnitude. The main reason is that they use an electric-powered train and ensuring environmentally friendly practices for their transportation mode. Different new systems are adopted by the countries for ensuring the lowest pollution levels.

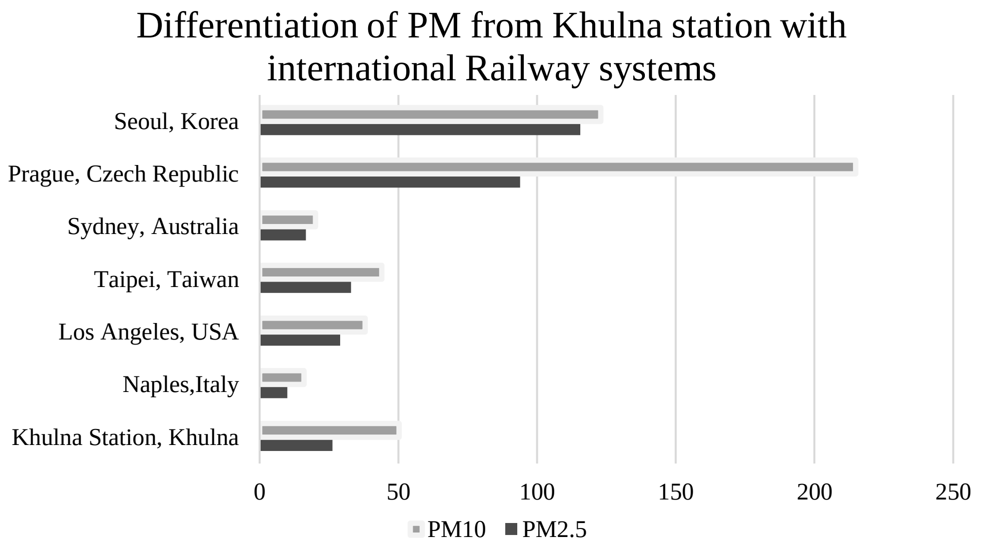

Figure 7: Comparison of various PM fractions in different railways (ground platform)

4. CONCLUSIONS

The concentration of PM and gaseous pollutants were measured both in the platform and background air quality station. The ratio of $PM_{2.5}/PM_{10}$ ratio is greater in the platforms than the background air. This result demonstrates that commuters are revealed to a relatively high amount of $PM_{2.5}$ in the platforms. The increasing values of pollutants concentration with traffic density in the peak hours also showed a linear relationship. On the other hand, the freight train emitted larger particles into the air that caused PM_{10} to reach its maximum value. The Higher AQI values are found from the platforms denoting little health concern to the sensitive groups. But all ground-level PM and gaseous pollutant concentrations are less than the national air quality standards. The lower value of (r^2=0.45) represents that the reason for moderate air quality in the station lies in the station and diesel emission is the main source of it. Based on our PM and gaseous pollutant measurements, It has also found that the value of PM also decreases with increasing the distance from the tracks. So future increments in rail traffic will raise the PM_{10} exposure and residents living close to the railway station, may suffer different carcinogenic diseases. So different new technologies and environmentally friendly practices should be adopted quickly to maintain the Khulna railway overall air quality.

5. ACKNOWLEDGEMENTS

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REFERENCES

Annadanam, S. K., & Kota, S. H. (2019). Emission of greenhouse gases and criteria pollutants from railways in India estimated using a modified top-down approach. *Journal of Cleaner Production, 213*, 610-617. doi:10.1016/j.jclepro.2018.12.206

Cartenì, A., Cascetta, F., & Campana, S. (2015). Underground and ground-level particulate matter concentrations in an Italian metro system. *Atmospheric Environment, 101*, 328-337. doi:10.1016/j.atmosenv.2014.11.030

Cha, Y., Olofsson, U., Gustafsson, M., & Johansson, C. (2018). On particulate emissions from moving trains in a tunnel environment. *Transportation Research Part D: Transport and Environment, 59*, 35-45. doi:10.1016/j.trd.2017.12.016

Cheng, Y.-H., Lin, Y.-L., & Liu, C.-C. (2008). Levels of PM10 and PM2.5 in Taipei Rapid Transit System. *Atmospheric Environment, 42*(31), 7242-7249. doi:10.1016/j.atmosenv.2008.07.011

Cusack, M., Talbot, N., Ondráček, J., Minguillón, M. C., Martins, V., Klouda, K., . . . Ždímal, V. (2015). Variability of aerosols and chemical composition of PM 10 , PM 2.5 and PM 1 on a platform of the Prague underground metro. *Atmospheric Environment, 118*, 176-183. doi:10.1016/j.atmosenv.2015.08.013

Fridell, E., Ferm, M., & Ekberg, A. (2010). Emissions of particulate matters from railways – Emission factors and condition monitoring. *Transportation Research Part D: Transport and Environment, 15*(4), 240-245. doi:10.1016/j.trd.2010.02.006

Gangwar, M., & Sharma, S. M. (2016). Risks, determinants, and perspective for creating a railway biodiesel supply chain: case study of India. *Journal of Cleaner Production, 133*, 182-187. doi:10.1016/j.jclepro.2016.05.005

Gehrig, R., Hill, M., Lienemann, P., Zwicky, C. N., Bukowiecki, N., Weingartner, E., . . . Buchmann, B. (2007). Contribution of railway traffic to local PM10 concentrations in Switzerland. *Atmospheric Environment, 41*(5), 923-933. doi:10.1016/j.atmosenv.2006.09.021

Gupta, S. K., & Elumalai, S. P. (2019). Exposure to traffic-related particulate matter and deposition dose to auto rickshaw driver in Dhanbad, India. *Atmospheric Pollution Research, 10*(4), 1128-1139. doi:10.1016/j.apr.2019.01.018

Jaffe, D. A., Hof, G., Malashanka, S., Putz, J., Thayer, J., Fry, J. L., . . . Pierce, J. R. (2014). Diesel particulate matter emission factors and air quality implications from in–service rail in Washington State, USA. *Atmospheric Pollution Research, 5*(2), 344-351. doi:10.5094/apr.2014.040

Kam, W., Cheung, K., Daher, N., & Sioutas, C. (2011). Particulate matter (PM) concentrations in underground and ground-level rail systems of the Los Angeles Metro. *Atmospheric Environment, 45*(8), 1506-1516. doi:10.1016/j.atmosenv.2010.12.049

Mohsen, M., Ahmed, M. B., & Zhou, J. L. (2018). Particulate matter concentrations and heavy metal contamination levels in the railway transport system of Sydney, Australia. *Transportation Research Part D: Transport and Environment, 62*, 112-124. doi:10.1016/j.trd.2018.02.015

Park, D. U., & Ha, K. C. (2008). Characteristics of PM10, PM2.5, CO2 and CO monitored in interiors and platforms of subway train in Seoul, Korea. *Environ Int, 34*(5), 629-634. doi:10.1016/j.envint.2007.12.007

Qiu, Z., Song, J., Xu, X., Luo, Y., Zhao, R., Zhou, W., . . . Hao, Y. (2017). Commuter exposure to particulate matter for different transportation modes in Xi'an, China. *Atmospheric Pollution Research, 8*(5), 940-948. doi:10.1016/j.apr.2017.03.005

Star, T. D. (March 06, 2019). Living in toxic air. Retrieved from https://www.thedailystar.net/frontpage/dhaka-second-most-polluted-air-city-in-world-living-toxic-air-1711213.

SALINITY MOVEMENT AND DISTRIBUTION IN PREPARED BRICK SAMPLES

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ABSTRACT

Brick structures due to hygroscopic ability absorb moisture from surrounding environment mainly from soil. The absorbed water rise from bottom to top of the structure through the pores of material. Water evaporates and deposits salt in pores. High salinity of water near coastal area causes damages such as efflorescence, corrosion, deformation etc. to brick structures. In Bangladesh locally available bricks are used for construction work cause they are lighter, cheaper and more locally available than stone. The structures near coastal area are more vulnerable to saline intrution because of high salinity of sea water. Accumulation of salt in pores hamper mechanical strength, aesthetic view of brick structures. The distribution pattern of saline water intrusion needs to be investigated throughly to reduce or solve this problems. For this reasons, in this experimental study salinity movement and distribution in locally available normal clay bricks, machine made bricks and mortar are investigated. Movement and distribution of sodium chloride solution in brick samples is mainly focused in this paper. 12 samples of 4.75”x4.5”x6.5” dimension were prepared by joining bricks with mortar. The samples were wrapped to allow unidirectional movement of water through pores of material. Four sets of experiment were done. Distilled water, tap water, saline water of 2000mg/L and 35000mg/L concentrations were applied to each set respectively. After observing for 105 days salinity test was conducted on the samples. From the observation, it is found that higher porosity indicates higher absorption and evaporation. Bricks with higher porosity are more susceptible to saline intrusion and salt attack near coastal region. Accumulation of salt increases with increase in concentration of saline solution. Distilled water dilutes salt in pores of both brick and motar and removes salt with the movement of water.

Keywords: *Absorption, Evaporation, Salinity movement, Porosity.*

1. INTRODUCTION

Even though brick was invented thousands of years ago, it is still popular and widely used as construction material in developing country because it is light, durable and economic. Brick are non-combustible, environmentally friendly and provides heat insulation, sound isolation. Bricks in the presence of moisture absorb it and by capillary uptake moves through the pores and gets distributed. When the moisture evaporates, salt deposits, brick absorbs more moisture and the process continues. It is a natural phenomenon. Soil moisture, humid environment, rain water, water bodies near the structure are the sources of moisture. Similarly brick structures near coastal area absorbs saline water which rises through the pores of material from bottom level to top level. Thus, saline water gets distributed in brick structures near coastal area.

Sea water contains several dissolved salts and among them sodium chloride is predominant. Presence of natural moisture does not affect the mechanical strength of brick. Increase in moisture content alone can decrease mechanical strength of brick (Sathiparan & Rumeshkumar, 2018). In natural condition saline water absorbed by brick structure, migrates through the pores of material and then salt crystal forms when water evaporates. Salt crystallization causes crystallization pressure, tensile stress, deformation of brick (Stryszewska & Kańka, 2017). When the tensile stress in pores exceeds tensile strength of material it causes crack in brick resulting in decrease in mechanical strength. Corossive exposure to sodium chloride environment causes most rapid destruction (Stryszewska & Kańka, 2017). Moreover saline intrution causes efflorescence which arises aesthetic problem.

Cement based materials deteriorates in presence of chloride ion. Chloride ion can enter and diffuse in cement-based materials (Cao, Guo, & Chen, 2019). It results in movement of saline water through mortar. When water evaporates salt crystal forms in mortar pores. Different types of materials have been proposed to mix with mortar, plaster (Karoglou, Bakolas, Moropoulou, & Papapostolou, 2013) for protection brick structure against salt dampness.

Previous researches investigated effect of salt crystallization on deformation (Stryszewska & Kańka, 2017), change in hygric properties (Todorovic´ & Janssen, 2018), moisture transport (Koronthalyova & Bagel, 2015) in brick. The intrusion pattern and distribution of sodium chloride is not fully understandable yet. Due to climate change sea level is rising resulting in increase in saline concentration near coastal area. It is increasing the probability of deformation, degradation, efflorescence of the brick structures near coastal areas. Therefore, salinity movement and distribution in brick and mortar are needed to be investigated to control or to mitigate the problems which arises from saline water intrusion.

2. METHODOLOGY

2.1 Collection of Bricks

For this investigation, locally available machine-made bricks and normal clay bricks were collected. Machine-made bricks of AFIL and TABL frog mark and normal clay bricks of SONY frog mark were used.

2.2 Preparation of Brick Samples

To accomplish this study, the bricks were cut perpendicular to the length into two equal halves. Two brick parts of different brick of same frog mark were joined using mortar. 1:6 mixing ratio was used to prepare mortar using Portland Pozzolana Cement (PPC) and locally available kushtia sand. To allow unidirectional movement of water through the samples and to allow evaporation through upper part of the samples, only specific outer sides were wrapped by pressure-sensitive tapes. Similarly, 12 samples of 4.75”x4.5”x6.5” dimension were prepared. Each of samples were placed in different brick container made of polypropylene. The containers were sealed and air tight using silicon sealant.

Figure 1: Preparation of brick samples

2.3 Application of Distilled Water and Saline Solution

The samples were divided into four sets. Each set consisting three samples. Distilled water, tap water, saline solution (NaCl solution) of 2000 mg/L and 35000 mg/L were applied respectively to each set. Distilled water and saline solution absorption data were recorded regularly.

2.4 Porosity and Absorption of Bricks

Porosity and 24-hour absorption of water of the bricks were determined to understand effect of porosity on absorption of water.

Table 1: Experimental program.

Brick container	**Brick frog mark**	**Concentration of saline solution (mg/L)**	**Brick container**	**Brick frog mark**	**Concentration of saline solution (mg/L)**
A-D	AFIL	0	A-2	AFIL	2000
T-D	TABL	0	T-2	TABL	2000
S-D	SONY	0	S-2	SONY	2000
A-T	AFIL	1250	A-35	AFIL	35000
T-T	TABL	1250	T-35	TABL	35000
S-T	SONY	1250	S-35	SONY	35000

Here, brick containers are designated as X-Y [where, X= A (AFIL), T (TABL), S (SONY) and Y= D (Distilled water), T (Tap water), 2 (NaCl solution 2000 mg/L), 35 (NaCl solution 35000 mg/L)]

2.5 Determination of Chloride Ion in Samples

After observing absorption of distilled water and saline water by the prepared brick samples for 105 days they were removed from the brick containers. The samples were crushed into small pieces. To extract salt properly from the pores ½" sieve passing and #8 sieve retaining brick chips were taken. The samples were soaked into distilled water for 24 hours. Chloride content of the samples were determined using argentometric method.

3. ILLUSTRATIONS

3.1 Figures and Graphs

Cumulative absorption of different types of solution are shown in figure (2~5) and total absorbed solution by the samples are shown in figure (6). From the observations, it is seen that normal clay bricks absorb more distilled water or saline solution than machine made bricks and is true for solution of different concentration of salt in same environmental conditions. The absorption amount in case of machine-made bricks of two different frog mark is found almost same for same type of saline solution as shown in figure (2~5). Higher absorption means higher evaporation of water. It is found that the absorption of saline water is corresponding to porosity of material. Bricks with greater porosity showed more absorption and evaporation of water than other bricks. According to the porosity of the bricks as shown in table (3) normal clay brick has greater porosity and figure (2~5) confirms that higher porosity indicates higher absorption and evaporation. Total absorption of normal clay brick in 105 days were maximum for different saline solution as shown in figure (6) also confirms it. The exceptional behaviour of A-2 sample may have occurred due to impurities or crack in the brick but that is beyond the scope of this study. High absorption and evaporation eventually deposit large amount of salt which is increased by the increase of concentration of saline solution. Though the total absorption of each sample subjected to 35000 mg/L saline water is lower than other solutions (figure 6) but high amount of salt was deposited. Hence, brick structures with high porosity are more vulnerable to salt attack and saline intrusion near coastal region. Table (2) shows the salinity of the samples subjected to distilled water. Salinity of brick parts in box shows the value of salinity after 105 days and value of other half brick is salinity before 105 days. Salinity of mortar before 105 days were 499 mg/kg and the values in table (2) is after 105 days observation. It is found that in the brick container salinity of the bottom brick decreased and salinity of upper brick increased. It occurred due to movement of salinity from bottom to top. Distilled water diluted the salt in brick and carried toward the flow and when water evaporated salt deposited. Thus, the excess salinity in the upper part of the sample accumulated from bottom parts. Similarly, salinity of the mortar decreased for two of the samples which indicates that salts in the pores of the mortar diluted with distilled water and removed with the movement of water. The salinity of mortar between TABL auto bricks increased. Investigating reasons behind deposition of salt instead of dilution is beyond the scope of this study. To understand this behaviour further investigation is required.

3.2 Equations

According to argentometric method,

$$Chloride\, ion\ (mg/L) = (FR - IR - 0.2) \times 24.96478 \times DF \tag{1}$$

Where,
FR= Final burette reading
IR= Initial burette reading
DF= Dilution factor.

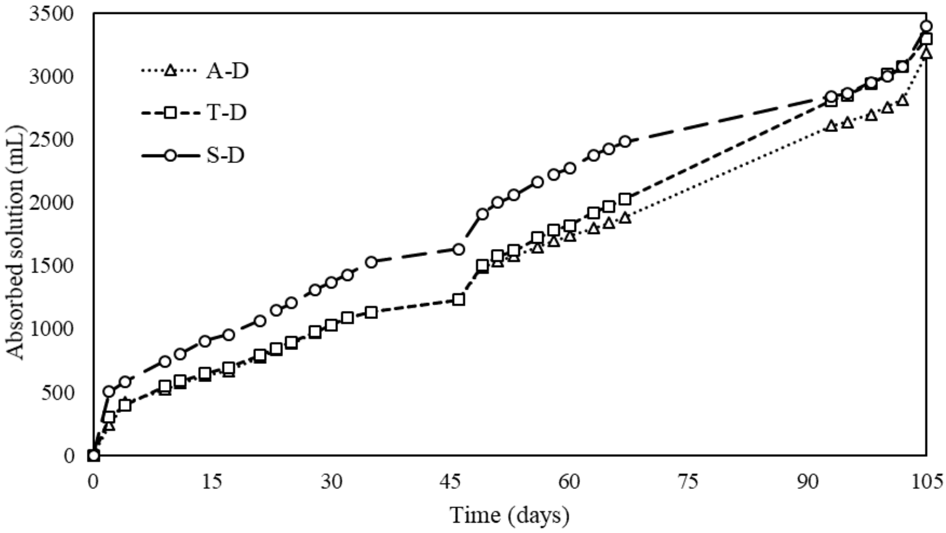

Figure 2: Cumulative absorption of distilled water with time

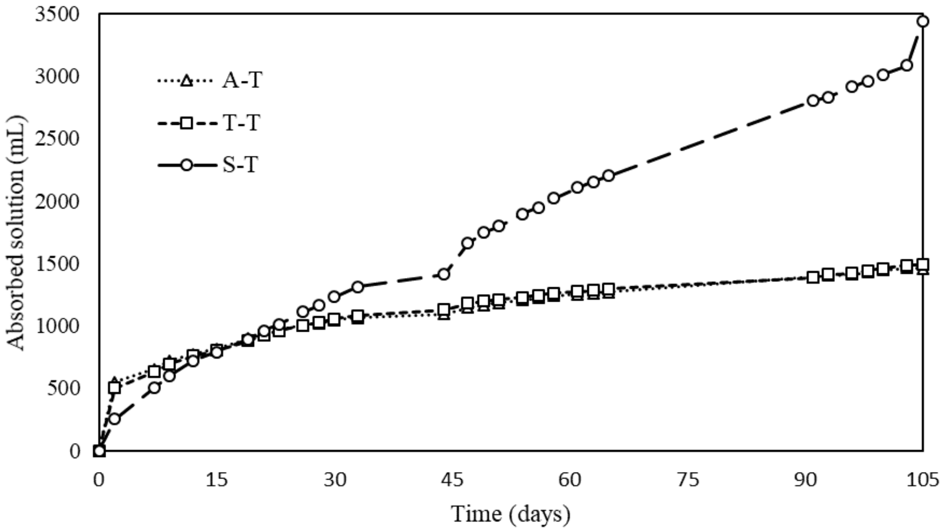

Figure 3: Cumulative absorption of tap water with time

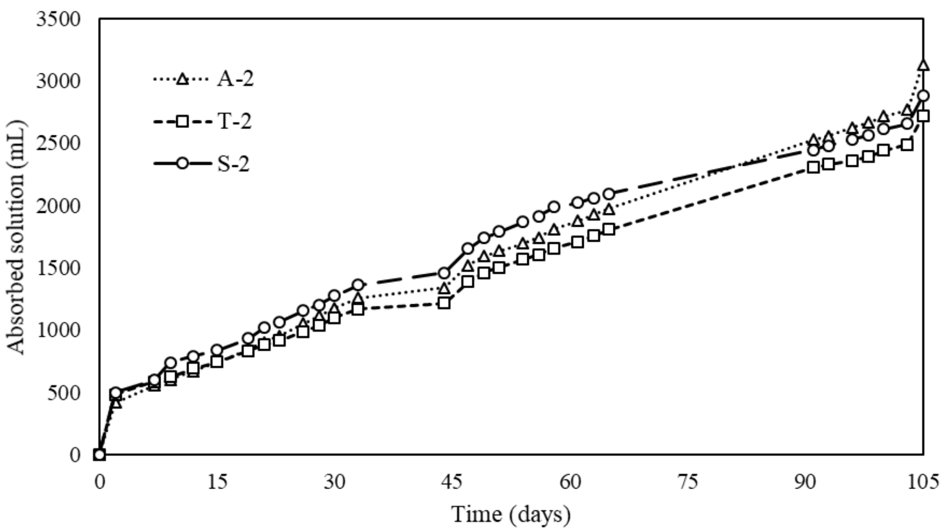

Figure 4: Cumulative absorption of sodium chloride solution (2000mg/L) with time

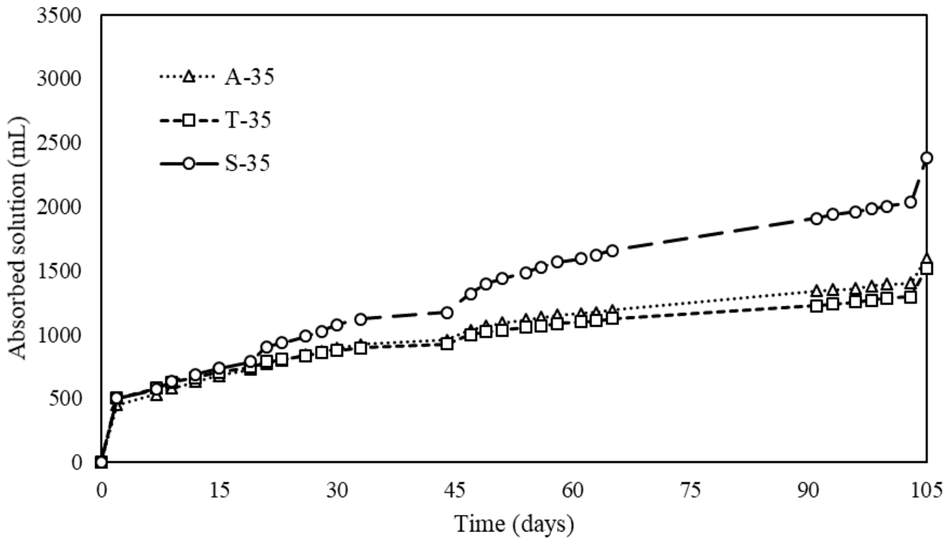

Figure 5: Cumulative absorption of sodium chloride solution (35,000mg/L) with time

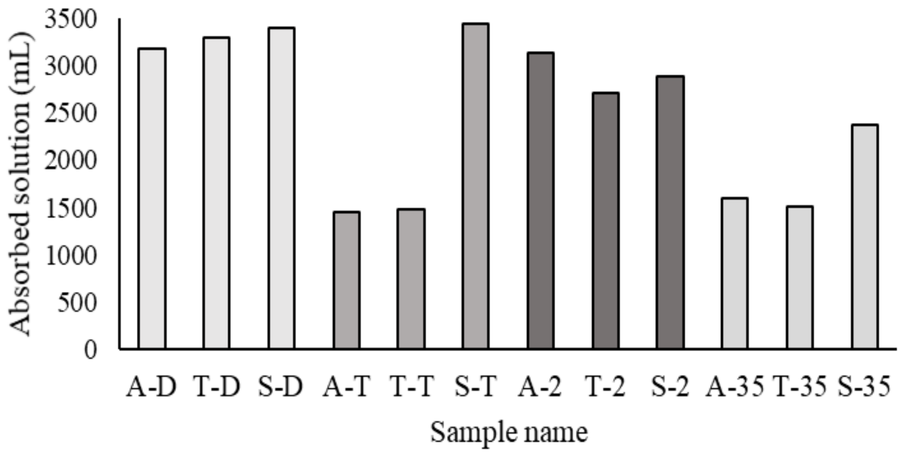

Figure 6: Total absorbed solution after 105 days

3.3 Tables

Table 2: Saline distribution in brick

Solution Type	Brick container	Brick frog mark	Brick parts in box (top/bottom)	Salinity (mg/kg)	Other half of brick	Salinity (mg/kg)	Mortar Salinity (mg/kg)
Distilled water	A-D	AFIL	82	583	81	516	383
			72	399	71	649	
	T-D	TABL	H1	682	H2	566	516
			G1	399	G2	449	
	S-D	SONY	8A	599	8B	499	366
			7A	383	7B	566	

Table 3: Porosity and 24 hours absorption of bricks.

Solution Type	Brick container	Brick frog mark	Brick parts in box (top/bottom)	Other half of brick	24 hrs Absorption (%)	Porosity (%)
Distilled water	A-D	AFIL	82	81	18.04	30.57
			72	71	15.30	26.22
	T-D	TABL	H1	H2	12.16	22.68
			G1	G2	15.43	27.64
	S-D	SONY	8A	8B	23.67	35.38
			7A	7B	19.74	31.84
Tap water	A-T	AFIL	11	12	16.34	29.16
			21	22	17.15	30.26
	T-T	TABL	A1	A2	18.55	32.36
			B1	B2	14.39	26.53
	S-T	SONY	2B	2A	21.80	33.52
			1B	1A	19.12	30.58
Saline water (NaCl solution 2000 mg/L)	A-2	AFIL	31	32	11.39	20.22
			41	42	12.84	22.23
	T-2	TABL	C1	C2	17.21	29.88
			D1	D2	16.77	30.29
	S-2	SONY	3B	3A	21.43	33.21
			4A	4B	21.09	32.97
Saline water (NaCl solution 35000 mg/L)	A-35	AFIL	61	62	13.96	24.41
			52	51	10.54	19.18
	T-35	TABL	E1	E2	15.65	28.49
			F1	F2	15.78	28.56
	S-35	SONY	5A	5B	20.55	32.51
			6B	6A	19.05	31.02

4. CONCLUSIONS

1. Normal clay bricks absorb and evaporate more water than machine-made bricks in same environmental conditions.
2. Higher porosity of brick indicates higher absorption and evaporation.
3. Accumulation of salt increases with increase in concentration of saline solution in the same duration of time.
4. Distilled water dilutes salt in pores of brick and mortar. Diluted salt removes with the movement of water.

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REFERENCES

Cao, Y., Guo, L., & Chen, B. (2019). Influence of sulfate on the chloride diffusion mechanism in mortar. *Construction and Building Materials*, 398-405.

Karoglou, M., Bakolas, A., Moropoulou, A., & Papapostolou, A. (2013). Effect of coatings on moisture and salt transfer phenomena of plasters. *Construction and Building Materials*, 35-44.

Koronthalyova, O., & Bagel, L. (2015). Moisture transport in salt free and salt contaminated ceramic bricks. *6th International Building Physics Conference* (pp. 1401-1406). Bratislava: Elsevier Ltd.

Sathiparan, N., & Rumeshkumar, U. (2018). Effect of moisture condition on mechanical behavior of low strength brick masonry. *Journal of Building Engineering*, 23-31.

Stryszewska, T., & Kańka, S. (2017). The effects of salt crystallization in ceramic bricks in terms of line. *International Conference on Analytical Models and New Concepts in Concrete and Masonry Structures* (pp. 120-127). Cracow: Elsevier Ltd.

Todorovic´, J., & Janssen, H. (2018). The impact of salt pore clogging on the hygric properties of bricks. *Construction and Building Materials*, 850-863.

ASSESSMENT OF THE ENVIRONMENTAL QUALITY OF SITAKUNDA SHIP BREAKING YARD

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ABSTRACT

Over two decades ship-recycling industry in Bangladesh has received considerable attention via providing raw materials to steel industry, shipbuilding industry and some other industries in Bangladesh and some other countries of South Asia. Bangladesh derives 80-90% of its steel from end-of-life ships. This industry affects the environment in some seriously harmful ways. Workers safety, child labor, environmental issues are also threatened by this industry. This paper focuses on the Environmental Quality around the Ship Breaking and Recycling Industry (SBRI) to access its present situation and impact on the environment.It tries to asses the water quality of sea water and ground water, air particulate matter, soil quality of the Ship Breaking yard . Additionaly, it tries to provide an up-to-date picture of environmental impact of ship recycling industry by available liturature reveiw.

The Ship Breaking Yards are located along 7 km long coastline of Sitakunda Upazilla, Chittagong District,Bangladesh.
After taking permission from the relative authority of the Ship Breaking Yard, water samples from the inside & Outside of the Ship Yard are collected.Soil samples are collected only from inside of the Ship Yard Zone.Then samples of water and soil are measured in Environment Engineering lab,CUET.To investigate Air Particulate matter a digital machine is used for taking reading. Heavy metals like Chromium and Cadmium are also tested from the samples.

From the analysis of samples of water for particular sites parameters like pH(SW & GW),EC(SW), Chloride(SW), BOD(SW & GW) and Oil & Grease values are within the permissible limits. On the other hand parameters like Turbidity(GW & SW), EC(GW),TDS(GW & SW), Chloride(GW), DO values are not within the permissible value. From the analysis of soil samples it is seen that, the soils of site are slightly alkaline(pH & Alkalinity). EC value indicates that, the soil is not suitable for plant growth and the TDS value is a matter of concern. But the amount of chloride in the soil is okay. As we have taken the reading of air particulate matter in rainy season, the values of particulate matters are within safe range. According to the results of the heavy metal, the water body is safe from cadmium and chromium concentration. In the soil, the cadmium value is okay but the chromium is in a alarming condition. Considering the overall results, the study suggests that a considerable approach should be taken to minimize the negative impacts of ship breaking activities in the coastal zone of Bangladesh

Keywords: *Water quality, Air quality, Physico-chemical parameters of soil sample, Heavy metal test.*

1. INTRODUCTION

Bangladesh has a long coastal belt of about 710 km which is enriched with natural resources specially fish and other aquatic species of different varieties and has been the focal point of different economic activities. Most of these seashore areas are situated in Chittagong. Sitakunda is a Coastal area situated a few kilometres north-west of Chittagong City where most of the ship-breaking yards are concentrated.

The only ship-breaking industry of the country has been developed in Sitakunda areas,
Chittagong. Now, there are about 20 ship-breaking yards in Sitakunda where thousand and hundreds of labours are working and hundreds of labours are working. The workers are all engaged in dangerous labour but they don‘t have safety equipment like helmets, goggles, gloves, boots and work suits, medical facilities and moreover financial security. Over the last twenty years more than 400 workers have been killed and 6000 seriously injured (shipbreakingbd.info) . It can be said that the human rights are seriously violated in this significant and potential industry in our country.

Ship-breaking is a potential industry for Bangladesh. At present, Bangladesh secures top position in ship-breaking(dhakatribune.com).The largest ships of the world are cut in the shipyard of Bangladesh.This industry pays about 700 crores taka each year to the government of Bangladesh. Bangladesh needs eight million tons of building materials per year, in which most needed material is iron and ship breaking industry is supplying 90% iron materials to the country (shipbreakingbd.info).There is no distinct and well-balanced policy for ship-breaking industries. Actually, still now it is not declared as industry by the government. Due to unconsciousness and un-patronization of government, the industry is facing several internal and external problems. Above all, to solve all these problems a distinct and well-balanced policy is necessary for ship-breaking industries. 70% of ships are simply run ashore in developing countries for disassembly, where (particularly in older vessels) asbestos, lead, polychlorinated biphenyls and heavy metals pose a danger for the workers. Burns from explosions and fire, suffocation, mutilation from falling metal, cancer, and disease from toxins are regular occurrences in the industry.

Although the age of ship breaking in Bangladesh is more than three decades, but primitive working atmosphere and the lack of compulsory control mechanism generally cause the scrapping yards as a source of environmental and occupational health problems. The problem is caused by negligence from national governments, shipyard operators, and former ship owners disregarding the Basel Convention. According to the Institute for Global Labour and Human Rights, workers who attempt to unionize are fired and then blacklisted. The employees have no formal contract or any rights, and sleep in over-crowded hostels. The authorities produce no comprehensive injury statistics, so the problem is underestimated. In Bangladesh, a local watchdog group claims that one worker dies a week and one is injured per a day on average. Child labour is also widespread: 20% of Bangladesh's ship breaking workers are below 15 years of age, mainly involving in cutting with gas torches.

Several United Nations committees are increasing their coverage of ship breakers' human rights. In 2006, the International Maritime Organization developed legally binding global legislation which concerns vessel design, vessel recycling and the enforcement of regulation thereof and a 'Green Passport' scheme. Water-craft must have an inventory of hazardous material before they are scrapped, and the facilities must meet health & safety requirements. The International Labour Organization created a voluntary set of guidelines for occupational safety in 2003. Many ship breaking yards operate in developing nations with lax or no environmental law, enabling large quantities of highly toxic materials to escape into the general environment and causing serious health problems among ship breakers, the local population, and wildlife. Environmental campaign groups such as Greenpeace have made the issue a high priority for their activities. Along the Indian subcontinent, ecologically-important mangrove forests, a valuable source of protection from tropical storms and monsoons, have been cut down to provide space for water-craft disassembly In Bangladesh, for example, 40,000 mangrove trees were illegally chopped down in 2009 (Wikipedia). The World Bank has found that the country's beaching locations are now at risk from sea level rise. 21 fish and crustacean species have been wiped out in the country as a result of the industry.

2. METHODOLOGY

1.1 Overview of the Project

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Taking permission from the relative authority to enter into the Ship Breaking Yard

Collecting Water samples from the inside & Outside of the Ship Yard.

Collecting soil samples from the Ship Breaking yard

Investigate the amount of Air Particulate Matter inside & outside of the Ship Breaking Yard

Tests of the Soil & Water samples in the laboratory

Determination of the present Environmental Quality of Air,Water & Soil

Graphical Representation of the physicochemical Parameters of Air, Water & Soil and Heavy Metals for water and soil

Figure1: Workflow Diagram

Figure 1 briefly exhibits the step by step procedure of how the complete work was conducted.

1.2 Study Area

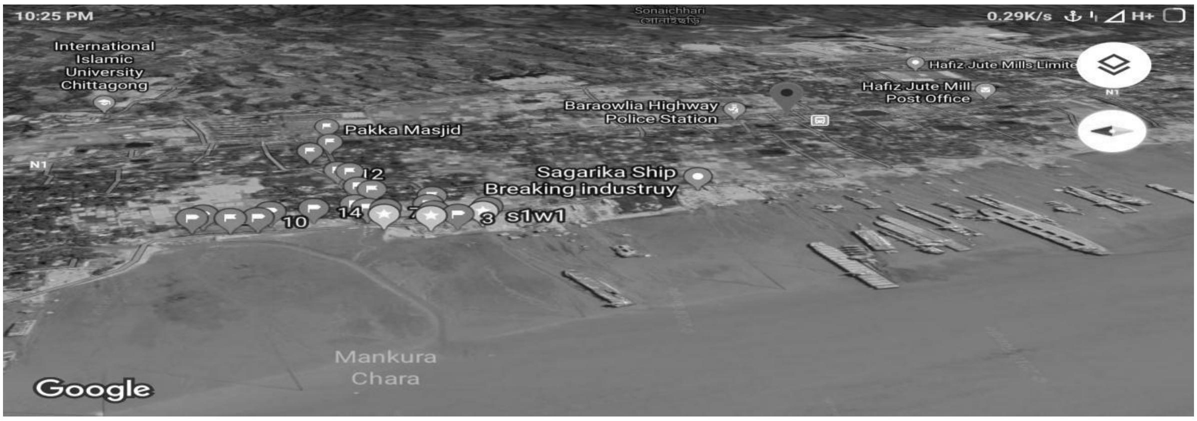

Figure 2 : Study area

Most of the Ship Breaking Yards of Bangladesh are situated at Sitakunda Upazilla in Chittagong District.The Ship Breaking Yards are located along 7 km long coastline of Sitakunda Upazilla.At present there are about 48 Ship Breaking Yards (36 yards are active and 12 yards are inactive) are lying along Dhaka Chittagong Highway which is 10 km. Away from the Chittagong City. Our project area is situated behind the well-known Baroawlia Pakka Mosque beside the Sagorika Ship Breaking

Yard.The industry is situated at the shore of Bay of Bengal,at the western side of Dhaka-Chittagong Highway.

1.3 Physicochemical Parameters for Water Sample and test apparatus:

The parameters that were selected for test of water samples are pH, Turbidity, Electrical Conductivity, Chloride, Total Dissolved Solid, Dissolved Oxygen, Biological Oxygen Demand and Oil & Grease and respected appurtenances are pH Meter; Turbid Meter; EC Meter; SX823-B Portable Multi-Parameter Meter; Titration; Separating Funnel.

1.4 Physicochemical Parameters for Soil Sample and test apparatus:

The parameters that were selected for test of filtered water samples are pH, Electrical Conductivity, Chloride, Total Dissolved Solid, Carbon-Di-Oxide, Alkalinity and respected appurtenances are SX823-B Portable Multi-Parameter Meter; Titration. For conducting these tests, at first, we had to prepare the soil sample. Preparation of soil sample consists of drying the soil sample in air dry conditions, making powder form when the sample becomes dry, weighing 25 gm of soil sample, mixing it with 100 ml of distilled water. Then the mixture is kept for one day so that the qualities of soil can be transferred into the water. And after one day, the mixture is filtered and filtered water is collected.

1.5 Air Particulate Matter determination in the air:

It is a digital machine to detect the particulate matter in the air. It is just to switch on the machine in the position from which we want to take the data of the air particulate matter.

3. RESULT & DISCUSSION

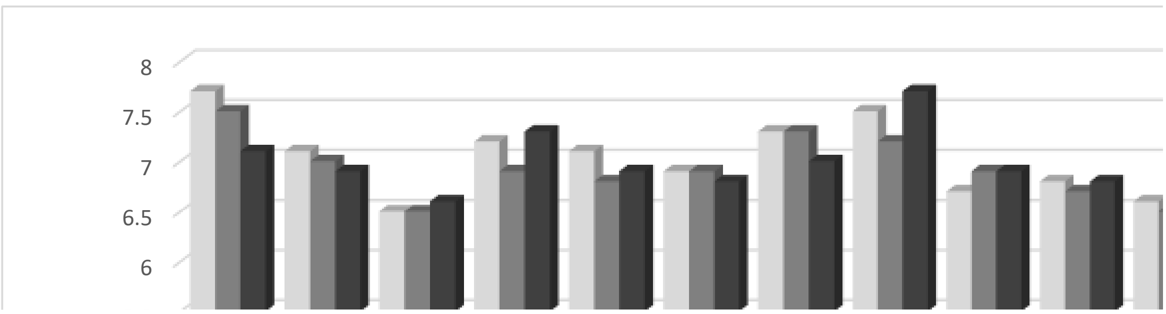

Figure 3: pH value of Water samples

The standard value range of pH for surface and ground water by the US-EPA guideline is 6.5-8.5 and pH of the samples are within the standard limit. In an average, the graph shows that, ground waters of the site are 10 times more acidic than the surface water. But, there is no risk in the pH value. Because, for fish reproduction, pH level is 6.5-9.0, so, the surface water is fit for fish propagation. And, the ground waters are used for drinking purpose in that area which is also found safe for this use.

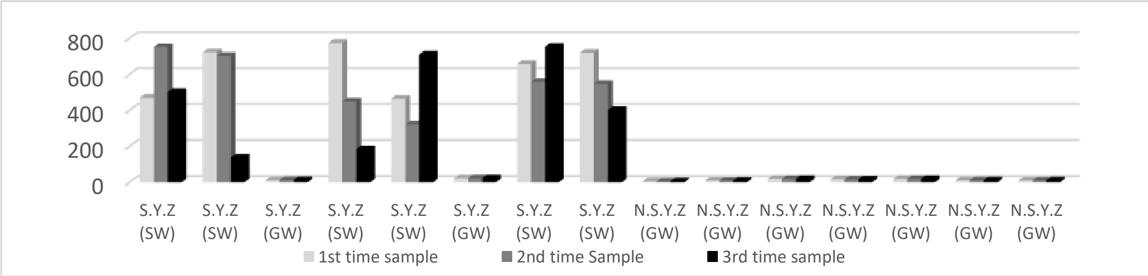

Figure 4:Turbidity (JTU) value of Water samples

The US-EPA Standard value of Turbidity for Surface Water is 72.5 JTU and for ground water is 12.5 JTU. In the surface water we can see from the Graph that, the values exceed the Standard Limit & 3 Tube well‘s turbidity value exceed the standard limit of No Ship Yard Zone. So, there is high risk in the surface water for turbidity. Turbidity value of some tube wells are within permissible limits, but 3 tube wells exceeds the limits,because they were shallow or poorly built wells and they were in the close proximity to the canals than the others.Hence, that 3 tube wells are risky for drinking purposes. In the surface water, as it is so much turbid, photosynthesis will be hindered and so the production of oxygen for fish and aquatic life will be reduced

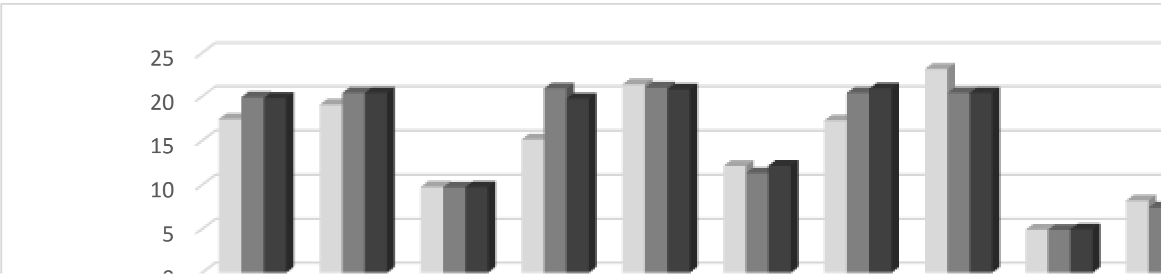

Figure 5: EC (mS/cm) value of water sample

The standard range of Electrical Conductivity for drinking water purpose is 0.05-0.5 mS/cm and the value of Standard Sea Water is 50 mS/cm. The EC values of the Surface Water are far under the permissible limit which is quite good for the fishes and other aquatic life, but all the ground water sources exceeds the permissible limits.This exceedence occured due to the change in land use pattern of the area ,leaching of pollutanats, saline water intrusionm or upconing of saline water . And hence the tubewell water is quite risky for drinking purpose.

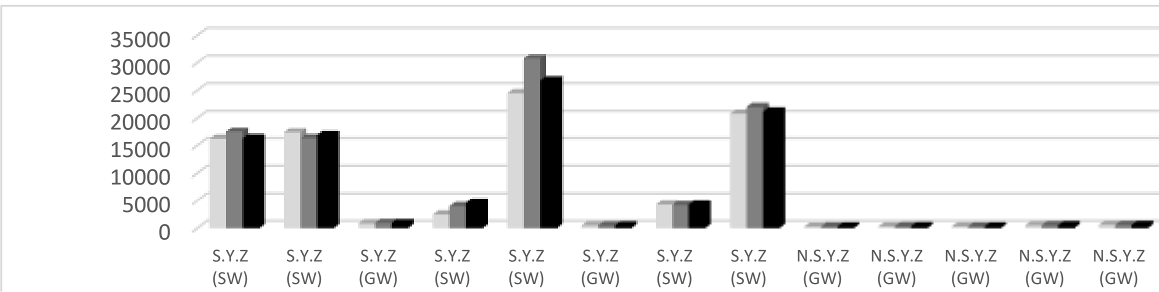

Figure 6: TDS (mg/L) value of water Samples

According to USEPA for ocean water standard TDS value is 35,000 mg/L & for ground water the permissible limit is 300-500 mg/L Here, from the Graph, we can see that, surface water TDS values are within permissible limit, which is ok for aquatic life. But, 3 Tube Wells in the No Ship Yard Zone and 1 tape water of Ship Yard Zone, the values exceed the permissible limit.This exceedence occured due to sea water intrusion,stormwater and agricultural runoff and point or non-point waste water discharges. And hence,these above mentioned sources of water are quite risky for drinking water purpose.

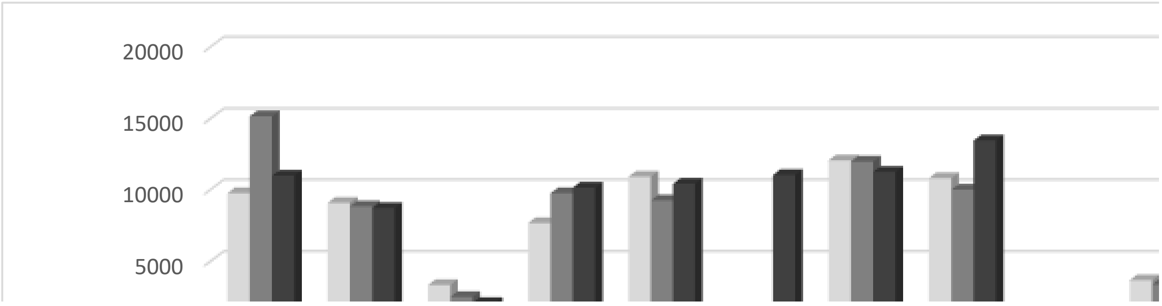

Figure 7: Chloride(mg/L) value of water sample

Here, from the graph, we can see that, the Chloride values for surface water are under the Standard limit which is quite safe for the aquatic life, but the chloride values of tube wells have exceeded the permissible limit, which is unsafe for drinking water purposes. Here, due to the salt intrusion the chloride values of Ground Water is increasing day by day

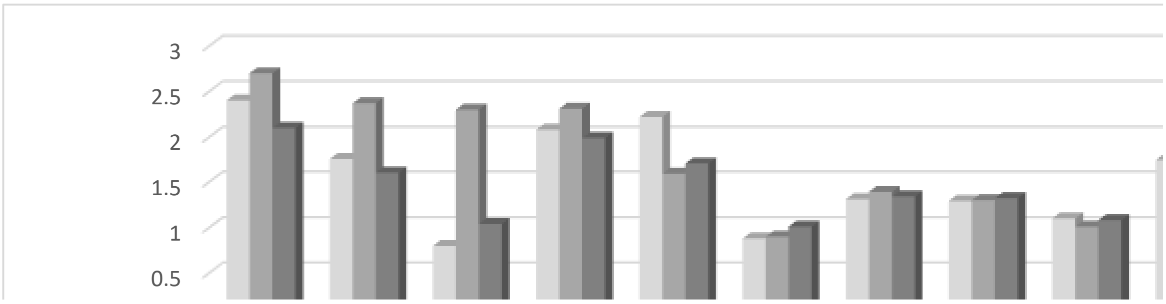

Figure 8: Dissolved Oxygen (mg/L) value of water sample

USEPA standard DO value 9.0 mg/L. Here, from the graph we can see that, the DO values of all the sources are quite below the Standard Value due to excessive algae and phytoplankton growth caused by phosphorous and nitrogen,die-off and decomposition of submerged plants or variation of water temperature and altitude. So, the tube well waters are not suitable for Drinking purpose and the surface water is not suitable for the fish propagation. Aquatic animals are most vulnerable to lowered do levels in the early morning on hot summer days when stream flows are low, water temperatures are high and aquatic plants have not been producing oxygens since sunset.

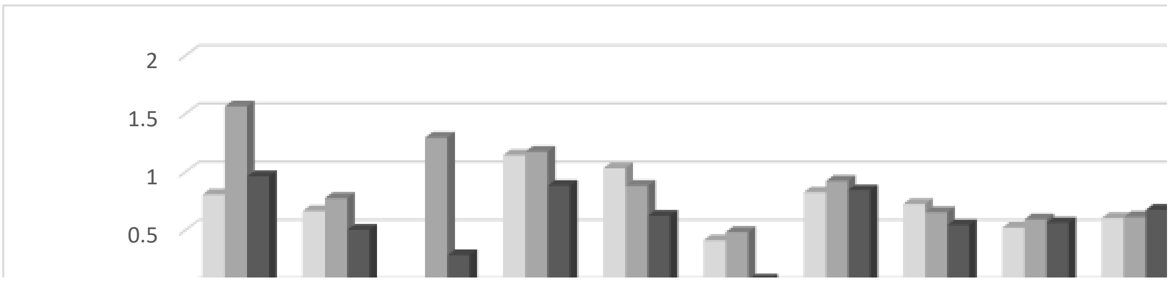

Figure 9: Biological Oxygen Demand(mg/L) value of water samples

The USEPA standard value for BOD is 5 mg/L. But the BOD value of the tasted samples of surface water and ground water is lower than the standard level. As we know, BOD indicates the amount of putrescible organic matter present in the water, therefore a low BOD is an indicator of good quality water and it ensures that there is enough oxygen left for fish and aquatic plants. It is also suitable for drinking water purpose.

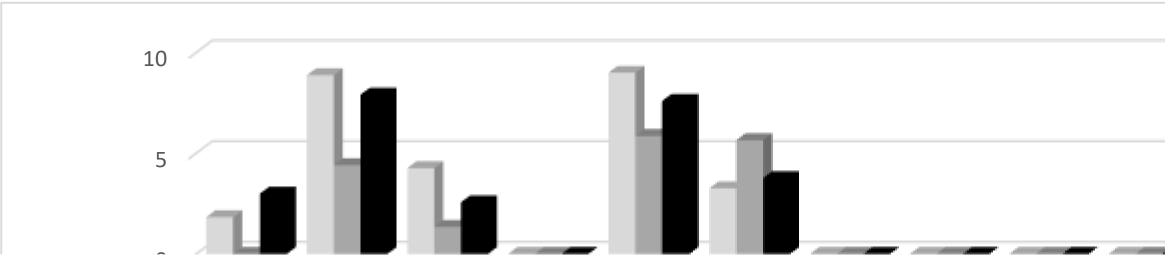

Figure 10: Amount of Oil & Grease in Water Samples

Here, from the Graph, we can see that, there are no oil in the Ground Water and in the Surface Water the amount of Oil is within the Standard Limit. So, the Surface Water is ok for aquatic life and the drinking water is also good for drinking purpose

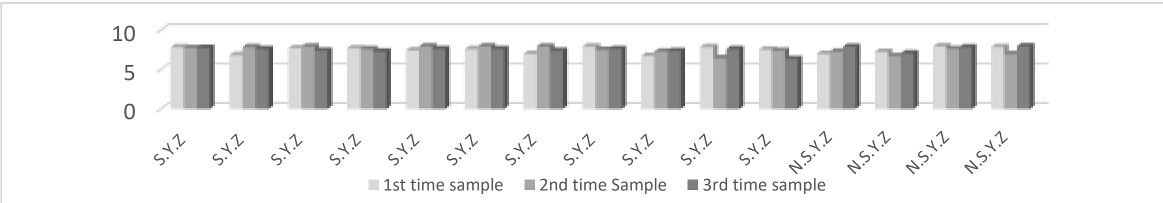

Figure 11: pH of soil Samples

According to graph the soil samples of the study area is slightly alkaline. As the soil pH decreases, most desirable crop nutrients become less available while others, often undesirable, become more available and can reach toxic levels.Plant nutrients leach the soil much faster at pH value below 6.0 than from the soils within the 6.0-7.5 range according to Eileen Ward, 2015. pH is not an indication of fertility, but it does affect the availability of fertilizer nutrients. The soil samples of the site are not within the Standard Limit so it is not a good sign for fertility

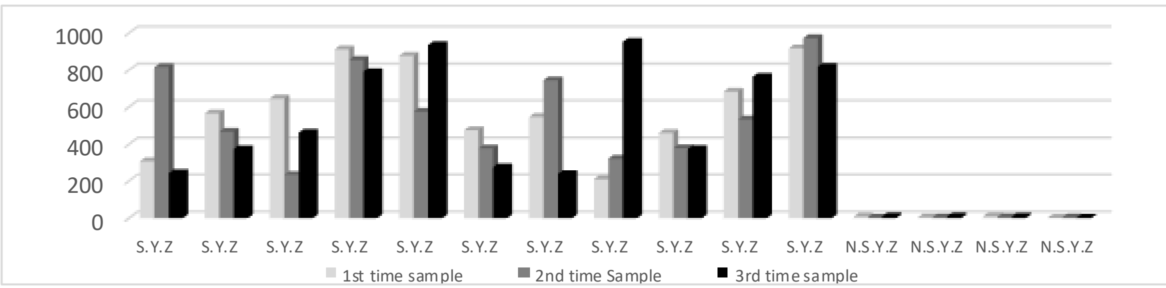

Figure 12: EC (ms/cm) of Soil Samples

In soil, Electrical Conductivity is a measure of the ability of the soil to conduct an electrical current. Optimal EC levels in the soil may range from 1.10-5.70 mS/cm. Too low EC levels indicate low available nutrients, and too high EC levels indicate an excess of nutrients. Low EC's are often found in sandy soils with low organic metal levels, whereas high EC levels are usually found in soils with high clay content. But the EC values of the Ship Yard Zone is too much higher which is not suitable for plant growth. The EC values of Not Ship Yard Zone also exceeds the Standard limit, but it is far ok than the Ship Yard Zone.

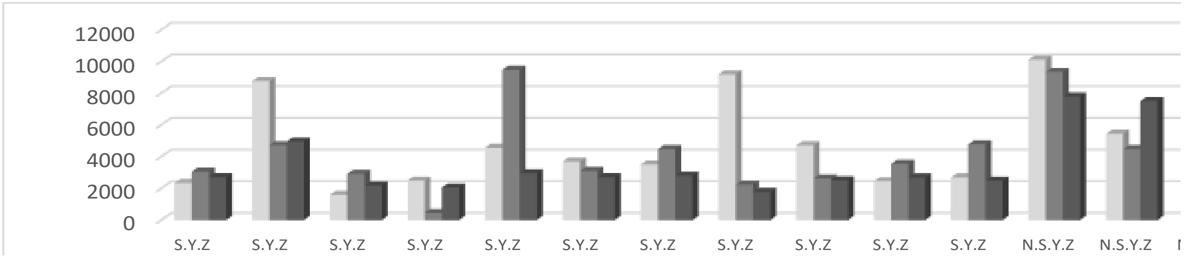

Figure 13: TDS(mg/kg) of Soil Samples

Here, from the graph we can see that, the dissolved oxygen in the soil of Ship Yard Zone is quite low from the No Ship Yard Zone. Because of the direct contact with the water, the dissolvable solid particles get dissolved into the sea water. As the amount of dissolvable solid is very high in the soil, it is a matter to be concerned. Because, these solids are dissolving in the water and the amount of Dissolved solid in the water is growing higher day by day

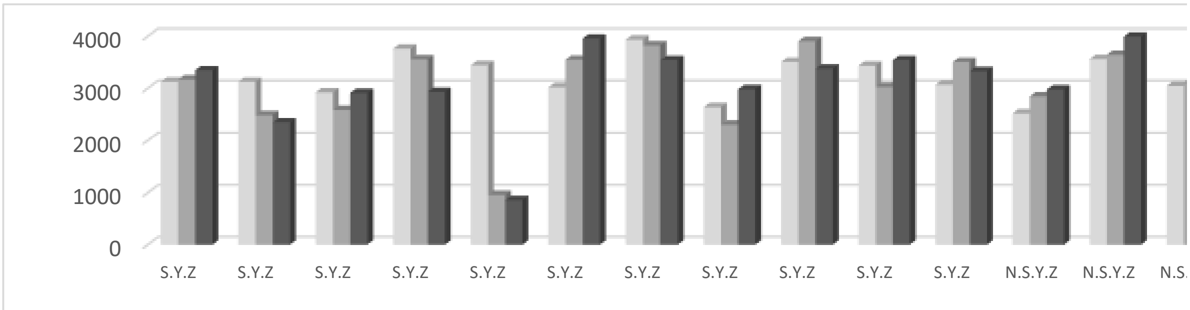

Figure 14: Chloride (mg/kg) of soil samples

Natural inputs of chlorine to soils come mainly from rainwater, sea spray, dust and air pollution. In addition, human practices, contribute significantly to chlorine deposition. As our site is a coastal region, we can see also from the graph 4.12 that, the value of chloride in soil is quite ok for the Crop production

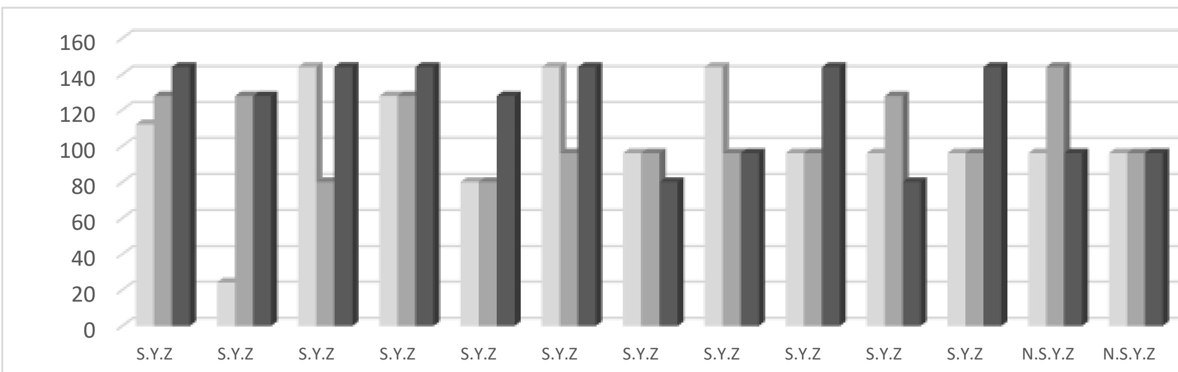

Figure 15: Alkalinity(mg/kg) in the soil samples

From the observation of result, it is clear that, the soil is slightly alkaline

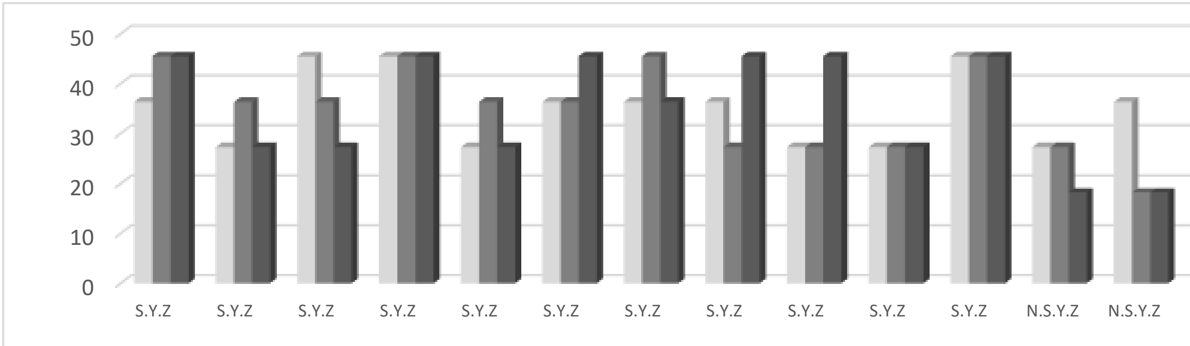

Figure 16: Carbon-dioxide(mg/kg) value of Soil Samples

From the observation of result, we found it that, the concentration of Carbon-dioxide in the Ship Yard Zone is much higher than the No Ship Yard Zone, because of the release of Carbon-dioxide during evaporation of water, the high solubility of Carbon-dioxide in soil water and high rate of microbiological activity.

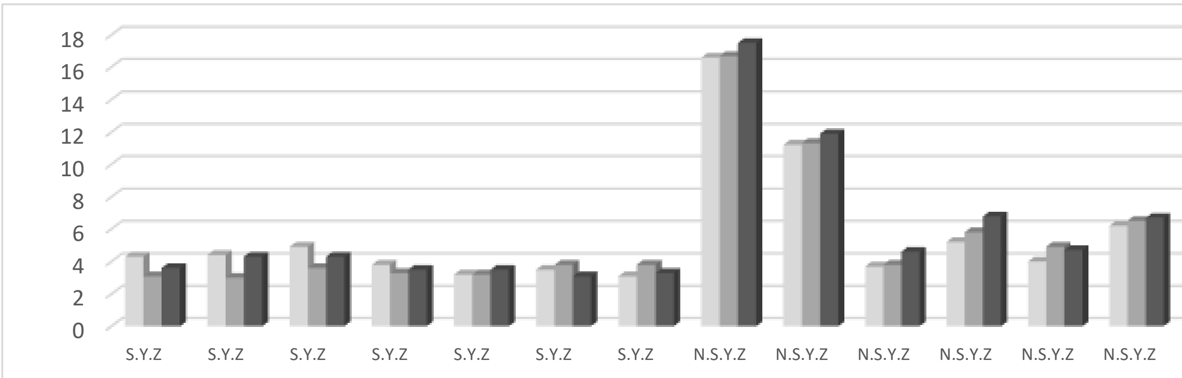

Figure 17: Amount of Air particulate matter ($PM_{2.5}$)

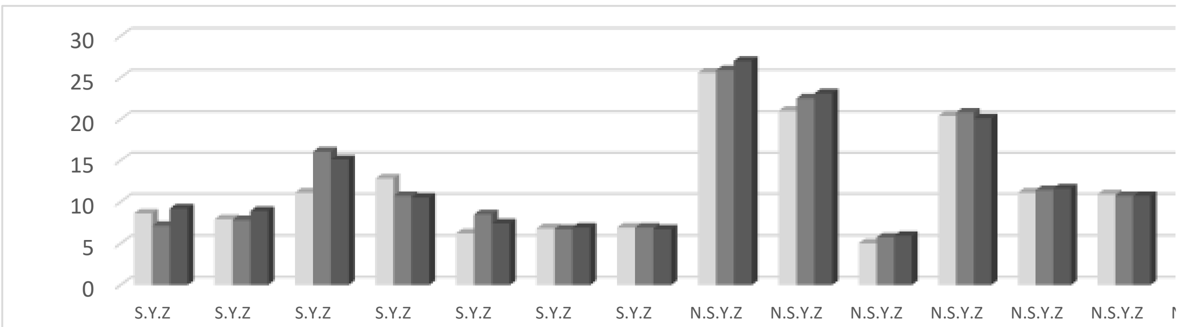

Figure 18 : Air particulate matter (PM_{10})

According to the USEPA standard we can see from results of the study area is that, the values of $PM_{2.5}$ and PM_{10} is within the range of standard value. As the reading was taken in a rainy day, the reading was quite good.

Generally in the winter season the amount of air particulate matter is high and in the rainy season the amount is low, because in the rainy season, in the air there is huge amount of fogs.So the value becomes very high. But in the rainy season the air becomes clear, so the value becomes very low

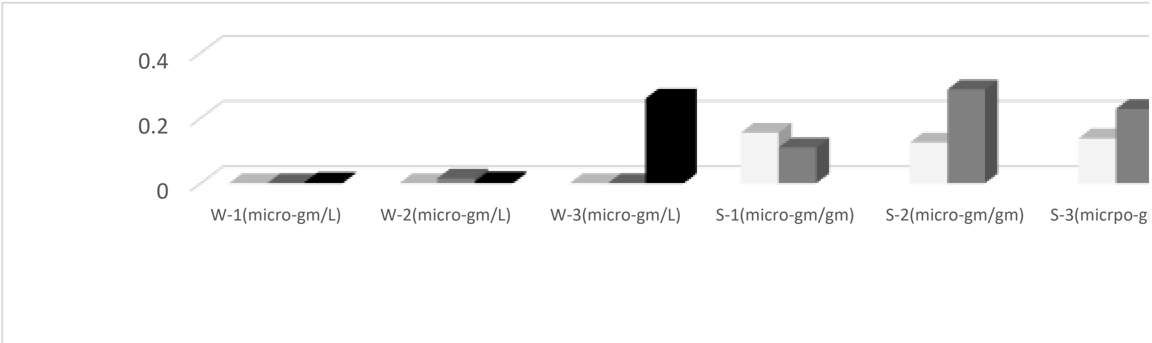

Figure 19: Chromium(Heavy metal) in the water & Soil sample

According to the USEPA standard limit, the Chromium value for water is 0.05 microgm/L and for soil it is 0.05 micro-gm/gm. From the test results, we have found that, Chromium concentration in the water body is okay but in the soil, the amount is quite alarming.

No Cadmium(Heavy metal) was found in the water and soil sample of the ship yard which is a good sign against heavy metal pollution.

4. CONCLUSIONS

From the analysis of samples of water for particular sites parameters like pH(SW & GW),EC(SW), Chloride(SW), BOD(SW & GW) and Oil & Grease values are within the permissible limits. On the other hand parameters like Turbidity(GW & SW), EC(GW),TDS(GW & SW), Chloride(GW), DO values are not within the permissible value. From the analysis of soil samples it is seen that, the soils of site are slightly alkaline(pH & Alkalinity). EC value indicates that, the soil is not suitable for plant growth and the TDS value is a matter of concern. But the amount of chloride in the soil is okay. As we have taken the reading of air particulate matter in rainy season, the values of particulate matters are within safe range. According to the results of the heavy metal, the water body is safe from cadmium and chromium concentration. In the soil, the cadmium value is okay but the chromium is in a alarming condition. Considering the overall results, the study suggests that a considerable approach should be taken to minimize the negative impacts of ship breaking activities in the coastal zone of Bangladesh.

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REFERENCES

Aktaruzzaman, M., Chowdhury M. A. Z., Fardous, Z.2, Alam, M. K., Hossain, M. S. and Fakhruddin, A. N. M. (2013). Ecological Risk Posed by Heavy Metals Contamination of Ship Breaking Yards in Bangladesh.

Dr. Md. M. Maruf Hossain. Mohammad Mahmudul Islam. (2006) ―Ship Breaking Activities and its Impact on the Coastal Zone of Chittagong, Bangladesh: Towards Sustainable Management. ISBN : 984-32-3448-0.

https://en.wikipedia.org/wiki/Ship_breaking

https://shipbreakingbd.info/worker-rights-violation/

https://www.dhakatribune.com/bangladesh/2019/11/14/bangladesh-secures-top-position-in-ship-breaking

https://www.shipbreakingbd.info/Baseline.pdf

Helal Ahammad, Mohammad Sujauddin. (2017). ―Contributions of Ship Recycling in Bangladesh: An Economic Assessment.‖ WBS Element No. TC/1514-01-2320

Hasan Muhammad Abdullah1, M. Golam Mahboob, Ahammad Al Biruni. ―Drastic expansion of ship breaking yard in Bangladesh: a cancerous tumor to the coastal environment‖

Khandakar Akhter Hossain (2017**)** **"**Ship Recycling Practice and Annual Reusable Material Output from Bangladesh Ship Recycling Industry.‖.. Hossain, J Fundam Renewable Energy Appl 2017, 7:5 DOI: 10.4172/2090-4541.1000238

https://www.bing.com/search?q=Parameters+of+water+quality+EPA+pdf&form=P

Khandakar Akhter Hossain.(2017). ‟ Ship Recycling Status in Bangladesh and Annual Reusable Material Output‖.. Open Acc J of Toxicol. 2017; 2(2): OAJT.MS.ID.555581 USEPA Standard April 30, 2018. Chapter 62-302.

Md. Imrul Jobaid, Md. Moniruzzaman Khan, A.K.M Kamrul Haque, Istiaque Ahmed Shawon.―Ship Recycling and Its Environmental Impact: A Brief Overview of Bangladesh.‖.. *IOSR Journal of Business and Management (IOSR-JBM) e-ISSN: 2278487X, p-ISSN: 2319-7668. Volume 16, Issue 10.Ver. I (Oct. 2014), PP 31-37 www.iosrjournals.org*

Md. Juel Rana Kutub, Nishat Falgunee, Shahreen Muntaha Nawfee and Yasin Wahid Rabby.(2017). ―Ship Breaking Industries and their Impacts on the Local People and Environment of Coastal Areas of Bangladesh.‖ DOI: 10.1515/hssr -2017-0013

Muhammad Muhibbullah (2013). ―Health hazards and risks vulnerability of ship breaking workers: A case study on Sitakunda ship breaking industrial area of Bangladesh.‖ Global Advanced Research Journal of Geography and Regional Planning (ISSN: 2315-5018) Vol. 2(8) pp. 172-184, November, 2013

Mosabbir. Pasha, Aziz. HasanMahmood, Istiakur. Rahman, and Abul. Hasnat. (2012). ―Assessment of Ship Breaking and Recycling Industries in Bangladesh - An Effective Step Towards The Achievement Of Environmental Sustainability.‖ International Conference on Agricultural, Environment and Biological Sciences (ICAEBS'2012) May 26-27, 2012 Phuke

Thanasis Karlis, Dionysios Polemis, Anastasios Georgakis (2016). ―Ship demolition activity. An evaluation of the effect of currency exchange rates on ship scrap values.‖.. SPOUDAI Journal of Economics and Business, Vol.66 (2016), Issue 3, pp. 53-70

Parameters of Water Quality, EPA, 1992**.**

REXEN&mkt=enus&httpsmsn=1&refig=544687ba02b043fc88804e39eff0d550&pq=parameters+of+w ater+quality+epa+pdf&sc=0-29&sp=-1&qs=n&sk

ADOPTION OF WATER EFFICIENT PLUMBING FIXTURES, A CASE STUDY OF A RESIDENTIAL BUILDING

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ABSTRACT

Water crisis is a severe problem in Dhaka and Chittagong city of Bangladesh. The current population of 2.28 crores of these cities is already deprived of clean water along with other basic facilities. In context of this problem, this study has tried to investigate whether use of water sensitive plumbing fixtures in households can minimize water crisis by reducing losses caused by using conventional plumbing fixtures or not. A cost benefit analysis has also been conducted to assess the financial viability of introducing these fixtures in the city. Various water saving equipment such as low flush toilets, low flow showerheads, low flow basin faucets etc. were considered while analyzing the efficiency of water savings. A thorough literature review was conducted to find out water requirement of the proposed and traditional fixtures. Cost of these water sensitive fixtures and also conventional ones were collected from field survey. Around 45% less annual water consumption was found in a typical 5 storied building for the water sensitive fixtures in comparison to traditional ones. The proposed system was also found financially durable as its cost minimization capacity was significantly higher than the conventional system. The results of the study indicate that current water crisis in big cities can be reduced noticeably by introducing water sensitive fixtures in households.

Keywords: *Water crisis, Water sensitive plumbing fixtures, Conventional plumbing fixtures, Water savings, Cost benefit analysis.*

1. INTRODUCTION

In this 21th century, civilization has entered into the flow of development and we are moving forward with a population of more than 6 billion. So sustainable development is utmost essential for reducing the water consumption.

With the rapid increase of population and the development of society and industry, many countries are facing a water shortage. A water shortage does not only result in a shortage of domestic water for people's lives, but also serious food shortages, impacts on eco systems and public health problems. Among other things, food shortages are particularly serious with about 800 million people are currently suffering from malnutrition and the world will become in need of food to sustain 2.4 billion people by 2025 as a result of an increase in the percentage of developing countries. (United Nations Population Estimation, 2017) Various other problems are also emerging, including water pollution caused by insufficient sewage disposal capacity, an increasing number of people dwelling on flood prone lowland areas and resultant flood damage, etc., and there is growing concern that these problems including water shortages will become more serious in future due to the increase in the world population and the impact of climate change.

While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50 %. This population growth – coupled with industrialization and urbanization – will result in an increasing demand for water and will have serious consequences on the environment.

This thesis will undertake the task of inspecting the water usage by the plumbing fixtures of a residential building. This is a comparative study which gives a message of water efficient fixtures that is eco-friendly. (Wadud Mushfique, 2011) Besides ground water level is decreasing day by day for too much water extraction. If we don't adopt new water usage method our future generation will face a great problem. So adoption of water efficient plumbing fixtures is the only solution to handle the water scarce problems. These types of fixtures may be costly but in the long period it saves too much water as well as money.

2. METHODOLOGY

To check whether the water efficient plumbing fixtures are feasible in the long run or not, two alternative measures are taken. In alternateve-1, water saving tap aerators are fitted internally or externally on existing taps from kitchen, bathroom & wash basins. And also flush valve toilets are used in place of flash tank system toilets. In alternative-2, only wash basin taps those are mentioned as CP Pillar Cock are alternated to sensor based smart taps. The remaining fixtures are kept same as the alternative-1.The whole procedure is explained below with essential figures.

2.1 Installation of Water Saving Aerators

Water Saving Aerators are one of the best innovative water saving solutions for any organization. Whether it is a washbasin, bath shower, sink taps or faucet. These products are created and designed with the purpose of dispensing water at a defined flow rate depending on the amount of liquid required. Most of the devices have the water saving capacity of several litres per day. Equipping these Water Saving Device could give huge water savings either at office or home.

Male fitting tap aerators are fitted internally on your taps while female fitting tap aerators available to order here are used when the tap on which you are fitting the aerator has external treads.

Figure 2.1: Sample of male and female aerators and their ways of installing.

They will reduce the water flow in your tap to just 4.5 litres per minute helping in reducing both water charges and energy bill when using hot water. These water saving tap aerators are self-cleaning with an anti-lime stainless steel sieve ensuring they are not susceptible to lime scale build up. Housed in a polished and chromed brass that one will get a soft comfort jet spray from taps when these are fitted which ensures no water splashes through the mixing of air and water.

Ideal for kitchen and bathroom taps these great tap aerators are very low maintenance due to the self-cleansing feature and come with a 12-month manufacturer's guarantee. The water saver faucet aerator is devised in such a way that it can be set-up on all kinds of tap faucets.

An aerated flow is when air mixes into the water. It produces a larger, whiter stream that is soft to the touch and non-splashing. This stream is the perfect choice for residential faucets and can go a long way to help one reducing domestic bills.

Figure 2.2: Water flow after installing aerator

Figure 2.3: Aerated vs Non-aerated flow

2.2 Installation of Water Efficient Showerheads & Flush Valve Toilets

Showering is one of the leading ways we use water in the home, accounting for nearly 17 percent of residential indoor water use. New high efficiency showerheads use less water than standard models without sacrificing performance, helping us conserve water and saving on energy.

Figure 2.4: Standard model showerheads vs. high efficiency shower heads.

Commercial toilets, or flush meter-valve toilets, are typically found in commercial, institutional, or industrial restrooms in such places as airports, theatres, stadiums, schools, and office buildings. These types of toilets have two main components—the toilet bowl and the flush meter valve.
By replacing old, inefficient flushometer-valve toilets a 10-story office building with 1,000 occupants could save nearly 1.2 million gallons of water and nearly $10,000 per year. Of those savings, nearly 870,000 gallons of water and $7,600 in water costs per year can be achieved by replacing the toilets in the women's restrooms alone.

Most of the old toilets have flush volumes as high as 3.0 to 7.0 gallons per flush (gpf)—far more water than the BNBC standard of 1.6 gpf. These flushometer-valve toilets, whether single- or dual-flush, use no more than 1.28 gpf, which is a 20 percent savings over the BNBC standard of 1.6 gpf.

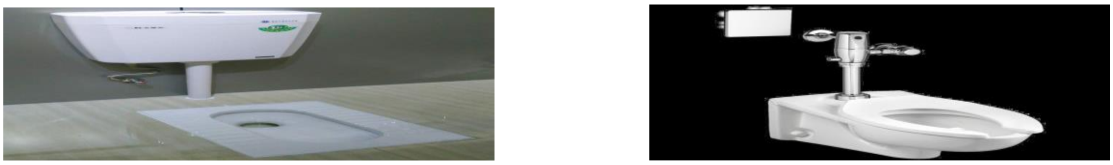

Figure 2.5: A typical long pan with flush tank system vs. a typical flushometer-valve toilet.

2.3 Installation of Sensor Based Faucets

Millions of gallons of water are wasted every year through faucets that are left running for too long or not closed properly after use. Simply going through the daily early morning routine of personal hygiene, cleaning one’s teeth, washing the face, etc. sees gallons running unused down the drain because few people think to turn the water on and off during this process.

Installing sensor faucets will reduce this kind of waste by stopping the water flow every time the hands are removed. So instead of the water continuing to run while teeth are being scrubbed, it stops until it is time to rinse. The same applies to the process of soaping the face and body.

It is believed that installing motion sensor faucets can save as much as 30% to 50% on overall water use, a saving that should not be taken likely both on financial and environmental cost.

Figure 2.6: A typical standard water faucet vs. a typical water efficient sensor faucet.

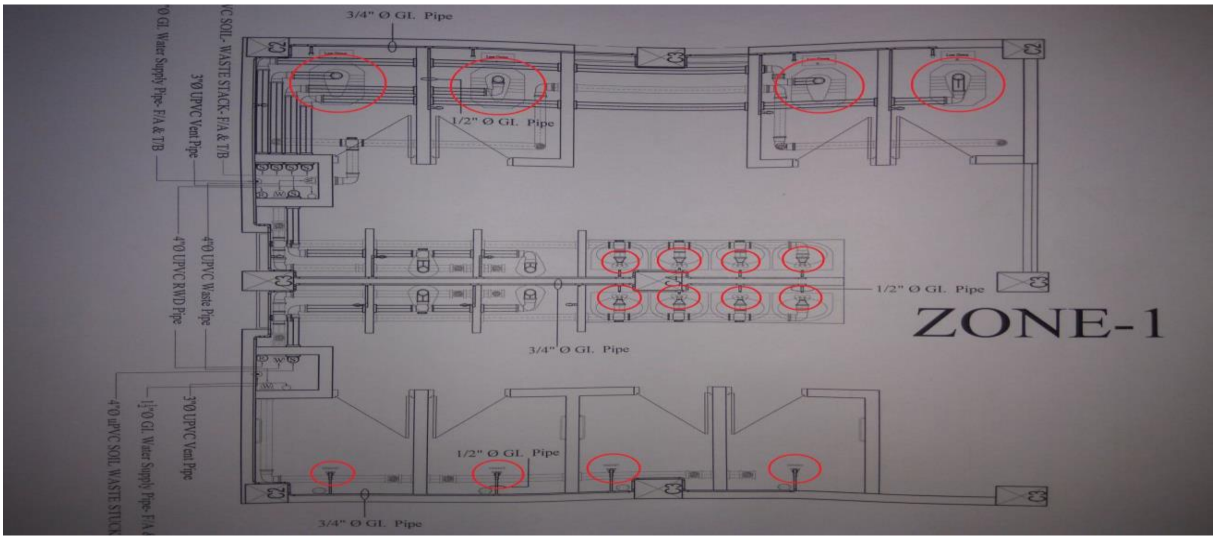

Figure 2.7: Plan of the washroom (zone-1), Sheikh Rasel Hall, CUET.
[Note: Red circles indicated the fixtures those are to be replaced by water efficient fixtures.]

3. ILLUSTRATIONS

3.1 Cost-Benefit Analysis

There are different types or methods of analysis to determine the economic efficiency of a project. The types those are covered in this thesis are:

1. Present Worth Method
2. Annual Worth Method

Present Worth Method:

Present worth method is the method of evaluating present value (PV) or current worth of a future sum of money or stream of cash flows given a specified rate of return. Future cash flows are discounted at the discount rate, and the higher the discount rate, the lower the present value of the future cash flows.

Annual Worth Method:

The annual method is commonly used for comparing alternatives. As illustrated in Chapter 4, AW means that all incomes and disbursements (irregular and uniform) are converted into an equivalent uniform annual (end-of-period) amount, which is the same each period.

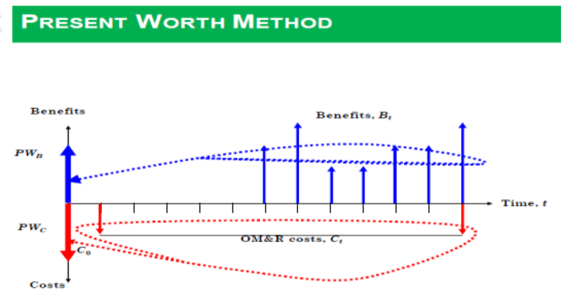

Figure 3.1: Present worth method

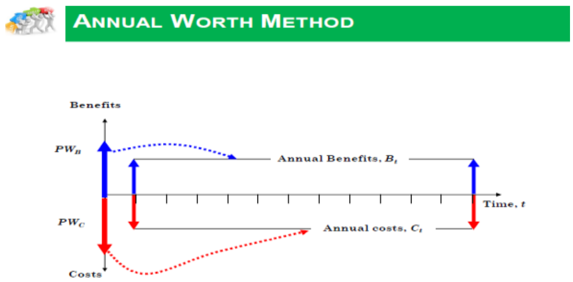

Figure 3.2: Annual worth method

present worth - annual payments

$PV = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$	present value or worth
$A = \frac{PV}{\frac{(1+i)^n - 1}{i(1+i)^n}}$	annual payment or cost

Figure 3.3: Formula for present worth

present worth analysis

$PV = \frac{F}{(1+i)^n}$	present value or worth
$F = PV \times (1+i)^n$	future value or worth
$i = \left(\frac{F}{PV}\right)^{1/n} - 1$	interest rate

Figure 3.4: Formula for annual worth

3.2 Relevant Data & Considerations Used

- Life Time of the Building = 50 years
- Occupants = 600
- Rate of Interest, i = 10%
- Lifetime of Fixtures used for calculation is given below in Table 3.1
- Price of Fixtures both traditional and WEF are given in Table 3.3, Table 3.4 and Table 3.5.
- According to WASA, 1000 liters of water = 10 taka.
- Throughout the 50 year lifespan lavatories need to be replaced twice and the water faucets need to be replaced 4 times.
- Average shower time per person is taken as 5 minutes.
- Faucet use was taken as 4 minutes per person per day.
- Daily average flushing was taken as 5 flushes per person per day.

Table 3.1: Normal lifetime of various fixtures

Fixtures	Lifetime (Year)	
	Traditional	**Water Efficient**
1. Long Pan	20	20
2. English Commode	20	20
3. Bib Cock	10	10
4. Pillar Cock	10	10
5. Sink Cock	10	10
6. Shower Head	10	10

Table 3.2: Standard flow rate through different fixtures

Fixtures	Water Usage (Old)*	Water Usage (WEF)*
1. Long Pan	3.5 gpm	Not Available
2. English Commode	5.0 gpm	1.28 gpm
3. CP Pillar Cock	3.0 gpm	1.5 gpm
4. CP Bib Cock	3.0 gpm	1.5 gpm
5. CP Sink Cock	4.5 gpm	2.5 gpm
6. Shower Head	2.5 gpm	2.0 gpm

* The values in the former old fixtures were taken according to the BNBC guidelines using Table 8.7.14 and Figure 01.

*The values of water efficient fixtures were taken from manufacture company values. For details www.amazon.in; www.alibaba.com

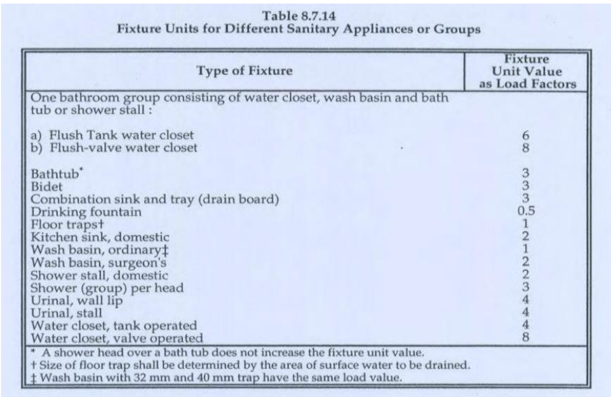

Table 8.7.14
Fixture Units for Different Sanitary Appliances or Groups

Type of Fixture	Fixture Unit Value as Load Factors
One bathroom group consisting of water closet, wash basin and bath tub or shower stall :	
a) Flush Tank water closet	6
b) Flush-valve water closet	8
Bathtub*	3
Bidet	3
Combination sink and tray (drain board)	3
Drinking fountain	0.5
Floor traps†	1
Kitchen sink, domestic	2
Wash basin, ordinary‡	1
Wash basin, surgeon's	2
Shower stall, domestic	2
Shower (group) per head	3
Urinal, wall lip	4
Urinal, stall	4
Water closet, tank operated	4
Water closet, valve operated	8

* A shower head over a bath tub does not increase the fixture unit value.
† Size of floor trap shall be determined by the area of surface water to be drained.
‡ Wash basin with 32 mm and 40 mm trap have the same load value.

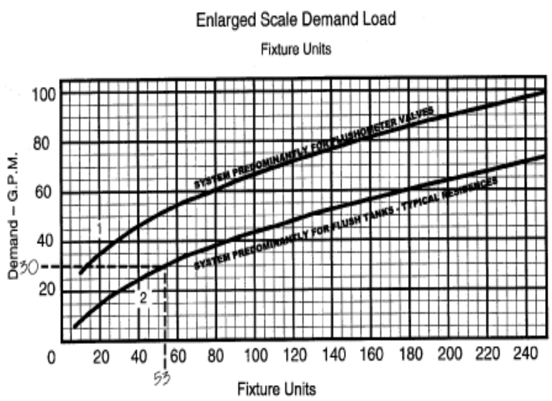

Figure 3.5: Fixture Unit vs Demand (gpm) Graph

Table 3.3: Prices of the traditional fixtures currently used

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. Long Pan (FT)	60	1909	114540.00
2. English Commode (FT)	5	2996	14980.00
3. CP Pillar Cock	120	697	83640.00
4. CP Bib Cock	165	555	91575.00
5. CP Sink cock	4	821	3284.00
6. Shower head	65	679	44135.00
		Total=	3,52,154.00

Table 3.4: Prices of the water efficient fixtures used in Alternative-1 (includes aerator based faucet)

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. English Commode (FT)**	65	5525	3,59,125.00
2. CP Pillar Cock*	120	910	1,09,193.00
3. CP Bib Cock*	165	768	1,26,720.00
4. CP Sink cock*	4	1034	4,136.00
5. Shower head*	65	760	49,400.00
		Total=	6,48,564.00

*The Price of the Cp pillar cock, bib cock & sink cock includes the aerator price (210 tk)
**The Price of English Commode (Flush Valve) was taken form https://www.alibaba.com/showroom/bangladesh-faucet.html

Table 3.5: Prices of the water efficient fixtures used in Alternative-2 (sensor based faucet)

Fixtures	Quantity	*Unit Price (Tk)	Total Price (Tk)
1. English Commode (FT)	65	5525	359125.00
2. CP Pillar Cock**	120	8000	960000.00
3. CP Bib Cock*	165	768	126710.00
4. CP Sink cock*	4	1034	4136.00
5. Shower head*	65	760	49400.00
		Total=	14,99,371.00

*The prices of the cp bib cock & sink cock include the aerator price (210 tk)
**Price of the Sensor based CP Pillar Cock was taken from https://www.alibaba.com/showroom/bangladesh-faucet.html

3.3 Analysis of Water Use by Old Fixtures

Table 3.6: Amount of water used by old fixtures in a year

Fixture	Total No. Fixtures	No. of Uses/ day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	3.5	5250	
2. English Com.	5	4	5	100	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		5,09,13,850
3. Pillar Cock	120	240	3	86400	
4. Bib Cock	165	66	3	32670	
5. Sink Cock	4	300	4.5	5400	
6. Shower Head	65	60	2.5	9750	

Table 3.7: Amount of water used by fixtures in Alternative-1 (includes Aerator based faucet)

Fixture	Total No. Fixtures	No. of Uses/ day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	1.28	1920	
2. English Com.	5	4	1.28	25.6	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		
3. Pillar Cock	120	240	1.5	43200	2,63,82,419
4. Bib Cock	165	66	1.5	16335	
5. Sink Cock	4	300	2.5	3000	
6. Shower Head	65	60	2.0	7800	

3.4 COMPARISON OF INSTALLMENT COST &WATER USE AT FIRST YEAR (ALTERNATIVE-1) (INCLUDES AERATOR BASED FAUCET)

Table 3.8: Instalment cost and water use after first year for Alternative-1

Fixture Type	Instalment cost (Taka)	Water use (gpy)
Conventional	3,52,154	5,09,13,850
WEPF	6,48,564	2,63,82,419
Difference=	2,96,410 Taka*	24531431 gpy*

[*Note: Extra cost for WEPF is 2,96,410 Taka and water saved after first year is 24531431 gallons.]

According to WASA cost of 1000 liters = 10 Taka.
Therefore, cost replaced by water saving after first year = 9,29,220 Taka

3.5 Economic Analysis for 50 Years (Old Fixtures)

Installment Cost at first year = 3,52,154tk
For Toilets = 1,29,520tk
Future worth after 50 years = 4,56,13,374tk (Includes two time changes at 20th year And 40th year.)
For Others = 2,22,634tk
Future worth after 50 years = 13,06,75,958tk (Includes four time changes at 10th, 20th, 30th & 40th year.)
Therefore, total future worth after 50 years = 17,62,89,332 Taka

3.6 Economic Analysis for 50 Years (Alternative-1) (Includes Aerator Based Faucet)

Installment Cost at first year = 6,48,564tk
For Toilets = 3,59,125tk
Future worth after 50 years = 12,64,79,362tk
For Others= 2,89,440tk
Future worth after 50 years = 16,98,87,986tk
Therefore, net future worth after 50 years= 29,63,61,948tk

3.7 Cost Comparison Between Both for 50 Years (Alternative-1) (Includes Aerator Based Faucet)

Extra cost of instalments after 50 years = (296361948 -176289332) = 120072616 tk
Extra cost of installments after 50 years (in present worth) = 1022844 tk
Water saving after 50 year is (24531431*50) = 1226571550 gallons which is equivalent to 5454526514 tk.
This value of water in present worth is approximately 46464660 tk.
[Note: According to WASA, price of 264 gallons is 10tk which worths 1174tk after 50 years. (i=10%)]

3.8 Analysis of Water Use by Alternative-2 (includes sensor based faucet)

Table 3.9: Amount of water used by fixtures in Alternative-2

Fixture	Total No. Fixtures	No. Of Uses/ Day	Consumption Rate (gpf)	Water Uses (gal/day)	Total Water Use (gal/year)
1. Long Pan FT	60	25	1.28	1920	2,00,75,219
2. English Com.	5	4	1.28	25.6	
Fixture		Using Time/day (min)	Consumption Rate (gpm)		
3. Pillar Cock	120	144	1.5	25920	
4. Bib Cock	165	66	1.5	16335	
5. Sink Cock	4	300	2.5	3000	
6. Shower Head	65	60	2.0	7800	

By following the previous steps, we can compare calculations with the Conventional Type Fixture and can estimate the cost replaced by water saving after first year = 11,68,130 Taka

3.9 Economic Analysis 50 Years (Alternative-2) (Includes Sensor Based Faucet)

Installment Cost at first year = 1499371 tk
For Toilets = 3,59,125tk
Future worth after 50 years =12,64,79,362tk
For Others= 11,40,246 tk
Future worth after 50 years = 66,92,74,541tk
Therefore, net future worth after 50 years= 79,57,48,503 tk

3.10 Economic Analysis Between Both (Alternative-2) (Includes Sensor Based Faucet)

Extra cost of installments after 50 years = (795748503-176289332) = 61,94,59,171tk
Extra cost of installments after 50 years (in present worth) = 52,76,894tk
Water saving after 50 years is (30838631*50) = 1541931550 gallons which is equivalent to 6856922878tk bill.
This water bill in present worth is approximately 5,84,11,050 tk.
[*Note: According to WASA, price of 264 gallons is 10tk which worth 1174tk after 50 years. (i=10%)]

4. CONCLUSIONS

Based on the analysis the following conclusions have been drawn:

1. From the water consumption analysis water efficient fixtures with alternate-1 (including aerator based faucet) saves 48% water yearly by the adopted fixtures.
2. In the alternate-2 (including sensor based faucets) it saves more than 60% without hampering its performance and user's comfort.
3. From the economic analysis both the alternates become feasible amazingly from 50 years cost analysis.
4. Alternative-1 requires less initial cost, less replacements and maintenance is easier than the other alternative. It is most suited for public and institutional buildings where the fixtures will be roughly used.
5. Alternative-2 looks a bit costly at first but it gives more returns than expected both economically and from the view of water saving.
6. Though the analysis was for 50 years but it is quite clear that the economic returns will increase greatly with the increase in the lifetime of the building.

REFERENCES

AzharulHaq, & Khondaker. (2006). *Water Management in Dhaka.*

Bernardo, D. J., Mapp, H. P., Sabbagh, G. J., Geleta, S., Watkins, K. B., Elliott, R. L., & Stone, J. F. (1993). *Economic and environmental impacts of water quality protection policies.* Water Resources Research, 29(9), (3069-3080)

Crotta, C. (2015). *House contributor, ways to save water at home.*

Devex. (2012). *Developing a Green Building Code (GBC) to Mandate Improvements in Energy and Water Usage in Bangladesh World Bank.*

Mahmud F. (2011). *Green Buildings- that's the watchword.*

GC Wedding, D. C. (2007). Journal of Environmental Management.

Jones, W. (2008). *Australia's greenest office building.*

Kenny. (2005). *Estimated use of water in the United States.*

Mon, M. (2012). *Global Water Consumption.*

Murray, J. (2018). *White Sustainable Build.*

Natverlal, A. (2011). *"Interview with Sanwar a Sunny: Green Building Council".* The Daily Star.

Populations, W. (2017). *United Nations Population Estimation.*

Rahman, S. (2011). *Green Buildings.* Jugantor.

RG-Evan. (2008). *Methods and technologies to improve efficiency of water use.*

Sexton, Ken & Linder, Stephen H. (2010). *The Role of Cumulative risk Assessment in Decisions about Environmental Justice.* Int. J. Environ. Res. Public Health 2010, 7, 4037-4049.

U.S. Environmental Protection Agency (EPA). Washington, D.C. *"Using Water Efficiently: Ideas for Communities."* March 28, 2008.

Vickers, & Amy. (2002). *Water Use and Conservation.*

Vickers, Amy. *Water Use and Conservation* Amherst, MA Waterplow Press. June 2002.

Water Preservation in Rural India http://iharnews.com/index.php/government/231-haryana-rural-water-policy-2012.

Wadud Mushfique. (2011). *Dhaka turns to rainwater harvesting tp ease water crisis.*

Zafar, S. (2017). *Features of green building.*

REMOVAL OF NUTRIENTS FROM WASTEWATER EFFLUENT BY THE CULTIVATION OF MICROALGAE IN PHOTOBIOREACTOR (PBR)

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ABSTRACT

Good water quality is vital and essential for human health, social and economical development and additionally also for the ecosystem. As populations develop and natural environments become decrease, ensuring there are enough and secure water elements for everyone is becoming increasingly more challenging. For the safety of water, wastewater needs to be treated before further uses. If these untreated wastewater having nutrients is discharged directly into the natural water bodies, it will cause eutrophication ultimately contaminate the water. For mitigating nutrients, wastewater needs tertiary treatment. In that case, the cultivation of microalgae will be an effective solution as microalgae are capable to assimilate inorganic nitrogen and phosphorus for their growth. Moreover, the production of microalgae biomass is considered as a third-generation renewable resource for bioenergy production. In this study, a photobioreactor (PBR) was designed using a transparent jar for producing microalgal biomass. Transparent jar is more effective and has more capability for receiving sunlight which helps to generate more microalgal growth. The reactor was seeded with Chlorella vulgaris.

After analyzing the data, it is found that the microalgae biomass has the capacity of removing nutrients from the wastewater effluents. The percentage of nitrogen removal is 84% in the form of nitrate and nitrite. The highest rate of phosphate removal was measured at day-5 which is about 97.6%. The efficient growth of microalgae cultivation was found in day-5 in proper sunlight conditions and by using CO2 through photosynthesis, while using wastewater effluent as a nutrient source.

Keywords: *Microalgae, Photobioreactor, Microalgal growth, Cultivation, Nutrients.*

1. INTRODUCTION

In the present world, good water quality is vital and essential for human health, social and economic development and additionally also for the ecosystem. As populations develop and natural environments become decrease, ensuring there are enough and secure water elements for everyone is becoming increasingly more challenging. In the last decades, big mounts of wastewaters have been produced, particularly because of anthropogenic activities, inclusive of agricultural practices, urbanization and industrialization (Aslan & Kapdan, 2006; Rawat, Kumar, Mutanda, & Bux, 2011). The continues disposal of waste waters without necessary treatment can pose extreme pollution. One of the major problems related to the non-stop discharge of effluents into water bodies is eutrophication phenomenon that is the enrichment of water sources in nutrients, specially enrichment with nitrogen and phosphorus.

Although primary and secondary wastewater treatment approaches easily mitigate settle particulate matters, and oxidize organic substances but cannot get rid of nutrients from wastewater. For mitigating nutrients, wastewater desires tertiary treatment. In that case, the cultivation of microalgae could be an effective tertiary biotreatment for wastewater because of microalgae are able to uptaking inorganic nitrogen and phosphorus for their growth. Microalgae have been at the focus of attention in current years as an alternative system for organic wastewater treatment with several applications in wastewater treatment (Kaya & Picard, 1996; Tredici et al., 1992).

Microalgae are photosynthetic organisms that assimilate nitrogen (N) and phosphorus (P) during their growth. They provide a manner for contaminants elimination (nitrogen, phosphorous and carbon) from wastewater while producing biomass that could locate use for the manufacturing of high-value chemicals (algae metabolites) and biogas through anaerobic digestion (Muñoz & Guieysse, 2006). It can also diminish the dangerous outcomes of sewage effluents and reduce eutrophication in good enough environments (Abdel-Raouf, Al-Homaidan, & Ibraheem, 2012). Wang et al. reported a decrease in nitrogen (83% N as NH_4^+) and phosphorous (90% P as PO_4^{3-}) in municipal wastewater by way of *Chlorella sp.*(Wang, Kuo-Dahab, Dolan, & Park, 2014). The main advantages of using microalgae as a source of biomass for biodiesel production are: excessive growth rates and short generation times, minimal land requirements, excessive lipid content, use of wastewater stream as nutrient fed with no need for chemicals. The resulting biomass can be used for the production of bioenergy, food, animal feed and prescription drugs and additionally an oxygenated effluent is discharged into water bodies (Aslan & Kapdan, 2006; Rawat et al., 2011) .

There are in particular two most important commercial cultivation systems for microalgae. One is open raceway ponds and some other is closed photobioreactors (Chinnasamy, Bhatnagar, Hunt, & Das, 2010; Chisti, 2007; Muñoz & Guieysse, 2006) . Light is one of the most vital parameters for the cultivation of microalgae and in this regard photobioreactor (PBR) has a top notch influence. Because, PBR use sunlight as a light source that may be effortlessly utilized in microalgae cultivation.

The important purpose of this study is to identify the best conditions for higher microalgae cultivation growth, suitable environments and removal performance of nutrients from wastewater effluent. The efficient growth of microalgae cultivation is mostly preferable at daylight conditions and by using the usage of CO_2 through photosynthesis.

2. METHODOLOGY

2.1 PBR Configuration

The PBR was constructed using locally available transparent water bottle having a capacity of 8000 cc. The transparent jar used for the cultivation of microalgae because of good capability of receiving sunlight. The schematic of the PBR system is shown in figure-1. The PBR system was setup in open space where sunlight can be easily absorbed by microbial culture. An air pump was installed to supply CO_2 in PBR during cultivation period as sunlight, water, nutrients and CO_2 are the primary requirements for microalgal growth. The system was operated by a timer, which was running for 10 min/hr during the 8 days of cultivation periods. The PBRs system were only run at day time during sunlight.

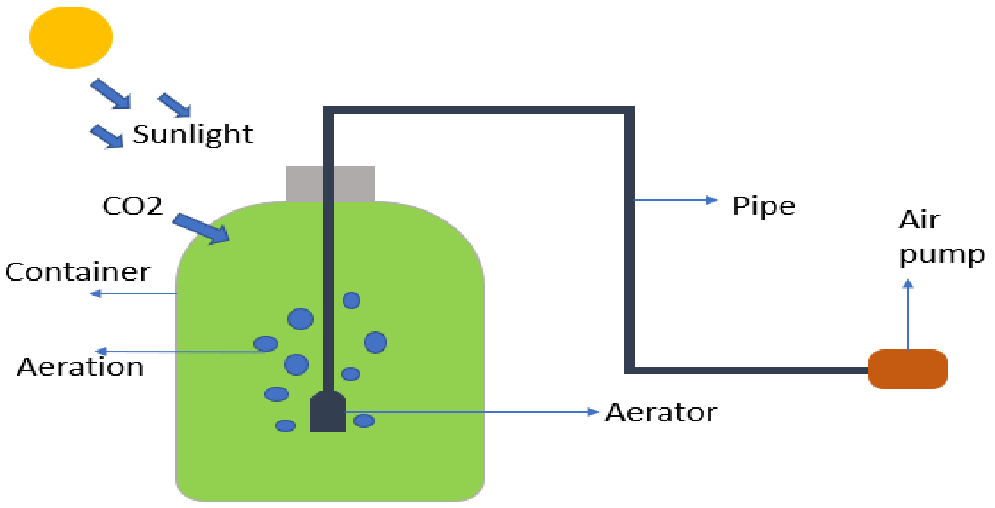


Figure 1: Experimental setup of the PBR system

2.2 Microalgae Cultivation

For the cultivation of microalgae, wastewater effluent was used as nutrients source. The seeds of *Chlorella vulgaris* were poured into the PBR with amount of 20 ml. *Chlorella vulgaris* was seeded due to good tolerance in saline water as the research (Khulna) is located near the coastal zone with high salinity. Moreover, many researchers have been reported that *chlorella vulgaris* have high lipid content.

Figure 2 : Cultivation of microalgae in PBR during experiment.

3. ANALYTICAL PROCEDURES

3.1. Sampling and Nutrients Analysis

A volume of 10 mL microalgae suspension was collected every day from each PBR for nutrient removal analysis starting from inoculation. Then, the samples were appropriately diluted and analyzed for COD, P^H, DO, ORP, Turbidity, NO_2^-, NO_3^-, NH_3^-, PO_4^- by the Spectrophotometer.
(Hach, 2008) The percentage of removal was obtained using the following expression:

$$Percentage\ removal\ W\% = 100\% *(C_o - C_i)/C_o \quad (1)$$

Where, C_o and C_i are defined as the mean values of nutrient concentration at initial time t_0 and time t_i, respectively.

3.2. Determination of Microalgae Growth

A correlation between the optical density(od) of *Chlorella sp.* at 680 nm and the dried biomass was pre-determined. od_{680} was measured every day using spectrophotometer (Jingke 722N, Shanghai, China). The correlation is shown below:

$$Dry\ weight\ (mg/L) = 3.387 * od_{680}; \qquad R^2=0.9913 \quad (2)$$

The specific growth rate y in the exponential phase of algal growth was measured by using following equation (Issarapayup, Powtongsook, & Pavasant, 2009):

$$y\ (day^{-1}) = ln(N_2/N_1)/(t_2 - t_1) \quad (3)$$

Where, N_1 and N_2 are defined as dry biomass (mg/L) at time t_1 and t_2, respectively. The biomass productivity (P) was calculated according to the following formula:

$$P = (DW_i - DW_0)/(t_i - t_0) \quad (4)$$

Where, DW_i and DW_0 are dry biomass (mg/L) at time t_i and t_0 (initial time), respectively.

4. RESULT AND DISCUSSION

4.1. Wastewater Characteristics

Some parameters wastewater effluent like P^H, DO, ORP, Turbidity, NO_2^-, NO_3^-, PO_4^-, COD were measured before microalgae cultivation which is summarized in table-1.

Table 1: Characteristics of wastewater effluent

Parameters	Units	Value
P^H	-	8.08
DO	mg/l	5.0
ORP	mV	88
Turbidity	NTU	19
NO_2^-	mg/l	0.012
NO_3^-	mg/l	0.2
NH_3^-	mg/l	25.2
PO_4^-	mg/l	7.2
COD	mg/l	20

After pouring the seeds of *chlorella vulgaris* into the PBR system the system was running for consecutive 8 days. For the analysis of nutrients removal performance and calculation of microalgal growth the others parameters (such as P^H, DO, ORP, Turbidity, NO_2^-, NO_3^-, PO_4^-, COD and algae concentration) were observed every day during the cultivation periods, which is summarized in table-2.

Table 2: Monitoring parameters during the cultivation periods

Parameters	**Units**	**Day-1**	**Day-2**	**Day-3**	**Day-4**	**Day-5**	**Day-6**	**Day-7**	**Day-8**
P^H	-	8.08	8.47	8.59	9.57	10.0	10.22	10.3	9.96
DO	mg/l	5.0	7.2	8.1	8.3	6.8	8.0	8.6	7.4
ORP	Mv	88	214	219	111	119	98	91	93
Turbidity	NTU	19	16.2	10.3	27.8	57.8	18.6	10.8	10.8
NO_2^-	mg/l	0.012	0.014	0.037	0.048	0.014	0.023	0.031	0.022
NO_3^-	mg/l	0.2	0.4	0.2	0.022	0.2	.04	0.4	0.1
NH_3^-	mg/l	25.2	24.6	20.1	15.4	14.84	11.48	8.6	4.91
PO_4^-	mg/l	7.2	0.3	0.3	0.51	0.17	0.17	0.17	0.16
COD	mg/l	20	131.7	124.4	117.12	224.48	114.68	102.5	12.2
Algae Conc.	mg/l	0.135	0.112	0.152	0.586	0.758	0.285	0.132	0.179

4.2. Microalgal Biomass and Growth Rate

The concentration of micralgal biomass is converted into weight from optical density by equation-2. From the experimental data which is showen in table-2, the maximum growth of microalgae is found out at day-5 and the amount is about 0.758 mg/l . In Fig-3, at first microalgal biomass is increased with time. But after day-5, the microalgal biomass growth started to reduce.

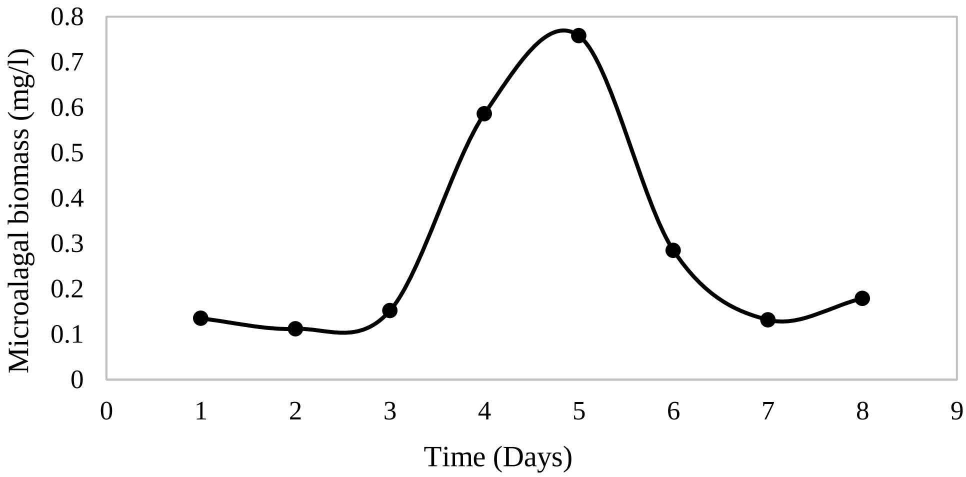


Figure 3: Microalgal biomass (mg/l) vs Time (Days) Graph.

Because , after day-5 the microalgae started to settle into the water bodies. As a result, the concentration of microalge started to reduce. The mean growth rate is found after day-8 is about 0.0353 mg/l using the equation-3. The mean biomass productivity of the PBR system is about 0.0409 mg/l using the equation-4.

4.3. Percentage of Phosphate Removal

Microalgae also removes the nutrients from the wastewater. Microalgal biomass use these nutrients as like the nutrients source for the photosyenthesis process. The mean removal percentage of phosphate is about 96.5%. The highest phosphate removed at day-5 which is around 97.6% because of the highest microalgae biomass. It has been found that , at day-5 microalgae biomasss grew the most. As a result, more phosphate used for microalgal growth which increases the removal percentage of phosphate.

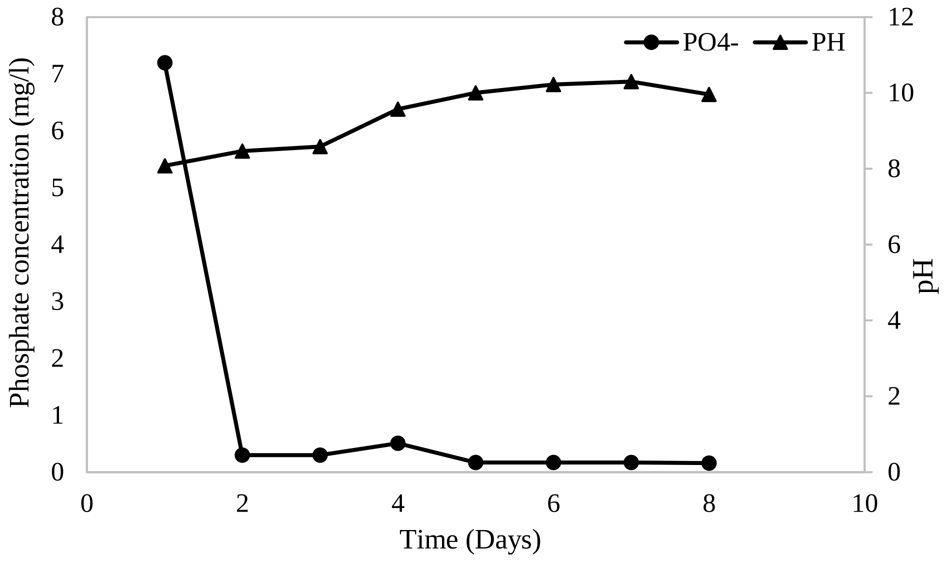


Figure 4: Relation between pH and Phosphate (mg/l).

Fig-4, showing the variation of pH and Phosphate concentration with the variation of time. For pH values above 8.0 and high oxygen concentrations, phosphorus precipitation may occur (Su, Mennerich, & Urban, 2012; Wang et al., 2014). From the Fig-4, it can be seen that, when the pH is larger than 8 the phosphate decreased. When the microalgae is most in the wastewater the phosphate found around 0.17 mg/l only (table-2). Because, most of the phosphate used in photosynthesis process for producing ATP and precipitated in waterbodies

4.4. Percentage of Nitrogen Removal

Microalgae also removed nitrogen from the wastewater. The mean removal percentage of nitrogen is about 84%. Most of the nitrogen moves when the microalgae grew most which is at day-5. The main reason for this is also the highest microalgal biomass growth at day-5.

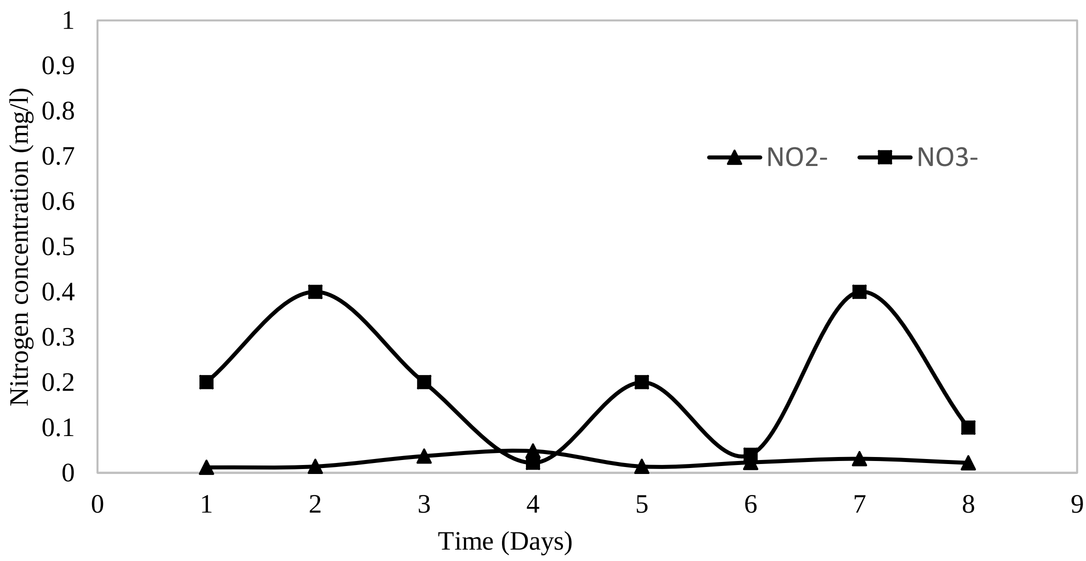


Figure 5: Nitrogen concentration (mg/l) Vs Time (Days) Graph.

Fig-5 shows that, the concentration of the NO_2^- and NO_3^- in wastewater. Microalgae biomass growth has less effect on nitrate (NO_2^-) whereas it has a great influence on nitrite (NO_3^-). Most of the nitrite removes at day-4 and day-6 when the wastewater has a large number of microalgae. After that, the nitrite increase because of the settlement on microalgae. Fig-6 shows that, the ammonia removes with the increase of microalgal biomass and time. The average ammonia removal is about 70% and removes about 18% of nitrogen from wastewater.

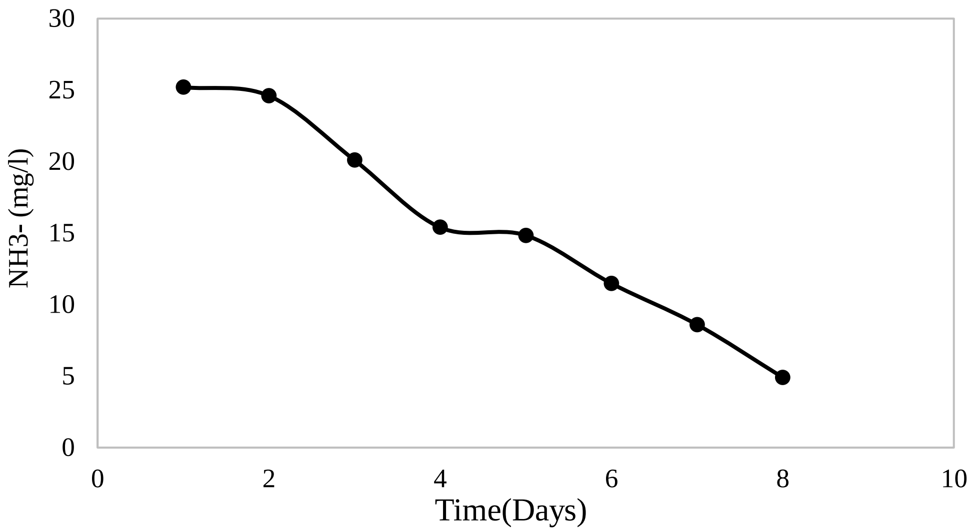
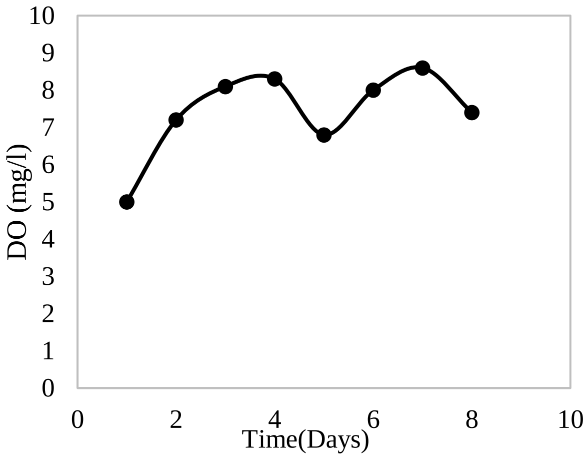


Figure-6: Ammonia removal (mg/l) vs Time (Days) Graph.

4.5. DO and ORP Variation

DO (Dissolved Oxygen) and ORP (oxidation reduction potential) also varies with the amount of microalgae present in wastewater. In Fig-7, the DO is increased with time of microalgae cultivation. The DO increase because of the microalgal biomass. Microalgae produce oxygen by photosynthesis process using carbon dioxide from air. But DO reduced at day-5 because of starting the settlement of microalgae. ORP also varies with microalgal biomass which produces oxygen in water by photosynthesis process (Fig-8).



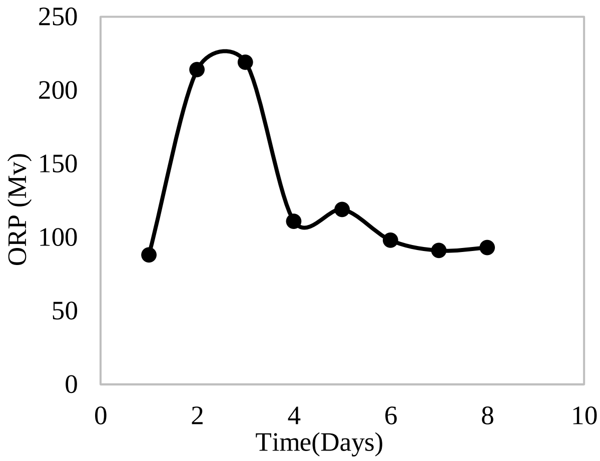


Figure-7: DO (mg/l) vs Time (Days) Graph.

Figure-8: ORP (Mv) vs Time (Days) Graph.

4.6. Turbidity

The turbidity of wastewater effluents varies with the increase of microalgae biomass. In Fig-9, the turbidity of wastewater increases most when the wastewater has the most microalgal biomass in the water which is at day-5. The turbidity is increased about 46% at day-5 comparing with Day-1.

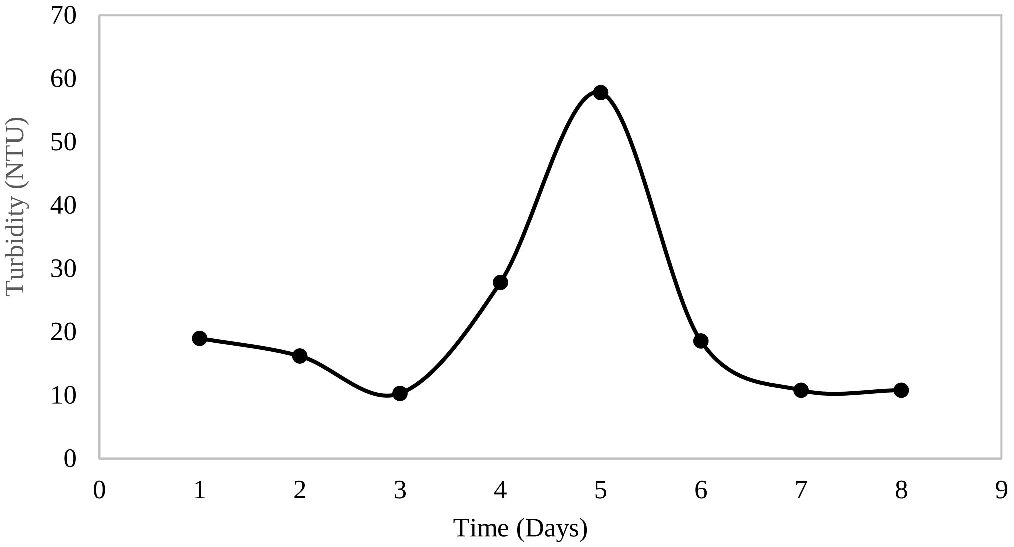


Figure-9: Turbidity (NTU) vs Time (Days) Graph.

4.7. COD Variation

The chemical oxygen demand (COD) also varies with time and the presence of microalgal biomass in wastewater. In Fig-10, COD increased with time when the microalgal biomass increasing. But after day-5, when the microalgae started to settle down the values of COD also started to decrease.

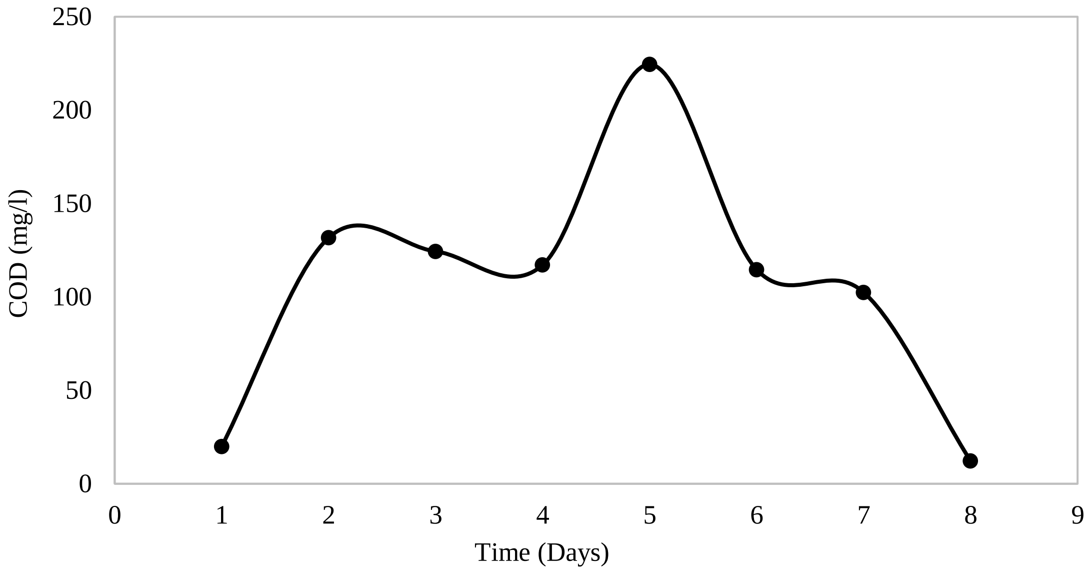


Figure-10: Chemical Oxygen Demand (COD) (mg/l) vs Time (Days) Graph.

5. CONCLUSIONS

In this paper, the proportion of dissolved nitrogen and phosphate removal, microalgal growth rate and productiveness had been studied. A clear information of anaerobic system mechanisms is required with the intention to improve PBR performances in terms of biomass productiveness and wastewater treatment. The percentage of nitrogen removal is 84% in the form of nitrate and nitrite. Ammonia stripping seems one of the mechanisms liable for nitrogen elimination, contributing to as a minimum 18% of N-removal. Nitrification changed into also a pathway for ammonium transformation in our experimental system. Around 96% of phosphate ions have been removed from the wastewater after 8 days. The highest rate of phosphate removal was measured at day-5 which is about 97.6%. The values of DO, ORP, Turbidity also vary with time, microalgal presence and concentration in wastewater effluents. As a conclusion, microalgal treatment of wastewater, via tertiary wastewater treatment mechanisms, may want to constitute an attractive addition to current biological treatments used to purify wastewaters. The advantages of the use of microalgae as a source of biomass for biodiesel production, excessive growth rates and quick generation times, minimum land requirements, excessive lipid content, use of wastewater stream as nutrient fed with no need for chemicals. The resulting biomass may be used for the production of bioenergy, food, animal feed and pharmaceuticals and also an oxygenated effluent which can discharge into water bodies.

REFERENCES

Abdel-Raouf, N., Al-Homaidan, A. A., & Ibraheem, I. B. M. (2012). Microalgae and wastewater treatment. *Saudi Journal of Biological Sciences*, *19*(3), 257–275. https://doi.org/10.1016/j.sjbs.2012.04.005

Aslan, S., & Kapdan, I. K. (2006). Batch kinetics of nitrogen and phosphorus removal from synthetic wastewater by algae. *Ecological Engineering*, *28*(1), 64–70. https://doi.org/10.1016/j.ecoleng.2006.04.003

Chinnasamy, S., Bhatnagar, A., Hunt, R. W., & Das, K. C. (2010). Microalgae cultivation in a wastewater dominated by carpet mill effluents for biofuel applications. *Bioresource Technology*, *101*(9), 3097–3105. https://doi.org/10.1016/j.biortech.2009.12.026

Chisti, Y. (2007). Biodiesel from microalgae. *Biotechnology Advances*, *25*(3), 294–306. https://doi.org/10.1016/j.biotechadv.2007.02.001

Issarapayup, K., Powtongsook, S., & Pavasant, P. (2009). Flat panel airlift photobioreactors for cultivation of vegetative cells of microalga Haematococcus pluvialis. *Journal of Biotechnology*, *142*(3), 227–232. https://doi.org/10.1016/j.jbiotec.2009.04.014

Kaya, V. M., & Picard, G. (1996). Stability of chitosan gel as entrapment matrix of viable Scenedesmus bicellularis cells immobilized on screens for tertiary treatment of wastewater. *Bioresource Technology*, *56*(2), 147–155. https://doi.org/10.1016/0960-8524(96)00013-2

Muñoz, R., & Guieysse, B. (2006). Algal–bacterial processes for the treatment of hazardous contaminants: A review. *Water Research*, *40*(15), 2799–2815. https://doi.org/10.1016/j.watres.2006.06.011

Rawat, I., Kumar, R. R., Mutanda, T., & Bux, F. (2011). Dual role of microalgae: Phycoremediation of domestic wastewater and biomass production for sustainable biofuels production. *Applied Energy*, *88*(10), 3411–3424.

Su, Y., Mennerich, A., & Urban, B. (2012). Synergistic cooperation between wastewater-born algae and activated sludge for wastewater treatment: Influence of algae and sludge inoculation ratios. *Bioresource Technology*, *105*, 67–73. https://doi.org/10.1016/j.biortech.2011.11.113

Tredici, M. R., Margheri, M. C., Zittelli, G. C., Biagiolini, S., Capolino, E., & Natali, M. (1992). Nitrogen and phosphorus reclamation from municipal wastewater through an artificial food-chain system. *Bioresource Technology*, *42*(3), 247–253. https://doi.org/10.1016/0960-8524(92)90028-V

Wang, M., Kuo-Dahab, W. C., Dolan, S., & Park, C. (2014). Kinetics of nutrient removal and expression of extracellular polymeric substances of the microalgae, Chlorella sp. And Micractinium sp., in wastewater treatment. *Bioresource Technology*, *154*, 131–137. https://doi.org/10.1016/j.biortech.2013.12.047.

RECOVERY OF MICROALGAL BIOMASS USING MORINGA OLEIFERA AS A LOW-COST BIOCOAGULANT

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ABSTRACT

This study reveals the influence of some physical and chemical parameters in the recovary process of microalgal biomass by coagulation and flocculation process using a natural coagulant, Moringa Oleifera (locally known as shojne in Bangladesh). It is locally available, cheap, non-toxic, and environmentally friendly. Moringa oleifera seeds were used as coagulant to remove microalgae cultured in photobioreactor (PBR). Jar-test has been carried out in order to evaluate the efficiency of this natural coagulant agent. The variables studied in this test were coagulant dose, mixing time and mixing rate. The dose was varied from 10 mg/L to 70 mg/L. It was observed that higher dose of moringa resulted in higher removal of microalgae. Mixing rate and mixing time also had significant impact on treatment. Low mixing rate and time gave more acceptable results. Highest 83% of microalgae was removed using 70mg/l of coagulant dose mixed at a rate of 20 rpm for 10 minutes. The optimum dose for Moringa Oliefera seeds as a coagulant was also determined.

Keywords: *Microalgae, Moringa oleifera, Coagulation, Recovery rate, Optimum dose.*

1. INTRODUCTION

Water is an unevenly distributed essential natural resource on our planet. Only 2.5% of global supplies of water is freshwater. From this amount, less than 1%, is easily accessible to the various uses for development (Yéwêgnon et al., 2016). Natural waterbodies like lakes and reservoirs & other surface water sources get affected by the eutrophication phenomenon frequently which, according to the definition of the Organisation for Economic Co-operation and Development (OECD), is an enrichment of nutrients in the water which leads generally to symptomatic changes such as increased algae production and other aquatic plants, degradation of fisheries and deterioration of water quality in general (Barrado-Moreno et al., 2016).

It is well known that microalgae have a huge potential for wastewater treatment as well as bioenergy (e.g. biofuel) production. Concerning environmental ones, microalgae can play an important role in bioremediation of wastewater and carbon dioxide sequestration. Furthermore, these photosynthetic microorganisms have been considered as a potential renewable energy source. Although microalgae have a huge application opportunity but the production is still not economically viable due to the difficulties of the separation process.

Mostly common used separation methods are filtration and centrifugation. For large microalgal cells, such as *Arthrospira sp.*(Papazi et al., 2010), filtration is effective. But for cells of smaller dimensions, it is not at all suitable. Again, by centrifugation, the separation of the microalgae can be done independent of size, although this process requirs high gravitational force by which cell structure can be damaged. A huge amount of energy is required in this method (Benemann and Oswald, 1996) which makes the process more costly (Knuckey et al., 2006). Moreover, the process is not very environmentally friendly (Walsby, 1995). Again, for wastewater treatment, usage of coagulants/flocculants is worldwide. A negative surface charge is always carried by the particles if the pH of water is around 5–9. As a result, the particles are colloidally stable and show resistant to aggregation. By adsorbing counter ions these particles are destabalized. Coagulent may be used for this purposes. Biological flocculants can be used as coagulents. They can interect with contaminents as they have bio macromolecular structures (Sharma et al., 2006). Hence, the use of natural coagulant would be an alternative solution. In this situation, *Moringa Oleifera* (locally known as shojne in Bangladesh) is a natural coagulant which can be used instead of chemical coagulants. Moreover, it is locally available, cheap, non-toxic, and environmentally friendly (Keogh et al., 2017).

The main objective of this reasearch is to analyze the efficieny of moringa oleifera as a naturant coagulant. Three basic parameters were choosen- coagulant dose, mixing rate & mixing time. By variation of this parameters in different condition, the influence of this parameters were observed. The optimum dose was also determined on the basis of highest recovary rate and efficiency of the system.

2. METHODOLOGY

The research method was mainly of three parts- 1) Microalgae culltivation & preparation of coagulant, 2) mixing the microalgae suspension & coagulant in jar test apparatus & 3) study the obtained result. The overall research methodology is presented in Figure 1 as a flowchart.

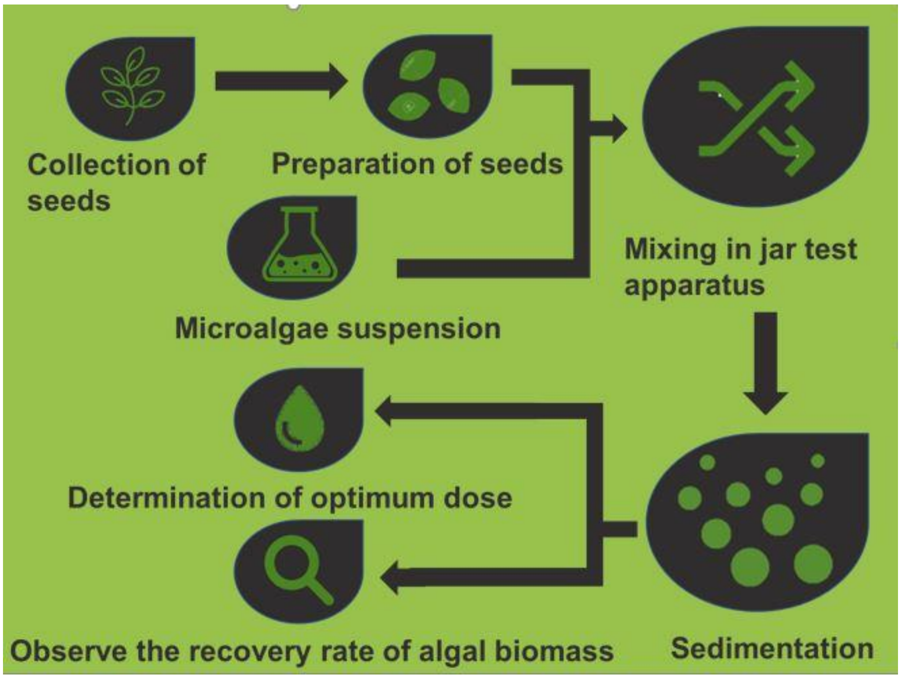

Figure 1: Research Methodology applied for using Moringa Oleifera as biocoagulant

2.1 Microalgae Cultivation

A photobioreactor (PBR) was used to produce microalgal biomass. It was constructed using locally available clear water container having capacity of 8L. For being transperant, it recieves more sunlight, which improves the microalgal growth. The reactor was seeded with Chlorella vulgaris as it has good tolerance in saline water. Moreover, the research area (Khulna) is located in costal zone with high salinity. An air pump was installed to supply CO2 in PBR for microalgae growth. The system was operated by a timer, which was programmed at 10 min/hr (at day) during the 8 day of cultivation period.

Figure 2 (a): Microalgae cultivation in photobioreactor (PBR)

2.2 Preparation of Coagulant

Moringa oleifera was collected from locally available trees. The seeds were separated and dried in natural sunlight for 3 days. After careful removal of seed coats and seed wings, the white kernels were reduced to powdered by a mechanical grinder. Then the powder were sequentially sieved through No #300 sieve in order to obtain the seed flour.

2.3 Jar Test

The experiment was carried out in nine batches, each batch containing five jars of microalgae suspension. the concentration of coagulant were 10, 25, 40, 55 & 70 mg/l in each batch. The suspension was mixed for three different time sets 10, 30, 50 mins in a mixing rate of 20, 60, 100 rpm. The sedimentation time and room temparature was constant, 30 min and 28 degree C respectively.
The microalgae removal efficiency was determined using the following equation:

Algae removal(%)= $[(Co-C_1)/Co]*100$

Where,
Co= Initial algae concentratrion
C_1= Final algae concentratrion

Figure 2 (b): Jar test

3. RESULTS & DISCUSSION

The variation of parameters has the following influence:

3.1 Dose

Coagulant dose was considered an important parameter for such research. From Fig: 1-6 we can see that the recovary rate increased with higher dose. For any mixing time & mixing rpm the rate of microalgae recovary is proportional to the coagulant dose. Which means higher dose of moringa oleifera will recover higher amount of microalgae.

3.2 Mixing Rate

Mixing rate can be an important parameter for an efficient treatment. For 10 mins mixing time (Fig 2), the inreasing rate of mixing had no significant impact on recovery rate. But for 30 & 50 mins mixing time, the removal rate reduced with higher rpm (Fig:3 & Fig:4). 60 & 100 rpm mixing rate resulted in similar resulted for higher mixing time (Fig: 3B, 3C, 4B, 4C). Best results obtained at 10 minutes mixing time at every mixing rate.

A B C

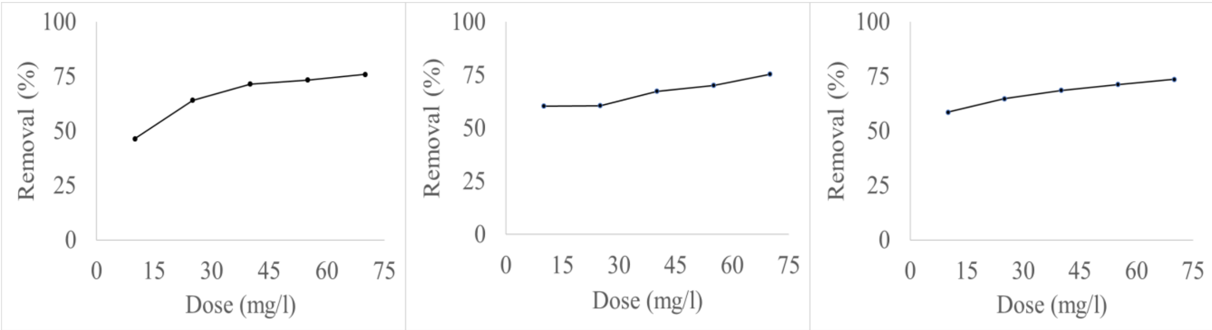

Figure 3: Influence of mixing rate for 10 min mixing time at (A)20rpm (B)60rpm (C)100rpm

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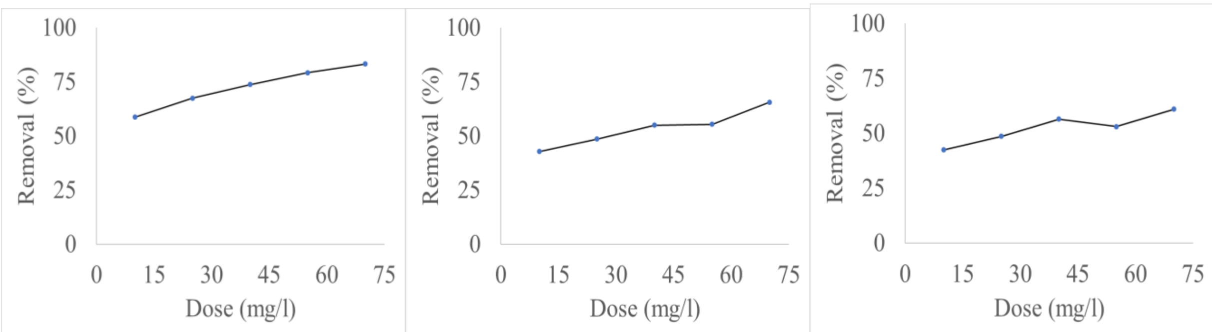

Figure 4: Influence of mixing rate for 30 min mixing time at (A)20rpm (B)60rpm (C)100rpm

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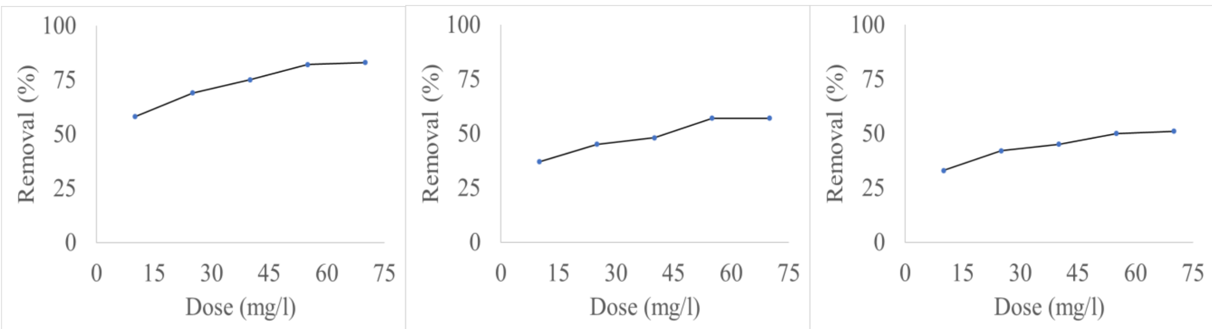

Figure 5: Influence of mixing rate for 30 min mixing time at (A)20rpm (B)60rpm (C)100rpm

3.3 Mixing Time: To evaluate the impact of mixing time, three mixing time was tested for three varyng mixing rate. As shown in the Fig: 4, 5 & 6, higher mixing time does not increase the removal rate. Rather low mixing time shows better results.

A B C

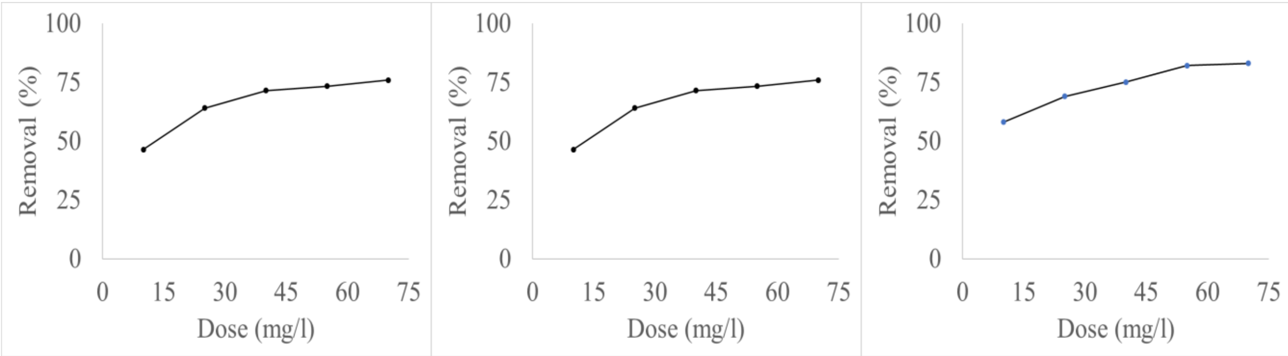

Figure 6: Influence of mixing time for 20 rpm mixing rate at (A)10 minutes (B)30 min (C)50 min

A B C

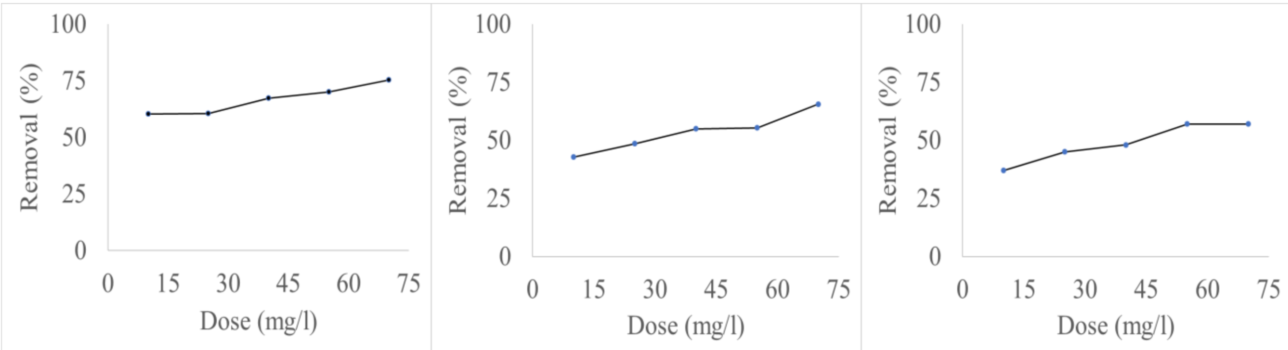

Figure 7: Influence of mixing time for 60 rpm mixing rate at (A)10 minutes (B)30 min (C)50 min

A B C

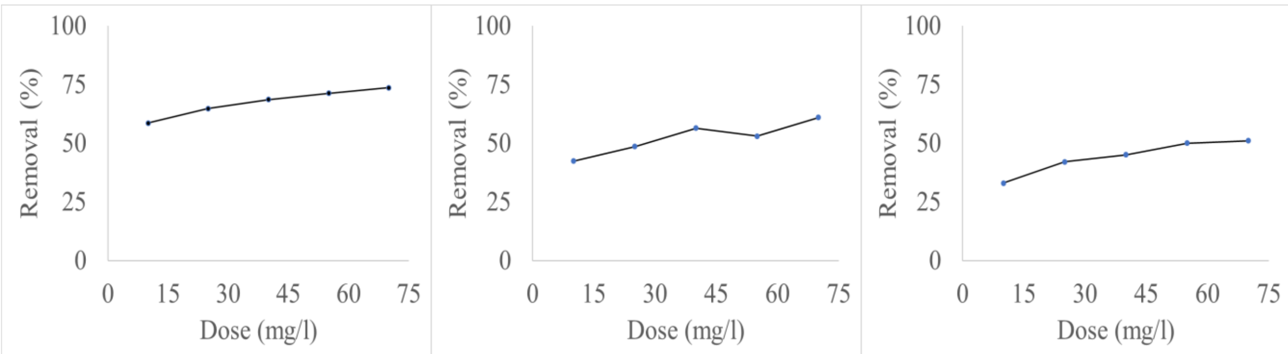

Figure 8: Influence of mixing time for 100 rpm mixing rate at (A)10 minutes (B)30 min (C)50 min

3.4 Optimum Dose

Higher dose of *moringa oleifera* resulted in higher removal rate. Mixing rate has no significant impact if the mixing time is low. But for higher mixing time, the mixing rate should be kept low to reach optimum. If the mixing time is low, any mixing rate can be choosed. But in case of higher mixing time, low mixing rate will give the best results.

4. CONCLUSIONS

The following conclusions were revealed from the present studies:
Coagulant dose has a positive impact on the microalgae removal rate. But higher dose of coagulant results in higher cost. In such circumstances higher mixing rate & lower mixing time can be adopted, where low dose of coagulant gives almost similar result as high ones. Low mixing time & mixing rate always had a positive impact with better economy.

5. REFERENCES

Barrado-Moreno, M.M., Beltran-Heredia, J., Martín-Gallardo, J., 2016. Microalgae removal with Moringa oleifera. Toxicon 110, 68–73. https://doi.org/10.1016/j.toxicon.2015.12.001

Benemann, J.R., Oswald, W.J., 1996. Systems and economic analysis of microalgae ponds for conversion of CO{sub 2} to biomass. Final report (No. DOE/PC/93204-T5). California Univ., Berkeley, CA (United States). Dept. of Civil Engineering. https://doi.org/10.2172/493389

Gassenschmidt, U., Jany, K.D., Bernhard, T., Niebergall, H., 1995. Isolation and characterization of a flocculating protein from Moringa oleifera Lam. Biochim. Biophys. Acta BBA - Gen. Subj. 1243, 477–481. https://doi.org/10.1016/0304-4165(94)00176-X

Jahn, S.A.A., 1988. Using *Moringa* Seeds as Coagulants in Developing Countries. J. - Am. Water Works Assoc. 80, 43–50. https://doi.org/10.1002/j.1551-8833.1988.tb03052.x

Keogh, M.B., Elmusharaf, K., Borde, P., McGuigan, K.G., 2017. Evaluation of the natural coagulant Moringa oleifera as a pretreatment for SODIS in contaminated turbid water. Sol. Energy 158, 448–454. https://doi.org/10.1016/j.solener.2017.10.010

Knuckey, R.M., Brown, M.R., Robert, R., Frampton, D.M.F., 2006. Production of microalgal concentrates by flocculation and their assessment as aquaculture feeds. Aquac. Eng. 35, 300–313. https://doi.org/10.1016/j.aquaeng.2006.04.001

Mendieta-Araica, B., Spörndly, R., Reyes-Sánchez, N., Spörndly, E., 2011. Moringa (Moringa oleifera) leaf meal as a source of protein in locally produced concentrates for dairy cows fed low protein diets in tropical areas. Livest. Sci. 137, 10–17. https://doi.org/10.1016/j.livsci.2010.09.021

Papazi, A., Makridis, P., Divanach, P., 2010. Harvesting Chlorella minutissima using cell coagulants. J. Appl. Phycol. 22, 349–355. https://doi.org/10.1007/s10811-009-9465-2

Rashid, U., Anwar, F., Moser, B.R., Knothe, G., 2008. Moringa oleifera oil: A possible source of biodiesel. Bioresour. Technol. 99, 8175–8179. https://doi.org/10.1016/j.biortech.2008.03.066

Sharma, B.R., Dhuldhoya, N.C., Merchant, U.C., 2006. Flocculants—an Ecofriendly Approach. J. Polym. Environ. 14, 195–202. https://doi.org/10.1007/s10924-006-0011-x

Walsby, A.E., 1995. Microalgae: Biotechnology and Microbiology. By E. W. Becker. Cambridge: Cambridge University Press (1994), pp. 230, £40.00, US$69.95. ISBN 0-521-35020-4. Exp. Agric. 31, 112–112. https://doi.org/10.1017/S0014479700025126

Yéwêgnon, N., Philippe, S., Abdoukarim, A., Abdou, Y., Alassane, K., Agbangnan D., C.P., Daouda, M., Koko, S., Dominique, C., 2016. Evaluation of Aloe vera leaf gel as a Natural Flocculant: Phytochemical Screening and Turbidity removal Trials of water by Coagulation flocculation 4, 1–9.

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HYDROTHERMAL LIQUEFACTION OF MICROALGAE CULTIVATED IN A PHOTOBIOREACTOR USING THE WASTEWATER EFFLUENT FROM AN ANAEROBIC REACTOR

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ABSTRACT

The rapidly increasing demand for energy depletes all fossil fuels available in the earth and searches for new alternative sustainable and renewable sources of energy. Among the different types of renewable sources of energy, microalgae are considered to be one of the potential feedstock for producing biofuels because of their primitive structure, high growth rate, carbon-neutral capacity and also its renewability. Recently, the researchers are focusing on several technologies that are capable of processing wet harvested microalgae to produce bioenergy in an easy way with using less energy and expenditure. Among the technologies, hydrothermal liquefaction (HTL) is one of the most alternative technology which producing liquid energy (biocrude) from wet microalgae by thermochemical conversion, next to gaseous, aqueous and solid by-products. The analysis of temperature parameter is presented here with constant holding time and without any addition of catalysts. The technology traditionally works at moderate temperatures (200^0-374^0C) and high pressures (2-20 MPa) although recent study is done at temperatures (260^0-280^0C) and pressure less than 5 Mpa with a holding time of 60 minutes. Biocrude obtained from a co-culture of microalgae (e.g. *Chlorella vulgaris*, *Chlorella sorokiniana*, *Scenedesmus simris002*) was cultivated in an 8-L photobioreactor using the wastewater effluent from an anaerobic reactor through this conversion process which is then further upgraded to biofuels. Finally, FTIR analysis was done to the biofuels for comparison. The FTIR data shows that the quality of biocrude heated at 280℃ is better than biocrude heated at 260℃.

Keywords: *Microalgae, Hydrothermal liquefaction, Biocrude, Biofuel, FTIR.*

1. INTRODUCTION

Wastewater has become a rising problem in the world which is now facing the third-generation revolution, but this wastewater can be an asset if we utilize it to make a profit as well as environment friendly. Wastewater can be treated in baffled reactor and then made it suitable for microalgae growth with proper aeration and sunlight. Then, the microalgae can be converted into bio-crude using thermochemical conversion (Suali & Sarbatly, 2012). There are mainly four types of thermochemical conversion which are transesterification, steam reforming, pyrolysis and hydrothermal liquefaction (HTL) (Goyal H.B. et al., 2008). Due to microalgae having high mass fraction of water (80%-90%), traditional thermochemical processes like pyrolysis and gasification are economically not very sustainable (Patil et al., 2008). The more sustainable process is the hydrothermal liquefaction whose primary requirement is water. Water in sub-critical state behaves like a catalyst and solvent for the HTL reaction (Patrick et al., 2001). One of the benefits of the process is that wet microalgae could be used in the HTL process where other conversion processes need dry microalgae. Other advantages are that HTL can be operated at moderate temperatures (200-374°C) and pressure (2-20 MPa) where pyrolysis requires higher temperature conditions (400-450°C) (Hu et al., 2018). The HTL is the low-cost process which has operational flexibility and at the same time enhances the capability of getting high yield with critical attributes such as lesser heteroatomic content, formation of low biochar and energy recovery. These are the factors for increased research interest towards it in recent years (Gollakota A.R.K. et al., 2018).

Hydrothermal liquefaction of microalgae is the thermochemical conversion which converts microalgae into high quality biofuels. The reactions occur in a hot environment under high pressure where water acts as a solvent to break down the solid biopolymeric structure to mainly liquid compounds (Toor S.S. et al., 2011). The three major steps of HTL are depolymerization, decomposition, and recombination (Toor S.S. et al., 2011). These reactions occur in the sub-critical state of water having some different characteristics. Water in this state can soluble organic compounds (hydrophobic). The ionic product of water (H^+ and OH^-) are available in the solution for acid and base catalyzed reactions which is in two orders of advanced magnitude (10^{-12} compared to 10^{-14} at 25°C). There are two main reactions in HTL: hydrolysis and recombination (Garcia Alba et al., 2011). In hydrolysis reaction, the decomposition and depolymerization of the microalgae breaks them into small compounds. These small compounds are highly reactive. High pressure and temperature enhances the polymerizing of the small compounds to form bio-crude, gas, and solid compounds (Demirbaş, 2000). With the increase of holding time, the viscosity of bio-crude decreases (Minowa T. et al., 1995). The gaseous fraction like CO_2, H_2, CH_4, N_2, C_2H_4 and C_2H_6 presents a yield of approximately 20% of the original organics existing in the microalgae feedstock (Brown et al., 2010).

Biofuels as a potential substitute for fossil fuels are a promising renewable energy source. Moreover it alleviates environmental complications such as global warming, climate change, etc. (Hill J. et al., 2006). Unlike other sources like solar energy and wind power, biofuels are carbon substances that can directly substitute petroleum products like transportation fuels (Schenk et al., 2008). If biomass were grown for energy to an amount equal to that consumed during any given production period, there would be no net increase of CO_2 in the atmosphere (Gao & McKinley, 1994). At present, biomass has the ability to fulfill 30% of global fuel demand through the conversion process to intermediate solid, liquid or gaseous biofuels without affecting the food production as well as environment. Microalgae are microscopic photosynthetic organisms that can absorb more CO_2 due to its higher photosynthetic efficiency, faster growth rate and higher area-specific yield than terrestrial biomass (Aresta M. et al., 2005). Microalgae needs water, light, carbon source and nutrients to grow and their main constituents are protein, carbohydrates, and lipids. Recently, another fraction named algaenans in the form of long aliphatic chains that is found in the outer cells of microalgae is another source of biofuels (Garcia Alba et al., 2011). The algaenans which are insoluble and non-hydrolysable biomacromolecules, resistant to drastic chemical treatments (Gelin et al., 1999).

Cultivation of microalgae brings along some advantages (Mata T.M., 2010) as they use the nutrients like NH_4^+, NO_3^- or PO_4^{3-} to grow. As wastewater can supply these nutrients, wastewater is suggested to cultivate microalgae and at the same time bioenergy is being produced. As the HABR effluent water holds large amount of nitrogen and phosphorus content, it is suitable for microalgal growth.

During the past decades, microalgal research has been focused mainly on optimization of cultivation methods, but less effort was spent on their processing for biofuels, chemicals or energy production. The main objective of this research is to analyze the quality of biocrude processed in low temperature (260°C and 280°C) and pressure less than 5 Mpa based on FTIR spectrum analysis. The IR analysis shows the chemical compounds present in the biomass, biocrude and biochar. Thus, biocrude quality assessment is done. The conversion process extracts high NO_x emissions, due to the high amounts of nitrogen in chlorophyll and proteins, very abundant in microalgae cells (Costa & De Morais, 2011). Another drawback of this process is that the aqueous phase contains substances toxic to several organisms and it can be classified as a petrochemical refinery wastewater (Appleford et al., 2005). Recent researches detect that several nitrogenous organic compounds were identified. In conclusion, the authors stated that HTL aqueous phase should be treated before discharging it to the environment.

2. METHODOLOGY

2.1 HABR Effluent

The wastewater was accrued from the septic tank. The water was then pumped to the HABR at 121 mL/hr. and the water passed through the baffle chambers to purify the wastewater. The reactor has seven chambers where the last two chambers are filter media. The individual chamber was again divided into two portions by hanging baffles, which separated each chamber in down- and up-flow zone. The ratio between down-flow and up-flow was 1:4, and the lowest portion of the baffle was inclined at 45° (Hasan M. et al., 2018). The water is forced into the reactor using pump for 10 minutes every hour. The water is suitable for microalgae growth as it was observed that the wall of filter media of HABR is covered by greenish color of microalgae. The water will also be used in HTL reactor as water behaves as the solvent for hydrothermal process at temperature 200~300°C. Water, temperature over 200°C and pressure over 2 Mpa, stays in sub-critical state. Normally water doesn't soluble the organic contents but in subcritical state water reacts with organic molecules. Then organic chemical reactions like depolymerization, decomposition, recombination of microalgae take place. Here water causes organic matter to break down and reorganize into fragments that is transformed into hydrocarbons. Thus, water helps to convert directly biomass to biocrude in HTL process. The main reason to use HABR effluent in microalgae cultivation is that the water contains a large amount of nitrogen and phosphorus content which supplies essential nutrients for microalgae growth.

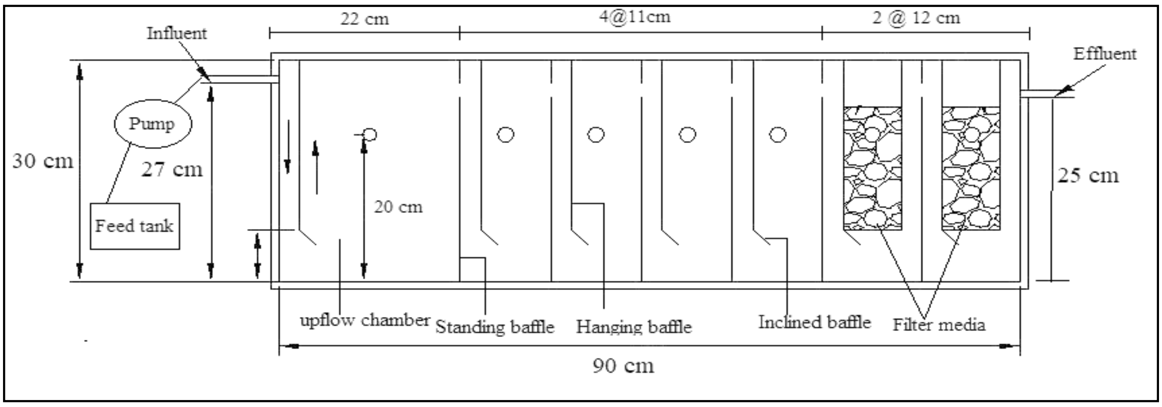

Figure 1: The schematic diagram of HABR

2.2 Microalgae Cultivation

A microalgal co-culture of *Chlorella vulgaris*, *Chlorella sorokiniana*, and *Scenedesmus simris002* (Figure 2) was cultivated in plastic containers (8000cc) and the plastic used was colorless. The containers had HABR effluents where 20ml microalgal co-culture seeds were poured into the container. The aeration was done for 12 hours (10 minutes per hour) per day for 5 days. Then by coagulation and flocculation, the microalgae were separated and collected for HTL process (Figure 2).

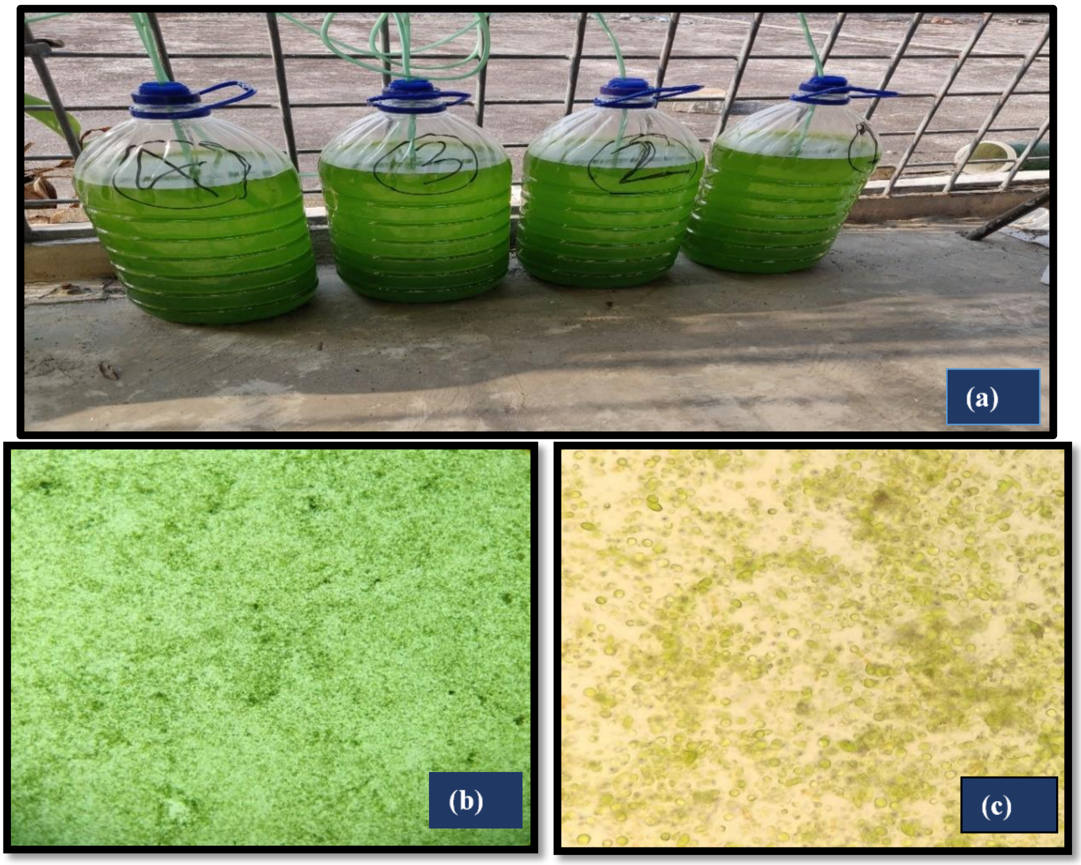

Figure 2 : Microscopic view of microalgae co-culture (a) cultivation (b)10X magnification and (c) 40X magnification

The microalgal co-culture was selected because of its high lipid content, high growth rate and less pollution (Chen et al., 2014). The classification of microalgae was done by matching its shape in the microscope.

2.3 Coagulant, Coagulation, and Flocculation

Recovery of microalgal biomass could be done using low-cost bio-coagulant. There may be chemical coagulants which are used to coagulate microalgae but they are very costly and have adverse health effect. So, the natural coagulant *Moringa oleifera* was used to flocculate the microalgae and let it settle. The main reasons for the selection of this bio-coagulant are locally available, cheap, non-toxic and environment friendly. The coagulation and flocculation were done by adding 50mg coagulant and the stirrer speed was set to be 100 rpm and the settling time was 30 minutes (Figure-3).

2.4 Dichloromethane

Dichloromethane (DCM) was bought from NIP Chemicals and Pharmaceuticals Ltd. with high purities (> 99.8wt%). Dichloromethane was used for solvent extraction which extracts the bio-crude from the product mixture. Moreover, DCM is dense, non-polar and highly volatile which makes homogeneous solutions with most of the organic solvents. DCM increases the solubilization of the bio-crude as well as extract maximum bio-crude from the product mixture (Chopra et al., 2019).

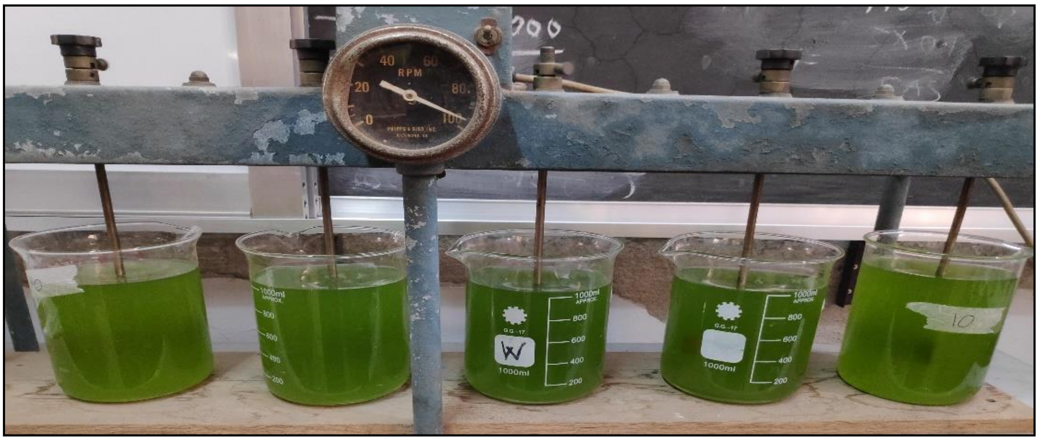

Figure 3 : Coagulation and flocculation process

2.5 HTL Reactor Setup

Reactions were carried out in a hydrothermal synthesis reactor (25ml) made of stainless steel 316 grade and which has a capacity of the working pressure of 5 MPa. The container specified as ppl liner of 25 mL was used to hold the microalgal solution and the reaction occurs inside the liner in high pressure and temperature. The liner has the capacity to be stable up to temperature 280°C and pressure of 5 MPa. The reactor has uniform wall thickness which allows the uniform heating of the reactor. There is also a rod attached to the top portion so that the reactor could be tightened firmly (Figure 4).

Figure 4 : Hydrothermal synthesis reactor

2.6 Experimental Methodology

In each experimental run 15 ml of sample including microalgae and HABR effluent water was taken into the reactor. The microalgae co-culture was taken 10wt% measured by the moisture content of the sample (Anastasakis & Ross, 2011). The reactor loading was 50% (Anastasakis & Ross, 2015). Then the reactor was taken to the muffle furnace and heated to the desired temperature (260°C, 280°C) (Tommaso et al., 2015) at an average heating rate of 60°C/min. After reaching the desired temperature the sample was kept inside the reactor for reaction time of 60 minutes (Ross et al., 2010). Once the holding time was finished the reactor was taken out from the muffle furnace and cooled it down by water bath in a basin for 5 minutes and 60 minutes at room temperature.

The outcomes of HTL of microalgae included gases, solids, aqueous phase, and bio-crude (Figure 5). After cooling down the reactor was cautiously opened and mixed with 30ml dichloromethane (DCM). The main reason for adding DCM is to extract the organic components from both liquid and solid products and also to be miscible with organic solvents. The bio-crude is also defined as DCM-soluble fraction (Biller & Ross, 2011). They were then taken into a conical tube and centrifuged at 3000 rpm for 10 minutes (He et al., 2018). After centrifugation, the organic phase dissolved in dichloromethane stays at the bottom and the aqueous phase stays at the top and the biochar stays in the middle that separates the organic phase with aqueous phase (Figure 6). Then the aqueous phase was carried into a glass tube by a pipette, and the DCM phase (dissolving biocrude) was taken out through filtering and then moved into a pre-weighed glass tube, and then dried at 40°C for 1 hr. The solids remaining on filter paper were dried at 100°C for at least 24 h before weighed (He et al., 2018). Two independent runs were carried out by the above procedure. Then FTIR analysis was done to the biocrude samples to represent the quality of biocrude samples.

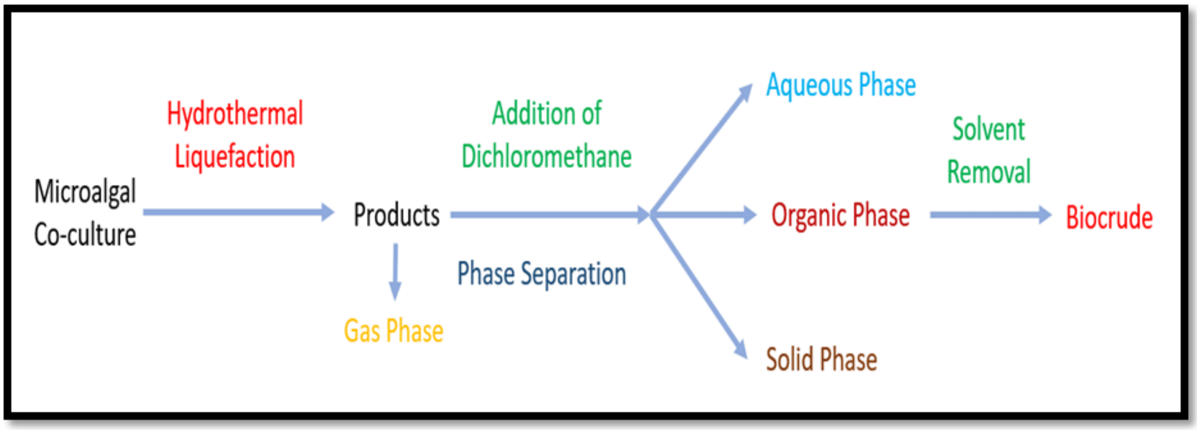

Figure 5 : Procedure for reaction and product work-up

2.6 FTIR Analysis

The characterization and elucidation of the functional group present in dry microalgae, biocrude and biochar were determined using FTIR spectroscopy study (Mahapatra & Ramachandra, 2013). FTIR analyses were conducted on microalgae dry cell, biocrude and biochar at room temperature using Shimadzu (IRTracer-100) FTIR spectrophotometer (Ansari A.A. et al., 2017). The dried algal biomass and biochar samples were further broken into powder as the requirement of the instrument. The powder of the samples was pressed against the diamond cell prior to scanning. The extracts from these samples were observed for their functionalities in the spectrogram. The spectra were collected in the mid-IR range from 4000 to 800 cm^{-1} (at a spectral resolution of 2 cm^{-1}) and data were analyzed using Microsoft Excel, irAnalyze-RAMalyze (Lab-Cognition GmbH & Co. KG) and Essential FTIR (Operant LLC).

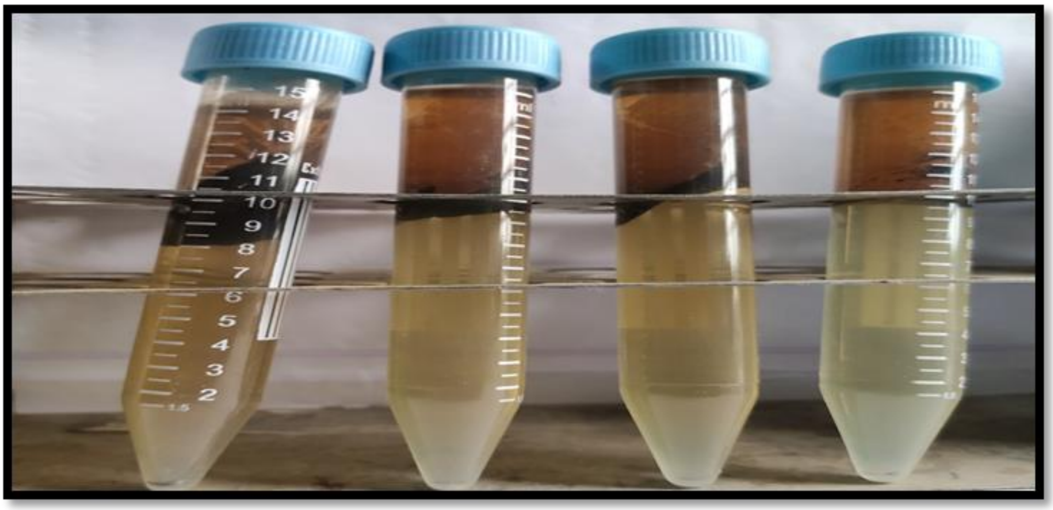

Figure 6 : Phase separation of HTL products

3. RESULTS AND DISCUSSIONS

3.1 Fourier Transformed Infrared Spectroscopy (FTIR) Analysis

FTIR Spectroscopy was employed to determine the presence of vibrations (stretching and bending) active functional groups (including CH_3 stretch, C=C-H, C-C-COOH (C=O), N-H Deformation, C-CX-COOH (C-O), C-H (Aromatics), C-H Stretch (Alkyl), C=C-COOH (O-H), N=O, C-N Stretch, N-H Stretch, C-N=O, N-H Bend, C-N-H Bend, Si-O Stretch) in dry microalgae co-culture cell sample, biocrude and biochar as presented in Table 1, Table 2 and Table 3 (Ansari et al., 2017). The most characteristic IR spectra peaks of the microalgae dry cell samples are shown in Figure 7, Figure 8 and Figure 9. IR spectra for all samples were found to be contaminated for CO_2 contamination (650-700 cm^{-1} and 2250-2450 cm^{-1}) and water vapor (3440- 3950 cm^{-1}). Removing these contaminations, baseline correction was done in software and then the spectrums were analyzed for active functional groups.

3.1.1 Dry Microalgal Biomass

The main absorbance bands of dry microalgal co-culture cell that reveals the specific functional groups and the presence of a related class of compounds was discussed (Figure 7 and Table 1). The band at 1406 cm^{-1} is related to methylene CH_2 bending and methyl CH_3 bending. The bend at 879 cm^{-1} may be due to the presence of aromatic compounds. Some small bands in the range (3010-3100cm^{-1}) shows the presence of double bonded carbon compounds (C=C-H). The strong peak at 1033 cm^{-1} is attributed to either C-O stretching in carbohydrates or Si-O stretching which is present in the cell wall of microalgae (Si-O-C), which disappeared in biocrude and biochar samples (Figure 8 and Figure 9). Peaks at 1537 cm^{-1} and 1645 cm^{-1} indicate the N=O bend, amide (C-N=O) bends, N-H bends, C-N-H bend which belongs to the protein fraction. The peak at 1718 cm^{-1} represents C=O which is rather weak according to the absorption of other peaks.

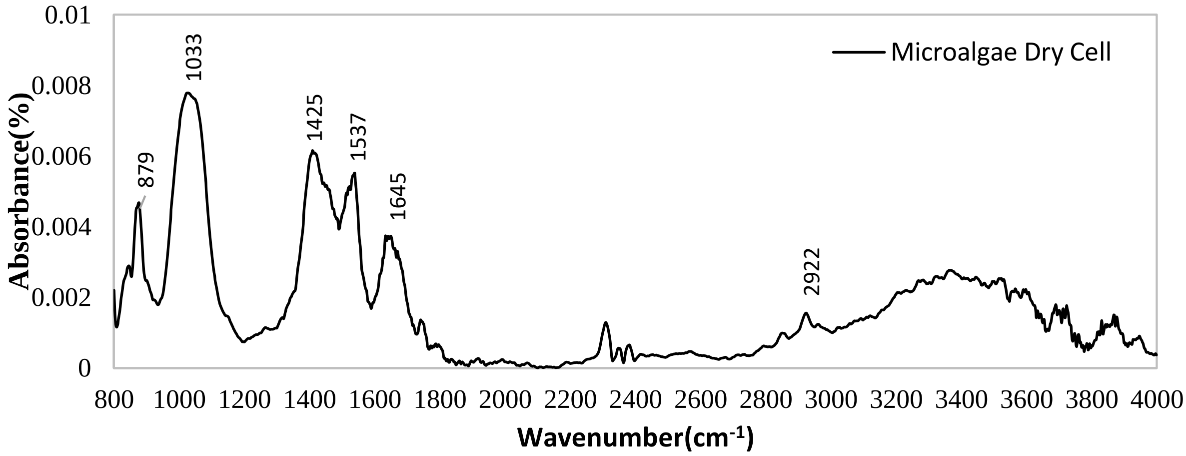

Figure 7: FTIR spectrum of microalgal co-culture dry cell

Table 1: FTIR band assignments for microalgae dry cell

Functional Groups	Spectra range (cm^{-1})	Strength of Spectra ranges
		Microalgae dry cell
CH3 / CH2 stretch	1400-1450	Strong
C=C-H	3010-3100	Medium
C-C-COOH (C=O)	1690-1715	Weak
C-H (Aromatics)	860-900	Strong
N=O	1500-1580	Stronger
C-N=O Amide	1630-1685	Strong
C-N-H Bend	1525-1550	Strong
Si-O/C-O Stretch	950-1050	Strong

3.1.2 Biochar

FTIR analysis of biochar samples biochar HTL at 260°C (biochar 260) and biochar HTL at 280°C (biochar 280), which were HTL effluent's solid phase, were observed to have quiet similar peaks (Figure 8). The aromatic ring skeletal bending (845-925 cm^{-1}) is found in both samples. The C-CO bend (1000-1150) is observed in both samples but the biochar 280 has more intensity according to absorbance. The both biochar samples have strong peak at 1410-1415 cm^{-1} which denotes the presence of S=O bend. The both samples have peaks at the range 1500-1580 cm^{-1} and 1630-1660 cm^{-1} which represents the N=0 and C=C bending of p-nitrophenol compound. A peak of 1848 cm^{-1} is observed in biochar 260 sample which represents C=O bending which is not seen in biochar 280 sample. Some peaks of low absorbance were observed near 2900-2975 cm^{-1} which indicates C-H bending of carbohydrates.

Table 2 : FTIR band assignments for biochar samples

Functional Groups	Spectra range (cm^{-1})	Strength of Spectra ranges	
		Biochar 260^0C	Biochar 280^0C
C-H Stretch	2900-2975	Variable	Variable
C-O	1070-1100	Strong	Strong
N=O	1500-1580	Stronger	Stronger
C=C	1630-1660	Strong	Medium
C-CO	1000-1150	Strong	Strong
S=0 stretch	1340-1420	Strong	Strong
Ring Skeletal	845-925	Variable	Variable
C=O	1840-1850	Weak	-

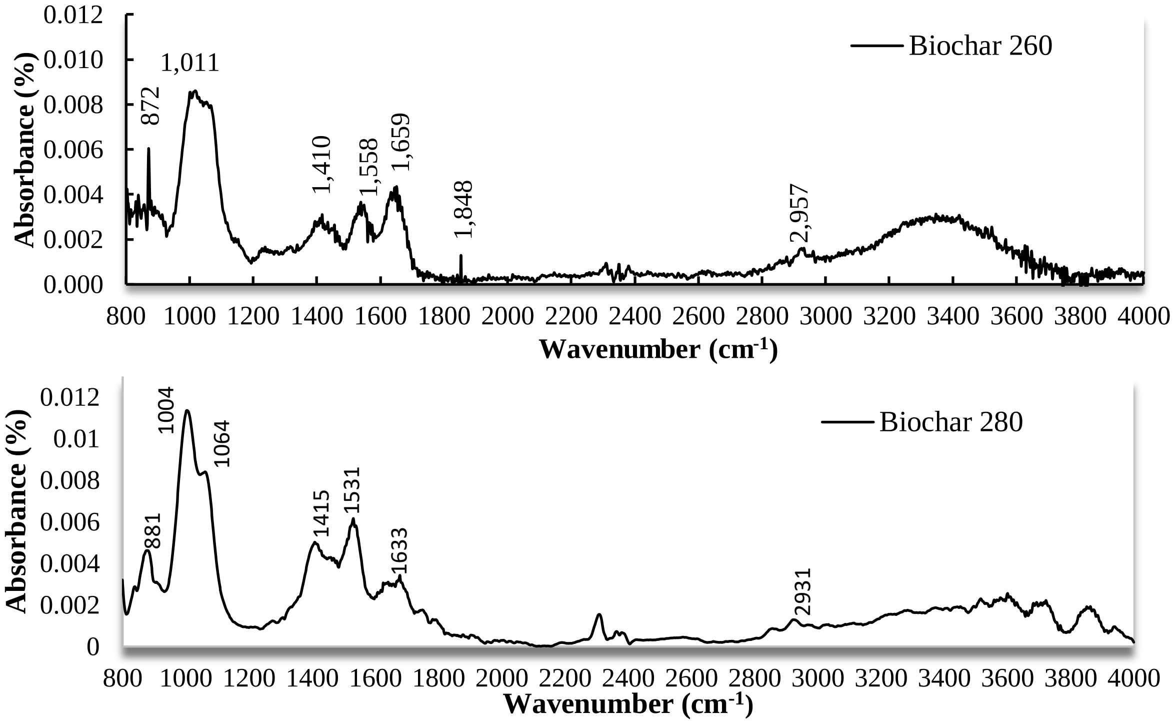

Figure 8: FTIR spectra of biochar at 260℃ and 280℃

3.1.3 Biocrude

IR spectra of biocrude HTL at 260℃ (biocrude 260) and HTL at 280℃ (biocrude 280)) were recorded between 800-4000 cm-1. The absorption bands that dominate the spectra of biocrude are aliphatic C-H bonds and organic groups containing oxygen, sulfur, nitrogen, and aromatics. The FTIR spectrum of the biocrude samples are presented in figure 9 and band assignments are shown in table 3. The broadband seen at 3445-3900 cm-1 for microalgal biomass can be attributed to O-H stretching which is not seen in the biocrude spectrums so this indicates the absence of moisture. The sharp peaks at 2859 cm^{-1}, 2855 cm^{-1}, 2920 cm^{-1}, 2924 cm^{-1}, 2957 cm^{-1} indicates the presence of methylene ($(CH_2)_4$-C) and alkyl group. Here the peaks in biocrude 280 samples are sharper and the intensity according to absorbance is more than biocrude 260 samples. The biocrude 260 sample has small peaks in 1734 cm^{-1} which indicates the presence of esters (COO), ketones aldehydes where no peaks were observed in biocrude 280 samples within this range. There was another strong peak of 1260 cm^{-1} indicates the presence of methyl (CH_3) group in biocrude 260 samples wherein biocrude 280 samples the peak is very weak. The peak in 1013 cm^{-1} in biocrude 260 sample defines the presence of C-O bend but this Bend is disappeared in biocrude 280 sample which is evidence of the hydrolysis reaction. Both of the spectrum has peaks around 1080 cm^{-1} which indicates the C-O-C bend but the intensity of absorbance is lower for biocrude 280 samples. Peaks at 1460, 1549, 1676 cm^{-1} indicate the methylene group, amide (N=O) and double bonded carbon (C=C) which also determines the presence of p-nitrophenol in biocrude 280 samples but no definite peaks were observed for biocrude 260 samples. The biocrude samples show less intense peaks for amide bonds and nitro groups as compared to biochar. This implies the majority of the nitrogen in the biomass has been captured in biochar.

Table 3 : FTIR band assignments for biocrude samples

Functional Groups	Spectra range (cm-1)	Strength of Spectra ranges	
		Biocrude 2600C	Biocrude 2800C
(CH2)4-C	2916-2936	Medium	Medium
C-H Stretch, Alkyl	2845-2975	Variable	Variable
CH2/CH3 Stretch	1415-1475	Variable	Variable
CH3 Stretch	1260	Very Strong	Weak
COO(Esters)	1720-1770	Medium	-
C-O-C	1080-1135	Strong	Strong
N=O	1500-1580	-	Variable
C=C	1610-1680	-	Variable
C-O Stretch	950-1050	Strong	-

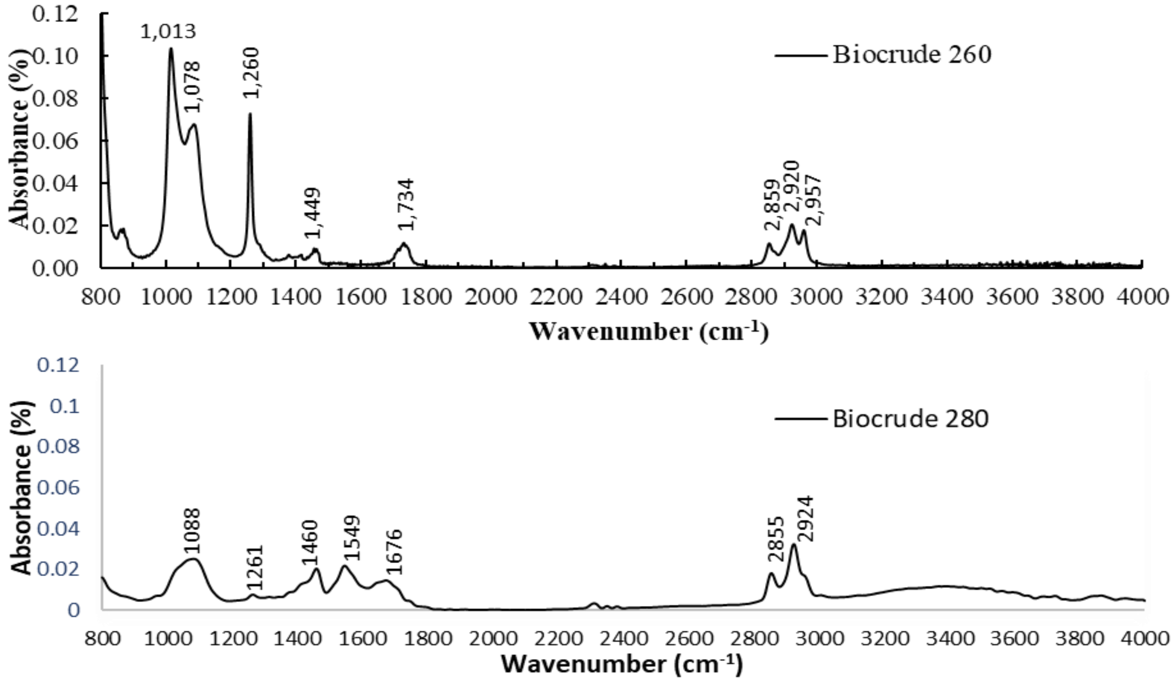

Figure 9: FTIR spectra of biocrude sample at 260℃ and 280℃

4. CONCLUSIONS

In conclusion, the analysis of biocrude FTIR clarifies the dehydration and decarboxylation reactions that happened as the C-H intensity rose. Again, the decrease in C-O and C=O peaks proved the decomposition step of hydrothermal liquefaction happened in the biomass. The thermochemical conversion of biomass to biocrude was proven. Between the two temperature steps of 260℃ and 280℃, the analysis of FTIR showed the biocrude 280 sample quality was better as the peaks for C-H had higher intensity level. The FTIR of both biocrude samples proved the reduction of nitrogen concentration compared to algal biomass. The nitrogen content in algal biomass shows that the microalgae absorbed the nitrogen substances from HABR effluent water. So, the microalgae are also treating the effluent water by decreasing its nitrogen content to reduce the drawback of HABR system. Furthermore, the microalgae also absorb CO_2 from environment to produce organic compounds using sunlight and photosynthesis process. The microalgae are the environment friendly micro-organism which can be cultivated in anaerobic reactor effluent using photoreactor and then converted into biocrude representing the alternate source for bioenergy.

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REFERENCES

Anastasakis, K., & Ross, A. B. (2011). Hydrothermal liquefaction of the brown macro-alga Laminaria saccharina: Effect of reaction conditions on product distribution and composition. *Bioresource Technology*, *102*(7), 4876–4883.

Anastasakis, K., & Ross, A. B. (2015). Hydrothermal liquefaction of four brown macro-algae commonly found on the UK coasts: An energetic analysis of the process and comparison with bio-chemical conversion methods. *Fuel*, *139*, 546–553. https://doi.org/10.1016/j.fuel.2014.09.006

Ansari, A. A., Khoja, A. H., Nawar, A., Qayyum, M., & Ali, E. (2017). Wastewater treatment by local microalgae strains for CO2 sequestration and biofuel production. *Applied Water Science*, *7*(7), 4151–4158.

Appleford, J. M., Ocfemia, K. C. S., Zhang, Y., Christianson, L., Funk, T. L., & Dong, R. (2005). Analysis and characterization of the product oil and other products of hydrothermal conversion of swine manure. *2005 ASAE Annual Meeting*, 1. American Society of Agricultural and Biological Engineers.

Aresta, M., Dibenedetto, A., & Barberio, G. (2005). Utilization of macro-algae for enhanced CO2 fixation and biofuels production: Development of a computing software for an LCA study. *Fuel Processing Technology*, *86*(14–15), 1679–1693.

Biller, P., & Ross, A. B. (2011). Potential yields and properties of oil from the hydrothermal liquefaction of microalgae with different biochemical content. *Bioresource Technology*, *102*(1), 215–225.

Brown, T. M., Duan, P., & Savage, P. E. (2010). Hydrothermal liquefaction and gasification of Nannochloropsis sp. *Energy & Fuels*, *24*(6), 3639–3646.

Chen, W.-T., Zhang, Y., Zhang, J., Yu, G., Schideman, L. C., Zhang, P., & Minarick, M. (2014). Hydrothermal liquefaction of mixed-culture algal biomass from wastewater treatment system into bio-crude oil. *Bioresource Technology*, *152*, 130–139.

Chopra, J., Mahesh, D., Yerrayya, A., Vinu, R., Kumar, R., & Sen, R. (2019). Performance enhancement of hydrothermal liquefaction for strategic and sustainable valorization of de-oiled yeast biomass into green bio-crude. *Journal of Cleaner Production*, *227*, 292–301.

Costa, J. A. V., & De Morais, M. G. (2011). The role of biochemical engineering in the production of biofuels from microalgae. *Bioresource Technology*, *102*(1), 2–9.

Demirbaş, A. (2000). Mechanisms of liquefaction and pyrolysis reactions of biomass. *Energy Conversion and Management*, *41*(6), 633–646.

Gao, K., & McKinley, K. R. (1994). Use of macroalgae for marine biomass production and CO 2 remediation: A review. *Journal of Applied Phycology*, *6*(1), 45–60.

Garcia Alba, L., Torri, C., Samorì, C., van der Spek, J., Fabbri, D., Kersten, S. R., & Brilman, D. W. (2011). Hydrothermal treatment (HTT) of microalgae: Evaluation of the process as conversion method in an algae biorefinery concept. *Energy & Fuels*, *26*(1), 642–657.

Gelin, F., Volkman, J. K., Largeau, C., Derenne, S., Damsté, J. S., & De Leeuw, J. W. (1999). Distribution of aliphatic, nonhydrolyzable biopolymers in marine microalgae. *Organic Geochemistry*, *30*(2–3), 147–159.

Gollakota, A. R. K., Kishore, N., & Gu, S. (2018). A review on hydrothermal liquefaction of biomass. *Renewable and Sustainable Energy Reviews*, *81*, 1378–1392.

Goyal, H. B., Seal, D., & Saxena, R. C. (2008). Bio-fuels from thermochemical conversion of renewable resources: A review. *Renewable and Sustainable Energy Reviews*, *12*(2), 504–517.

Hasan, M., Khalekuzzaman, Md., & Alamgir, Md. (2018). *Compartment-wise variation of hydrodynamic characteristics of the modified anaerobic baffled reactor*.

He, Z., Xu, D., Liu, L., Wang, Y., Wang, S., Guo, Y., & Jing, Z. (2018). Product characterization of multi-temperature steps of hydrothermal liquefaction of Chlorella microalgae. *Algal Research*, *33*, 8–15.

Hill, J., Nelson, E., Tilman, D., Polasky, S., & Tiffany, D. (2006). Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences*, *103*(30), 11206–11210.

Hu, Y., Wang, S., Li, J., Wang, Q., He, Z., Feng, Y., … Hui, C. (2018). Co-pyrolysis and co-hydrothermal liquefaction of seaweeds and rice husk: Comparative study towards enhanced biofuel production. *Journal of Analytical and Applied Pyrolysis*, *129*, 162–170. https://doi.org/10.1016/j.jaap.2017.11.016

Mahapatra, D. M., & Ramachandra, T. V. (2013). Algal biofuel: Bountiful lipid from Chlorococcum sp. proliferating in municipal wastewater. *Current Science*, 47–55.

Mata, T. M., Martins, A. A., & Caetano, N. S. (2010). Microalgae for biodiesel production and other applications: A review. *Renewable and Sustainable Energy Reviews*, *14*(1), 217–232.

Minowa, T., Yokoyama, S., Kishimoto, M., & Okakura, T. (1995). Oil production from algal cells of Dunaliella tertiolecta by direct thermochemical liquefaction. *Fuel*, *74*(12), 1735–1738.

Patil, V., Tran, K.-Q., & Giselrød, H. R. (2008). Towards sustainable production of biofuels from microalgae. *International Journal of Molecular Sciences*, *9*(7), 1188–1195.

Patrick, H. R., Griffith, K., Liotta, C. L., Eckert, C. A., & Gläser, R. (2001). Near-critical water: A benign medium for catalytic reactions. *Industrial & Engineering Chemistry Research*, *40*(26), 6063–6067.

Ross, A. B., Biller, P., Kubacki, M. L., Li, H., Lea-Langton, A., & Jones, J. M. (2010). Hydrothermal processing of microalgae using alkali and organic acids. *Fuel*, *89*(9), 2234–2243.

Schenk, P. M., Thomas-Hall, S. R., Stephens, E., Marx, U. C., Mussgnug, J. H., Posten, C., … Hankamer, B. (2008). Second generation biofuels: High-efficiency microalgae for biodiesel production. *Bioenergy Research*, *1*(1), 20–43.

Suali, E., & Sarbatly, R. (2012). Conversion of microalgae to biofuel. *Renewable and Sustainable Energy Reviews*, *16*(6), 4316–4342.

Tommaso, G., Chen, W.-T., Li, P., Schideman, L., & Zhang, Y. (2015). Chemical characterization and anaerobic biodegradability of hydrothermal liquefaction aqueous products from mixed-culture wastewater algae. *Bioresource Technology*, *178*, 139–146.

Toor, S. S., Rosendahl, L., & Rudolf, A. (2011). Hydrothermal liquefaction of biomass: A review of subcritical water technologies. *Energy*, *36*(5), 2328–2342.

CHARACTERIZATION OF URBAN STORM WATER QUALITY FOR DIFFERENT LAND USES

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ABSTRACT

Urbanization results in the diversification of land use with large natural vegetated lands converted into impervious areas such as roofs, roads and other paved surface. The increased fraction of impervious surfaces leads to generation of pollutants through various anthropogenic activities during dry periods and washout these pollutants during rainfall events which finally enter into the receiving water bodies. This further deterioate the water quality and unbalance the aquatic ecosystem. Hence, characterisation of urban stormwater quality is critically important to select treatment system to safeguard the water sources. The research study focused on the characterisation of urban stormwater quality for three different land uses such as residential, commercial and industrial. The storm water samples were collected from three different land use areas in Rajshahi city. Collected samples were tested in the laboratory by using standard quality control and test methods specified in APHA 1999. The test results showed that suspended solids (SS), turbidity, electric conductivity was found higher for industrial areas where pH and BOD were found higher in residential and industrial areas respectively. The study results will provide guideline to the storm water management authority for selection of suitable treatment system or management system for different land uses in Rajshahi city.

Keywords: *Storm water runoff, Storm water quality, Land use, Rajshahi City, Principal component analysis.*

1. INTRODUCTION

Water pollution is a crucial concern now- a -days. It has created many problems to human beings and water bodies. People are suffering from a lot of water born diseases. It has become a threat to the fishes and other water bodies. Soni et. al. (2019) conducted study on categories, causes and control of water pollution. The study results showed that water pollution affects the entire biosphere of plants and organisms living in the water bodies as well as the plants that might be exposed to the water.

Currently, stormwater runoff has become one of the major source of water pollution. Due to rapid urbanisation process natural land turns into impervious surface which are suitable platform for pollutant buils-up and wash-off by rainfall events (Goonetilleke et. al., 2015). The stormwater runoff enter into the nearby water bodies through drainage systems or overland flow without treatment and deteriorate the receiving water quality. The type and amount of pollutant generation depend on many factors such as geology of the land, topography, geography, rainfall intensity and pattern, and land use type (Sarukkalige, 2011). Guzman et. al. (2018) conducted study on influence of land use on urban runoff quality in Bogota, Colombia. This study has evaluated the influence of land use on the concentrations of physical-chemical parameters in urban runoff. For this, an artificial rain was used at three points with different land uses such as residential, industrial and vehicular parking in the city of Bogotá. They showed that industrial sector presented higher concentrations of all parameters such as nitrates, nitrites, suspended solids, COD and alkalinity and residential area and recreational areas represented the similar variations due to the presence of traffic and vegetal species.

Lucke et. al., (2018) conducted study on urban stormwater characterization and nitrogen composition from a large scale catchment. This study investigated the pollutant concentrations variability of pollutant build-up parameters in different land use types such as seven residential areas and five commercial areas in Australia. They showed that the values of suspended solid, nitrogen and phosphorus were higher in urban residential areas than the commercial areas. Maharjan et. al., (2017) conducted study on modeling of stormwater runoff, quality and pollutant loads in a large urban catchment. Their study mainly focused on development of build-up model for the Mustoja basin in Tallinn. The build-up rate was slightly higher in commercial area than in the residential area and the industrial area had slightly higher than the commercial area. Khatun et. al., (2014) conducted study on variability of pollutant build-up in different land uses of Guwahati city, Assam, India. For this study, stormwater samples were collected from five different land use types; residential, commercial, recreational, heavy traffic and industrial, around Guwahati city, Assam (India). They analysed the collected samples to measure different build-up parameters to investigate the variability of pollutant build-up parameters in five different land use types. They showed that industrial areas had higher value of co-efficient of variations.

Jarvelainen (2014) studied on land use based storm water pollutant load estimation and monitoring system design in Lahti city, Finland. In this study, the quality and quantity of storm water being generated in city areas was estimated. He found that industrial and commercial areas had higher amount of heavy metals and pollutants.

Based on above review it was understood that the types and amount of pollutants generated varies with diferrent land use types. Hence, proper characterization of urban stormwater quality for different land use type is essesntial for selection of suitable treatment method. The aim of this study is to characterize the urban stormwater quality for three different land uses such as residential, commercial and industrial areas in Rajshahi City. The study will show us the variation among the parameters of urban stormwater in residential, commercial and industrial areas after a regular time interval.

2. METHODOLOGY

2.1 Study Site Selection

The stormwater samples were collected from three different land use such as residential, commercial and industrials areas in Rajshahi city. Rajshahi is the 4th largest among the eight divisions in Bangladesh. It’s being developed day by day due to many industries and educational institutes. Due to rapid urbanization process, stormwater gets polluted by the pollutants generated in road surfaces and washout during rainfall events. The sample collection point were six different road surface runoff such as Alokarmor, New market; Belderparamor; Zero- point, Shaheb Bazar; Moni Chattar; Bscic, Sapura and Match Factory Mor in Rajshahi City (Figure 1). The characteristics of these study sites are discussed in Table 1.

1(a)

1(b)

1(c)

2(a) 2(b) 2(c)

Figure 1: Study area

Table 1: Characteristics of Study Sites

Land use type	Site Name	Road type	Texture depth (mm)	Location Coordinate
Residential	Alokarmor	Main road	1.78	$24^{o}22^{/}1.0^{//}$N $88^{o}36^{/}10.8^{//}$E
	Belderparamor	Branch road	1.63	$24^{o}22^{/}7.1^{//}$N $88^{o}36^{/}22.5^{//}$E
Commercial	Zero- point, Shaheb Bazar	Main road	2.67	$24^{o}21^{/}55.5^{//}$N $88^{o}35^{/}59.9^{//}$E
	Moni chattar	Main road	2.39	$24_{o}21^{/}58.0^{//}$N $88^{o}35^{/}50.8^{//}$E
Industrial	Bscic, Sapura	Branch road	2.58	$24^{o}23^{/}14.3^{//}$N $88^{o}36^{/}19.8^{//}$E
	Match factory mor	Main road	2.92	$24^{o}23^{/}12.8^{//}$N $88^{o}36^{/}20.6^{//}$E

2.2 Sample Collection

The sample collection was undertaken based on the standard procedure recommended by EPA, 1992. Sample was collected three times from selected location at different rainfall events (Table-2) to understand the effect of dry periods on the variability of stormwater quality. After sample collection, the bottle was properly sealed and leveled for future identification.

Table 2: Sample Collection Time

Sample collection date	Sample no.
02/06/2019	RA1-1,CA1-1,IA1-1
09/06/2019	RA1-2,CA1-2,IA1-2
25/06/2019	RA1-3,CA1-3,IA1-3
29/08/2019	RA2-1,CA2-1,IA2-1
04/09/2019	RA2-2,CA2-2,IA2-2
09/09/2019	RA2-3,CA2-3,IA2-3

2.3 Data Analysis Method

Univariate and multivariate analysis techniques were used.

2.3.1 Univariate Analysis Tools

Mean: The average of a set of data points is measured by it.

$$\bar{X} = \frac{\sum x_n}{N} \tag{1}$$

Here, $\sum x_n$= sum of data values.
N = total number of data points.
$\bar{X}$ = mean

Standard Deviation (SD): The dispersion of data set is measured from its mean.

$$\sigma = \sqrt{\frac{\sum(x-\bar{X})^2}{N-1}} \tag{2}$$

Here, x= individual data points
$\bar{X}$=mean/average of the data points
N = total number of data point , σ= standard deviation

Coefficient of variation (CV): The level of dispersion around the mean is measured by CV.

$$CV = \frac{\sigma}{\bar{X}} \tag{3}$$

Here, σ= Standard deviation.
$\bar{X}$=mean

2.3.2 Multivariate Analysis Tools

Principal Component Analysis:

A statistical procedure that convert a set of observations of possibly correlated variables into a set of values that linearly uncorrelated variables. This transformation is defined in such as a way that the first principle component has the largest variance and each succeeding component in turn has the highest variance. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables.

3. RESULT AND DISCUSSION

Table 3 shows the summary of the analysis results for selected stormwater quality parameters for each individual land use category. It can be seen that these pollutants concentrations vary considerably for each land use, which indicates that pollutant distribution throughout the catchment is highly dependent on the land use. Suspended solids are one of the main indicators of water quality. Most of the pollutants absorbed by suspended solids and transport by stormwater runoff.

Table 3: Average pollutant loading for each specified land use

Land use type	Sites	pH			TURBIDITY (NTU)			CONDUCTIVITY (mg/L)			SUSPENDED SOLIDS (mg/L)			BOD (mg/L)		
		MEAN	SD	CV (%)	MEAN	SD	CV (%)	MEAN	SD	CV (%)	MEAN	SD	CV (%)	MEAN	SD	CV (%)
Residential	Alokar Mor	6.90	0.20	1.95	10.00	0.40	3.58	1066.7	115.5	10.82	115.73	10.8	9.39	2.22	0.02	1.82
	BeldarPara Mor	6.78	0.02	0.29	10.16	0.28	2.76	1050.0	50.00	04.76	117.85	2.65	2.25	2.15	0.13	6.04
Commercial	Zero Point	6.57	0.10	1.64	08.52	0.10	1.54	1433.3	57.74	04.02	189.99	4.30	2.26	8.23	0.30	3.06
	Moni-Chattar	6.55	0.05	0.76	08.36	0.26	3.11	1483.3	28.86	01.94	189.87	0.93	0.49	8.32	0.16	1.92
Industrial	Bscic, Sapura	6.42	0.10	0.80	13.17	0.90	6.85	1533.3	57.72	03.76	394.45	4.32	1.09	3.17	0.30	9.11
	Match Factory Mor	6.38	0.02	0.31	12.93	0.02	0.15	1566.6	57.73	03.68	394.31	03.67	0.93	3.27	0.02	0.62

Storm water in residential area demonstrated the cleanest appearing storm water with lowest average amounts of suspended solids within the storm water. With a low variance for suspended solids (SS) and turbidity, residential sites are cleanest among the other sites.

The stormwater quality in industrial area was found highly polluted than other land use. This is due to recording the highest amounts of SS and turbidity in the storm water when compared to the other land use. The industrial location also recorded the higher BOD value than the residential sites. Presence of organic matter in industrial area causes the highest BOD value in industrial area than residential area. Commercial storm water resulted in containing low concentrations of suspended solids and turbidity value then industrial sites. But commercial area are recorded the highest BOD value than the other sites. This is due to the generation of highest organic waste which decomposed on road surfaces and washout through storm water runoff. The organic wastes in commercial areas are produced from local market, fruit seller, decomposed fruit bunch or vegetable waste and distribute along road side. In contrast, industrial area produces small amount of organic waste that's why the value of BOD is lower than the commercial areas.

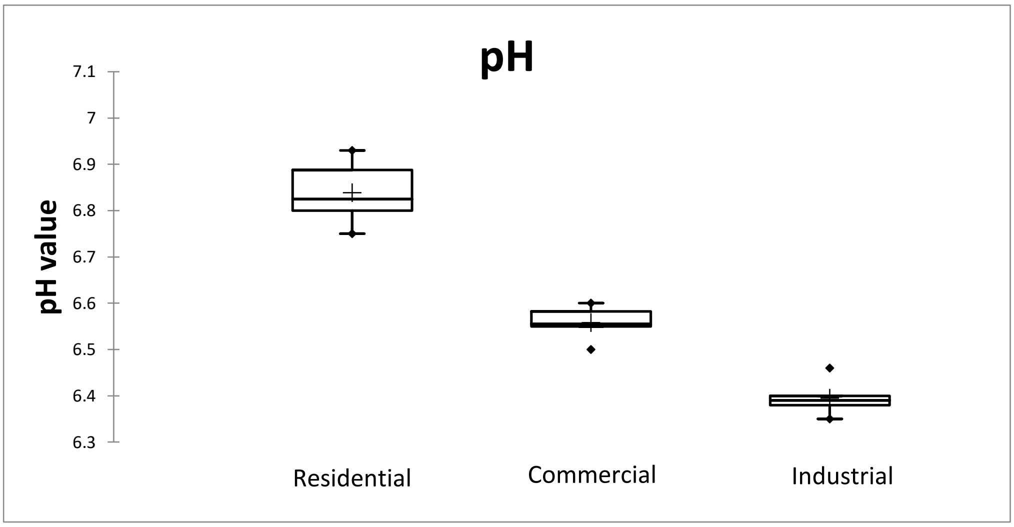

Figure 2: Variation of pH for different land uses

The variation of water quality parameters for three land use are presented by Box Whisker plot in Figures 2-6. As seen in Figure 2, the highest pH value was found 6.93 in residential area where mean value was 6.83. Commercial area shows the highest value of 6.6 and mean value is about 6.55. Residential area has the higher concentration compared to industrial and commercial areas. From Table 3, pH value in residential area displays the highest standard deviation among the three different land use areas. This indicates a high variability in the value of pH concentration. pH value was found lower for both commercial and industrial areas. This can be due to the presence of chemical and metal that reacts with water and decrease the pH value.

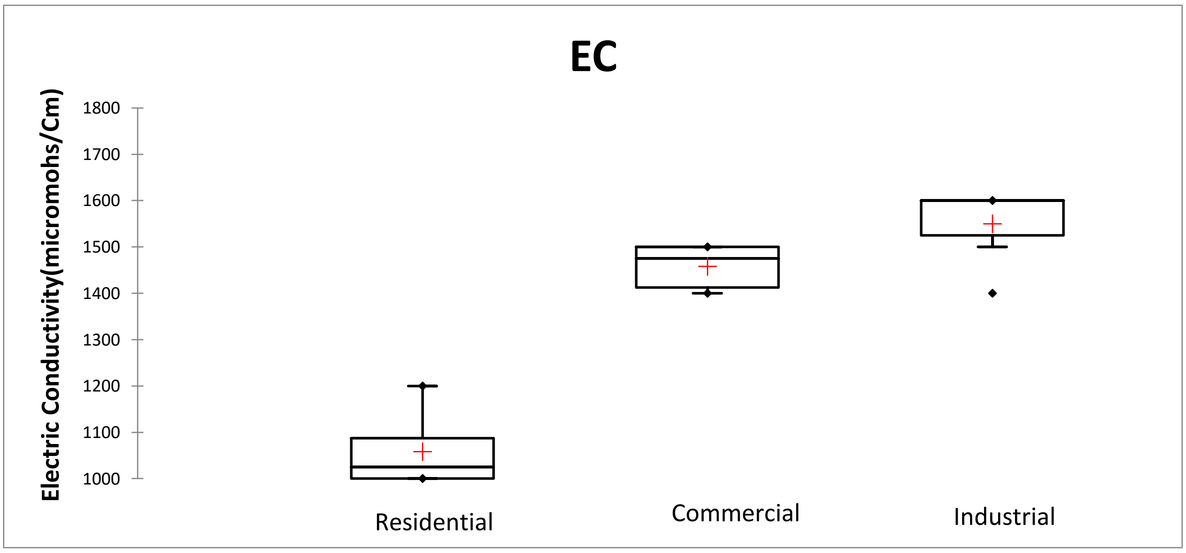

Figure 3: Variation of Electric Conductivity for different land uses

The variation of Electric Conductivity (EC) is shown in Figure 3. Industrial area has the highest conductivity (mean 1550 micromohs/Cm) than residential (mean 1060 micromohs/Cm) and commercial (mean 1460 micromohs/Cm) areas. The reaction of chemical and metal substances with the water flowing from industrial area is the reason of having higher value of EC in industrial area.

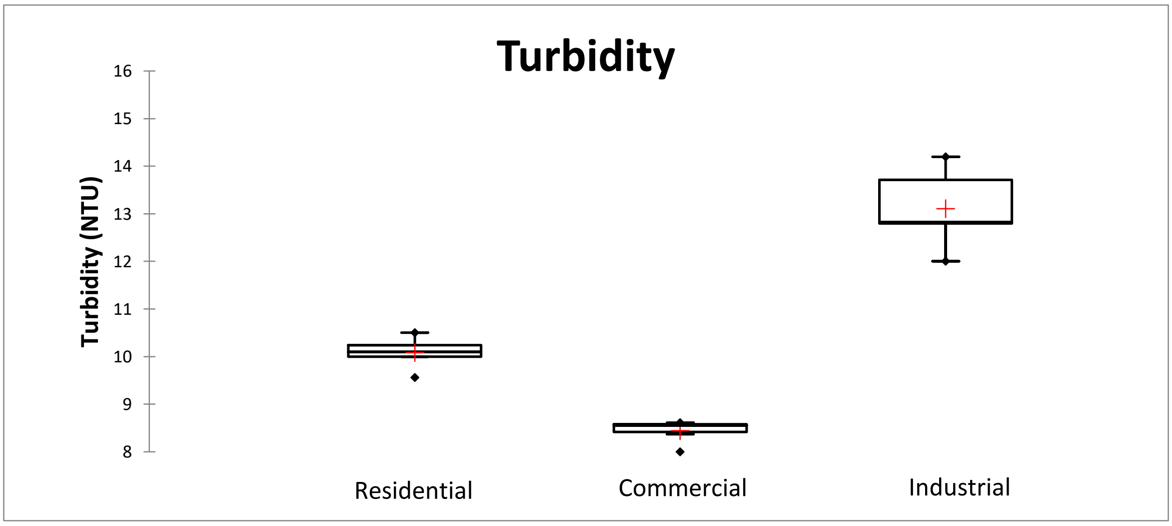

Figure 4: Variation of Turbidity for different land uses

The significant differences of turbidity among three land uses are presented in Figure 4. Water turbidity is directly caused by the presence of suspended matters such as clay, silt etc. The overall patterns of SS and turbidity concentration in different land uses were similar. Commercial land use type was significantly less turbid (mean value is 8.45 NTU) than all other land use types. The highest turbidity was found in industrial area (mean value 13.15 NTU). This can be due to the presence of the fine particles from production process of goods and distributed on the road surface by traffic, wind, workers during loading and unloading time.

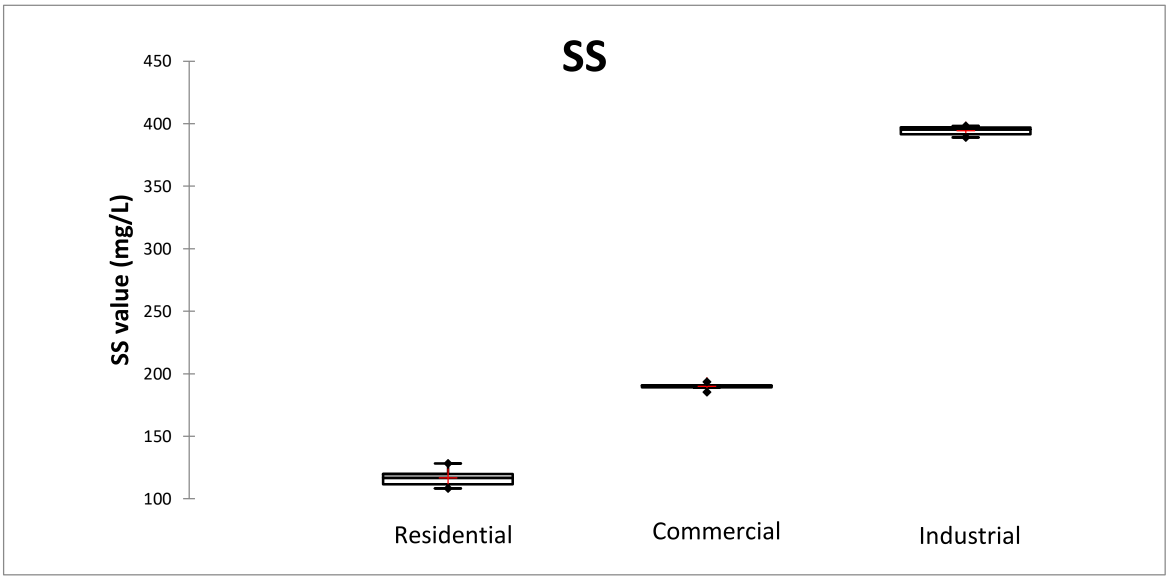

Figure 5: Variation of Suspended Solids for different land uses

The variation of SS for three different land uses shown in Figure 5. The residential area has lower mean SS value (116.75 mg/l) compared to other land uses. This can be due to the periodic cleaning of road surfaces by street sweepers. It can be seen that the average concentration of SS in industrial area (394.25 mg/l) was almost two and a half times the values for residential areas. The commercial and industrial area produces high level of SS. This is due to high population density, traffic density and various anthropogenic activities occur by human and distribute by traffic and wind.

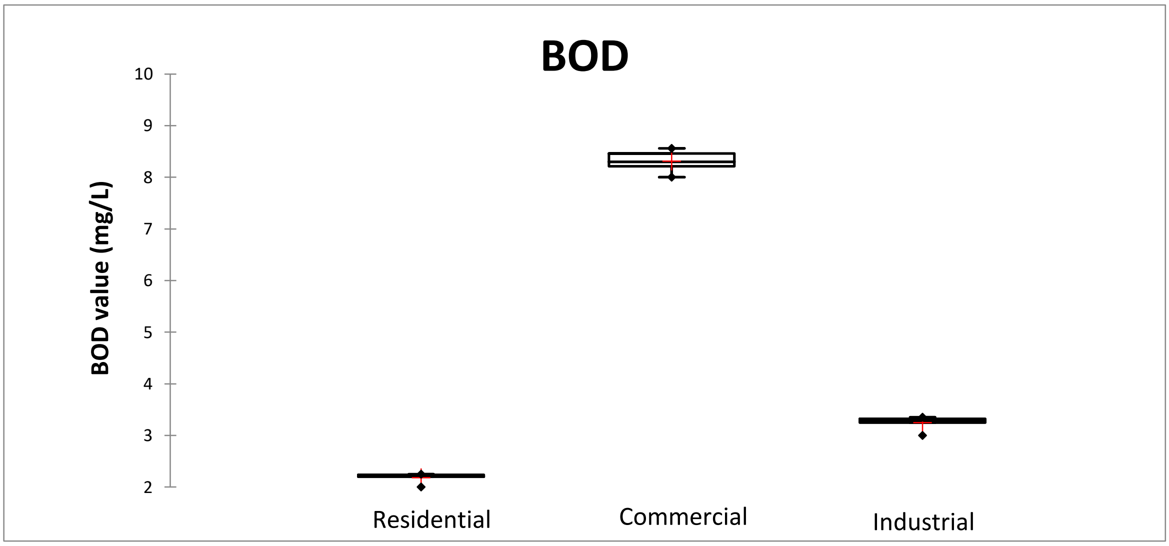

Figure 6: Variation of BOD for different land uses

The variation of BOD concentration is shown in Figure 6. The highest BOD value in residential area is found 2.25 mg/l and mean value is 2.18 mg/l. Commercial area shows the highest value of 8.5 mg/l mean value is about 8.3 mg/l. Residential area has the lower concentration compared to industrial and commercial areas. From Table 3, BOD value in commercial area displays the highest standard deviation. This indicates a high variability in the value of BOD concentration. As we know, BOD value measures the amount of dissolved oxygen to biologically decompose the organic matters. The presence of organic matter is higher in commercial area that are produced from local market, fruit seller, decomposed fruit bunch or vegetable waste and distribute along road side. Residential area produces small amount of organic waste that's why the value is lowest among the others.

Table 4: Pearson correlation matrix

Variables	pH	EC	Turbidity	SS	BOD	ADD
pH	1	-0.913	-0.464	-0.888	-0.302	-0.051
EC	-0.913	1	0.278	0.789	0.472	-0.009
Turbidity	-0.464	0.278	1	0.792	-0.638	-0.020
SS	-0.888	0.789	0.792	1	-0.102	-0.007
BOD	-0.302	0.472	-0.638	-0.102	1	-0.016
ADD	-0.051	-0.009	-0.020	-0.007	-0.016	1

The correlation among water quality parameters is essential to identify possible relationship between them. Table 4 shows the pearson correlation co-efficient between each water quality parameters.
From the correlation matrix, the pearson correlation co-efficient value greater than 0 indicates a positive correlation; that is, as the value of one variable increases, so does the value of the other variable. A value less than 0 indicates a negative correlation; that is, as the value of one variable increases, the value of the other variable decreases. A value of 0 indicates that there is no relation between the two variables. The highest negative correlation shows between pH and EC. That means if the value of pH increases, the EC decreases. Turbidity and SS shows highest positive relation. That indicates the proportional relation between them. As the value of turbidity increases, the value of SS also increases. SS has similar relationship with EC and Turbidity. pH has negative correlation with other water quality parameters. EC has positive correlation with Turbidity, SS and BOD. on the other hand, BOD has only positive correlation with EC.

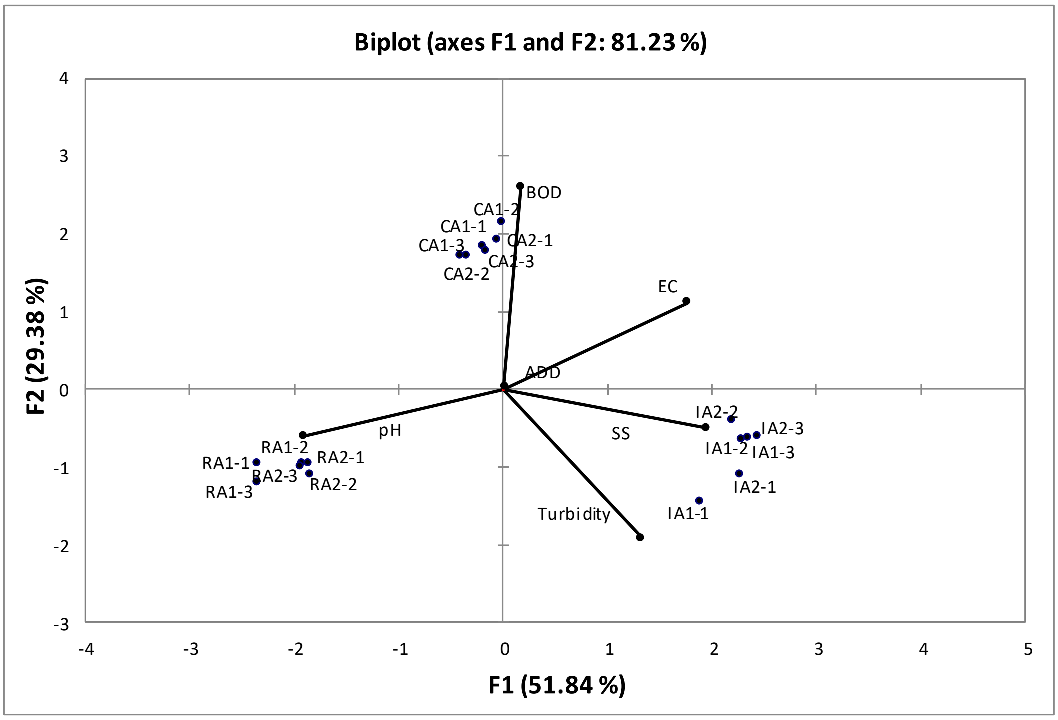

Figure 7: Component Bi-pots

Multivariate techniques were applied to identify linkage between various water quality parameters for three different land use. Using the principal components PC1 which described the largest data variance and PC2 the next largest amount of data variance, it was possible to develop biplots for the three different land uses.

The principal component analysis of the water quality parameter resulted in the most of the data set variance being contained in the first two components. The angle between the loading vector is significant as the degree of correlation between water quality parameters is inversely related to it. As the angle reduces the degree of correlation increases. Vectors situated closely together represent variables that are highly correlated while orthogonal vectors represent variables that are uncorrelated.

The realtive distance travelled along the attribute vectors from different areas represent the relative differences in performances among them. Residential areas perceived to be similar as they are close to each other. They perform similarly with respect to the pH and EC. For commercial and industrial areas the relative distance from EC and pH are much greater then residential areas. In that case rasidential areas and commercial areas are perceived to be dissimilar to each other.

Water quality parameters such as SS and turbidity are very close to each other. Thats why they are highly correlated with each other. Industrial areas are close to SS and turbidity. So, they exibited high correlation with SS and turbidity. Residential areas and commercial areas perform similarly withb respect to SS and turbidity. Residential and industrial areas are performed similar with respect to BOD value as their relative distance from attribute vector are same. Commercial areas are highly influecend by BOD as they are very close to each other.

From the discussion, in short, for residential area pH is the most influential factor, where in commercial area BOD is the most significant water quality parameter. Industrial areas are highly influenced by suspended solids and tyrbidity. Industrial sites contributed substantially higher value of SS compared to the other. For example, mean SS from the industrial sites were comparable around 395mg/L while mean SS from residential area was 116.75 mg/L (Table 3).

4. CONCLUSIONS

There are differences in the results of the data analysis among the land uses. A number of reasons behind to this situation. Comparing the three different urban forms, industrial area has the most adverse footprints. This is based on the concentration of various pollutants, their high variability etc.
Turbidity and SS are the major pollutant from surface runoff. Turbidity and SS value of industrial area is comparatively higher than the other areas. Excessive use of chemical, industrial production of fine particles such as cement, lime etc. increases the value of water quality parameters such as SS, turbidity, conductivity in industrial area. For the residential areas, the variance of pH is more than other water quality parameters. pH is the prime influencing factors for residential areas. The highest BOD value was recorded in commercial lands. The BOD value was recorded in commercial area is greater than residential and industrial areas. The study results will provide guideline to the storm water management authority for selection of suitable treatment system or management system for different land uses in Rajshahi city.

REFERENCES

Soni , H.B. (2019). Catagories,causes and control of water pollution. *International Journal of Life Sciences Leaflets,*107: 4-12. (ISSN: 2277-4297).

Sarukkalige, P.R. (2011). Characteristics of storm water runoff in different land uses areas. *Journal of 2nd International Conference on Environmental Science and Development IPCBEE,* vol. 4, No.1, pp. 301-304.

Guzman, C.P., Mora, M., Gerena, J. and Becerra, P. (2018). Impact of land use on runoff quality in Bogota, Colombia. *Journal of Applied Environmental Sciences, vol. 13, No. 4, pp.65-372.*

Khatun, A., Bhattachariyya, K.G. and Sharma, H.P. (2014). Variability of pollutant build-up in different land uses of Guwahati city, Assam, India. *International journal of Scientific and Research Publication, vol. 4, ISSN 2250-3153.*

Jarvelainen, J. (2014). Land use based storm water pollutant load estimation and monitoring system design in Lahti city, Finland. *Aalto University Schools of Technology.*

Maharjan, B., Pachel, K. and Loigu, E. (2017). Modeling storm water runoff, quality and pollutant loads in a large urban catchment. *Journal of Proceedings of the Estonian Academy of Sciences, vol. 66, No. 3, pp. 225-242.*

*Lucke, T., Drapper, D. and Hornbuckle, A. (2018). U*rban storm water characterization and nitrogen composition from a largescale catchment. *Journal of Science of the Total Environment 619- 620, pp. 65-71.*

An Liu (2011). Influence of rainfall and catchment characteristics quality on urban storm water quality. *Queensland University of Technology.*

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COLOR REMOVAL FROM INDUSTRIAL WASTEWATER BY ADSORPTION USING BANANA LEAVES ASH

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ABSTRACT

This paper presents the feasibility of removal of basic dye Methylene Blue from aqueous solutions by using a low cost natural adsorbent banana leaves ash in batch adsorption technique. The adsorption experiments were carried out under different conditions of shaking time, shaking speed, pH, incubation temperature and centrifuging time. All batch experiments were carried out with adsorbent dosage of 16 mg/100 ml of aqueous solution of dye. It was found that banana leaves ash with particle sizes varying from 0.053-0.075 mm was found to have a high adsorptive capacity towards Methylene blue dye and show favourable adsorption of MB dye. The highest removal of color is 87.66% was obtained through the experiment by shaking at 350 rpm for 3 hours, 6.30 pH and 30^{o}C temperature. Therefore, it could be mentioned that the banana leaves ash can be used as locally available low cost adsorbent for the removal of synthetic dye from dying industry effluent.

Keywords: *Wastewater, Adsorption, Color removal, Banana leaves ash, Batch adsorption.*

1. INTRODUCTION

During the last few decades the mobility and distribution of dyes in water have been studied extensively due to their toxic effects to humans, animals, plants and the aquatic organisms. Many of the industries, such as dyestuffs, textile, paper, leather, foodstuffs, cosmetics, rubber and plastics are using enormous quantity of synthetic dyes in order to give colour for their products and consume substantial volumes of water. It is estimated that there are about 10,000 different commercial dyes and pigments exist and over $7x10^5$ tones of synthetic dyes are produced annually world-wide (Shitu and Ibrahim, 2014). Approximately 40,000 tonnes of dyes out of roughly 450,000 tonnes in total production are not used but discharged into wastewaters. A large variety of dyestuffs is available under the categories of acid, basic, reactive, direct, disperse, sulphur and metallic dyes. Textile and dyeing industry are among important sources for the continuous pollution of the aquatic environment. Because they produce approximately 5% of them, end up in effluents. The textile and dyeing industries effluents are discarded into rivers, ponds and lakes; they affect the biological life various organisms.

Dye-containing effluents are undesirable wastewaters because they contain high levels of chemicals, suspended solids, and toxic compounds. Colour causing compounds can react with metal ions to form substances which are very toxic to aquatic flora and fauna and cause many water borne diseases. The color is the first contaminant to be recognized in wastewater. Effluents with small amounts of dye can cause local environmental problems and at the same time might significantly affect the aquatic life, leading to decrease growth of bacteria and hence decreasing the bio-degradation of impurities in water. The release of untreated colored wastewater into the ecosystem can seriously be damaging to the receiving water bodies. The presence of even very small amounts of dyes in water (less than 1ppm for some dyes) is highly visible and undesirable (Banat, et al, 1996). Because of their synthetic and toxic nature, dyes have a severe impact on human health, causing many problems, such as allergies, dermatitis, skin irritation, caner and mutations (Nasuha, et al., 2010). Hence, it is necessary to treat the industrial effluents to reduce the concentration of color prior to its release into environment.

Various methods of dye/color removal such as aerobic and anaerobic microbial degradation, coagulation, and chemical oxidation, membrane separation process, electrochemical, dilution, filtration, flotation, softening, adsorption and reverse osmosis have been proposed from time to time. The advantages and disadvantages of each method have been extensively reviewed (Lorenc et al., 2007; Cooper, 1993). However, all of these methods suffered with one or more limitation and none of these were successful in removing color from the wastewater completely. Although biological treatment processes remove biochemical oxygen demand (BOD), chemical oxygen demand (COD) and suspended solids (SS) to some extent, they are largely ineffective in removing color from wastewater because most of these are toxic to the organisms used in the process. The coagulation process effectively decolorizes insoluble dyes but fails to work well with soluble dyes. Photochemical degradation in aqueous solution is likely to progress slowly because synthetic dyes are in principle designed to possess a high stability to light. Accordingly, the removal of dyes from effluent in an economic fashion remains a major problem. The convectional biological treatment process is not very effective in treating a dyes wastewater, due to low biodegradation of dyes. However, these processes were very expensive and could not be effectively used to treat the wide range of dyes waste (Garg and Babu, 2003).

Many of the methods are available for the removal of pollutants from water, of these methods, adsorption technique is a most versatile and widely used technique (Gupta et al, 2009), because of its inexpensive nature and ease of use. It is an effective method of lowering the concentration of dissolved dyes in the effluent resulting in color removal. Adsorption systems are rapidly gaining prominence as treatment processes that produce good quality effluents that are low in concentration of dissolved organic compounds such as dyes. The process of adsorption has an edge over the other methods due to its sludge free clean operation and completely removed dyes even from the diluted solution (Malik, 2003). Activated carbon (powdered or granular) is extensively used as an adsorbent due to its high level of effectiveness and has excellent adsorption efficiency for the organic compound, extended surface area, micro porous structure, high capacity and high degree of reactivity. However, commercially available activated carbons are very expensive (Malik, 2003). This has led many researchers to search for inexpensive and locally available adsorbents so that the process can become economically feasible.A wide variety of low cost material such as Wool Fiber and Cotton Fiber, Banana pith (Namasivayam, and Kanchana, 1993; Namasivayam, et al., 1993), Biogas residual slurry (Namasivayam and Yamuna, 1992a,b), Carbonized coir pith (Namasivayam, et al, 2001a,b), Coir pith (Namasivayam. and Kavitha, 2002), Hardwood (Asfour, et al, 1985), Mahogany sawdust, rice husk (Namasivayam, et al, 1992b), Parthenium hysterophorus (Rajeshwarisivaraj and Subburam, 2002), Neem (*AzadirachtaIndica*) husk (Alau, et al, 2010), Rice husk (Singh and Srivastava, 2001), Silk cotton hull, coconut tree sawdust (Kadirvelu, et al, 2003), Gypsum (Rauf, et al, 2009), Tamarind Fruit Shell (Saha, 2010) are used as low cost alternatives to activated carbon. The development of low cost alternative adsorbent has been the focus of recent research.

Here, the use of banana leaves ash as an adsorbent for the removal of a basic dye, Methylene Blue, is proposed. Banana leaf is a naturally occurring substance which is locally available in plenty of Bangladesh; when it is burnt to a suitable temperature, turns into ashes. Therefore, this study focuses on exploring the potential adsorbent from banana leaves ash for the removal of colorfrom aqueous solution of Methylene Blue dye through adsorption batch studies. Therefore, the main aim of the study is to find the influence of different parameters; such as shaking time, shaking speed, pH of solution, incubation temperature and centrifuging time on adsorption for color removal from MB dye solution.

2. METHODOLOGY

2.1 Material Collection and Preparation of Adsorbent

A lot of agricultural products and byproducts are producing throughout the year abundantly in Bangladesh. In this study, locally available Banana leaves are collected from locality of Rajshahi city, Bangladesh. The collected banana leaves are completely dried under the sun shine and burnt to obtain ash in present of oxygen. The powdered banana leaves ash is sieved through sieve no. 200 to get the desired particle size in between 0.053-0.075 mm of adsorbent. The sample is stored in air tight container. Physical characteristics of banana leaf and its ash are presented in Table 1.

Table 1: Characteristics of banana leaf and its ash

Ash content of leaf (%)	**Bulk density (g/cm^3)**	**Dry density (g/cm^3)**	**Moisture content (%)**	**Particle size (mm)**
5.13	0.303	0.282	7.41	0.053-0.075

2.2 Preparation of Dye Solution

Methylene blue was purchased from scientific store, Rajshahi, Bangladesh. An accurately measured quantity (10 mg) of dye was dissolved in 1000 ml distilled water to prepare the solution for experimental analysis. The stock solution of dye is preserved in refrigerator below the temperature of 4^oC for conducting the laboratory scale treatment experiment.

2.3 Experimental Design

Five important process parameters shaking time, shaking speed, pH, incubation temperature and centrifuging time were selected from literature which could influence the removal of color from aqueous solution through adsorption process. Methylene Blue aqueous solution of 100 ml was taken in a beaker and required adsorbent dose of 16 mg was added with the solution according to Bari and Sultana (2016). The varying pH level was adjusted by using HCl and NaOH solution. Colour removal efficiency from aqueous solution of methylene blue is expressed in terms of percentage. All experiments were conducted in triplicate and average was taken. The experimental design is shown in Table 2.

Table 2: Experimental design

Parameters	**Variation**	**Fixed parameters**
Shaking time (min)	15, 30, 45, 60, 75, 90, 105, 120, 135 and 150.	Shaking speed: 200 rpm; Temp: 30 °C; p^H= 6.30
Shaking speed (rpm)	150, 200, 250, 300 and 350.	Shaking time: 3 hours; p^H= 6.30, Temp: 30 °C
P^H	5.30, 6.30, 7.30, 8.30 and 9.30	Shaking speed: 200 rpm; Shaking time: 3 hours; Temp: 30 °C
Incubation temperature (°C)	20, 30,40, 50 and 60	Shaking speed: 200 rpm; Shaking time: 3 hours; p^H= 6.30
Centrifuging time (min)	3, 6, 9, 12 and 15	Shaking speed: 200 rpm; Shaking time: 3 hours; p^H= 6.30; Temp: 30 °C

3. RESULTS AND DISCUSSION

The experiment for the color removal from aqueous solution, Methylene blue is carried out following batch adsorption process with five different varying parameters of shaking time, shaking speed, P^H, incubation temperature and centrifuging time. The absorbent dose is kept constant as 16 mg/100 ml of solution. The highest efficient parameter is selected from the batch experiment. The experimental results are presented and discussed in following sections.

3.1 Effect of Shaking Time

The shaking time of adsorbent with colored aqueous solution is one of the important parameters for the removal of color. Orbital rotary shaker was used to facilitate the intimate contact of adsorbent with dye solution. The contact time was varied at ten levels from 15 minutes to 150 minutes. The adsorbent dose was used of 16 mg/100 ml and shaking speed was maintained at 200 rpm. The experiment was carried out at natural solution of pH measured at 6.30. The results are presented in Figure 1.

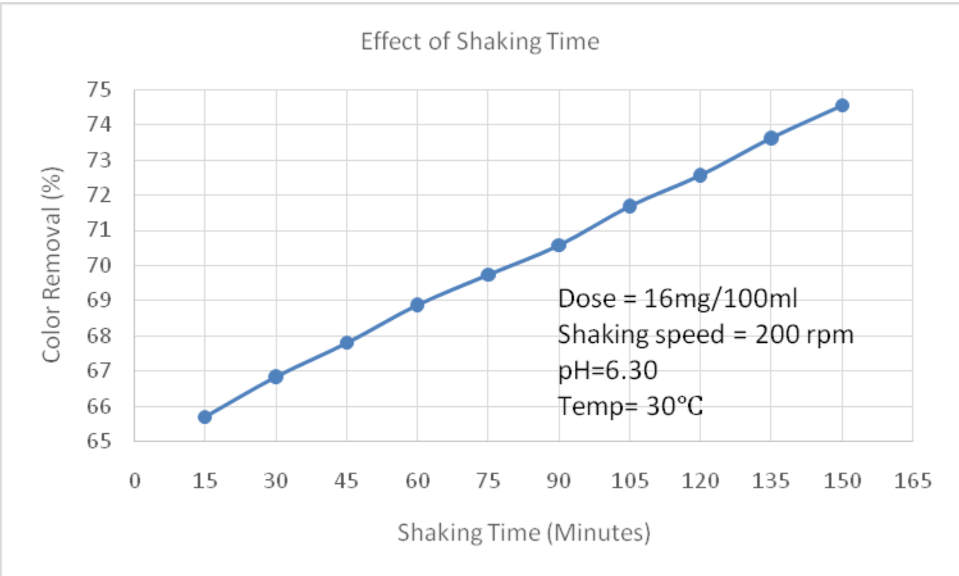

Figure 1: Effect of shaking time on removal of color from aqueous solution

The Figure 1 shows that the color removal efficiency is gradually increasing with the increase of shaking time. It can be said that the active surfaces of adsorbent are coming in intimate contact with the color particles those are gradually adsorbed on the surface. However, the removal was not reached to the equilibrium state within the experimental duration. It is evident that more contact time is required to reach in equilibrium. Moreover, though the experiment was not reached to the equilibrium, it is clear from the result that shaking time plays an important role in color removal.

3.2 Effect of Shaking Speed

Shaking speed is very important factor for influencing adsorption or de-adsorption of dye particle with adsorbent. The shaking speed is one of the mass transfer parameter in the bio-sorption phenomenon, influencing the distribution of the solute in the bulk solution and formation of the external boundary film (Khodaie, et al., 2013; Farah and El-Gendy, 2013). The speed was varied from 150 rpm to 350 rpm at five levels. The average results are presented by plotting in Figure 2. The removal of color increases with the increase of mixing speed and the highest removal of about 87.66% was found at 350 rpm speed.

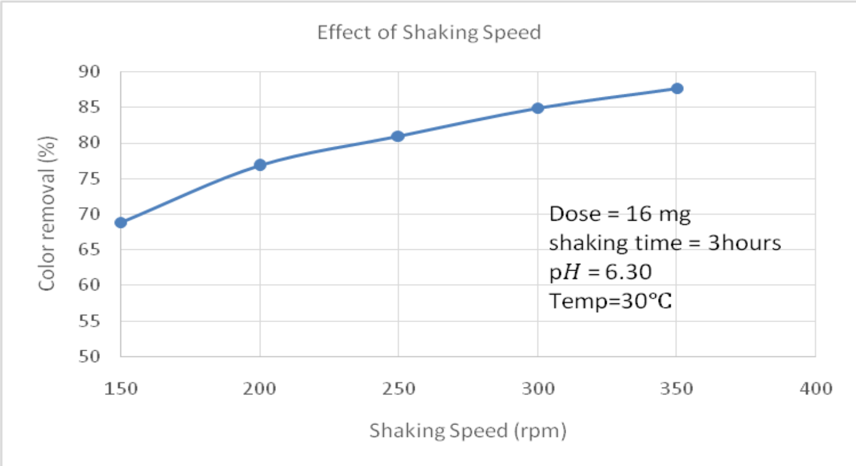

Figure 2: Effect of shaking speed on removal of color from aqueous solution

3.3 Effect of pH

The pH is the most important factor affecting the adsorption process. The actual pH of the solution was recorded as 6.30. The pH was varied from 5.30 to 9.30 with five levels set for this experiment. The obtained results of color removal are presented in Figure 3. The removal of color was induced with lowering of pH and increased with rising of pH from 6.3. The color removal was obtained of 65.50% at pH of 5.30 and the highest of 80.67% at pH of 9.30.

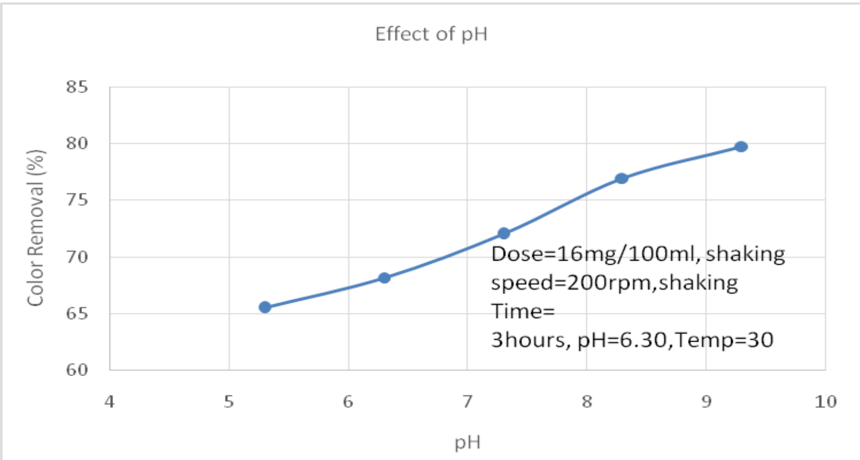

Figure 3: Effect of pH on removal of color from aqueous solution

3.4 Effect of Incubation Temperature

To observe any of variation of temperature on removal efficiency of color with locally available selected adsorbent, aqueous dye solution with adsorbent was incubated at varying temperature of 20℃, 30℃, 40℃, 50℃ and 60℃. The effect of variation of incubation temperature is presented in Figure 4. It was observed from the experiment that the removal of color decreased with the increase of incubation temperature.

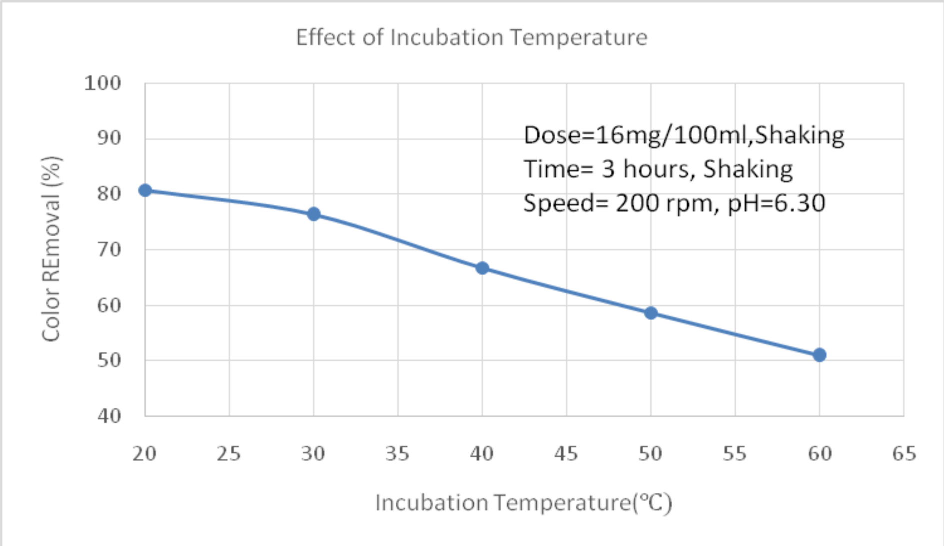

Figure 4: Effect of incubation temperature on removal of color from aqueous solution

3.5 Effect of Centrifuging Time

Centrifuging was used to separate the solid and liquid phase from aqueous solution methylene blue with adsorbent in order to determine the percentage of color removal from aqueous solution. The effects of centrifuging time on the removal of dyes are illustrated in Figure 5. From the experimental results, it can be seen that the percentage of color removal is increased with the centrifuging time. The color removal increased from 69.22% to 82.40% with 12 minutes of centrifuging at 9000 rpm. This indicates that the removal efficiency is higher as the centrifuging time is prolonged until equilibrium is reached. Moreover, color removal efficiency was reduced at 15 minutes of centrifuging time.

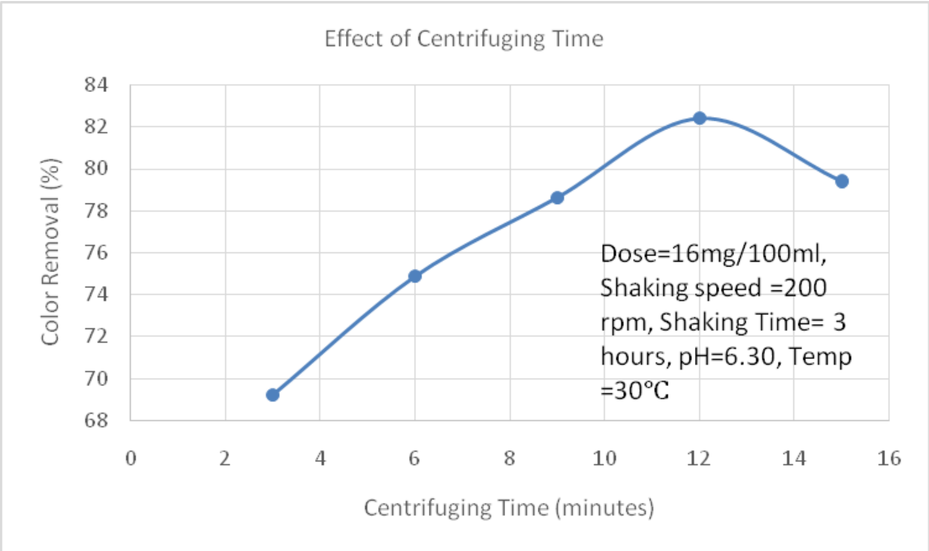

Figure 5: Effect of centrifuging time on removal of color from aqueous solution

4. CONCLUSIONS

Dying industries are producing huge quantity of effluent containing synthetic dye elements. Indiscriminately this colored wastewater is reaching to the environment and polluting the environment that becomes threat to the flora and fauna. Dye wastewater effluent is one of the major contributors to a variety of water pollution problems. Various measures and scientific techniques have been taken for the removal of dyes from wastewater. Adsorption technique has been used in this study and tried to develop a protocol for the removal of dye elements from the colored wastewater by using a locally available low-cost material banana leaves ash as adsorbent. Five parameters, shaking time, shaking speed, p^H, incubation temperature and centrifuging time were considered as the controlling factors. The highest color removal of 87.66% was achieved at shaking speed of 350 rpm for 3 hours, incubation temperature of 20^{o}C, pH of 9.3 and centrifuging time of 12 minutes at 9000 rpm while particle size of banana leaves ash was maintained between 0.053-0.075 mm. Therefore, inexpensive and widely available banana leaves ash can be used as potential adsorbent for the removal of color from effluent discharges from dying and textile industry.

REFERENCES

Alau, K.K., Gimba, C.E., Kagbu, J.A. (2010). "Removal of Dye from Aqueous Solution using Neem (AzadirachtaIndica) Husk as Activated Carbon. Archives of Applied Science Research, 2(5), 456-461.

Asfour, H.M., Fadali, O.A., Nassar, M.M., El-Geundi, M.S. (1985). "Equilibrium studies on adsorption of basic dyes on hardwood." Journal of Chemical Technology and Biotechnology, 35(1), 21-27.

Banat I.M., Nigam P., Singh D., Marchant R. (1996). "Microbial Decolorization of Textile Dye Containing Effluents: A review", Bioresour. Technol., 58, 217–227.

Bari, M.N. and Sultana, A. (2016). "Selection of potential absorbent from locally available materials for the removal of color from the industrial wastewater". Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD-2016), 12~14 February 2016, KUET, Khulna, Bangladesh.

Farah, J.Y. and El-Gendy, N.S. (2013). Performance, kinetics and equilibrium in biosorption of anionic dye Acid Red 14 by the waste biomass of Saccharomyces cerevisiae as a low-cost biosorbent. Turkish Journal of Engineering & Environmental Sciences. 37: 146 - 161

Garg, V.K., Gupta, R., Yadav, A.B., Kumar, R. (2003). "Dye removal from aqueous solution by adsorption on treated sawdust". Biore-source Technology 89(2), 121–124.

Gupta S, Babu BV. (2009). "Modeling, simulation, and experimental validation for continuous Cr(VI) removal from aqueous solutions using sawdust as an adsorbent". Biores Technol 100(23):5633-40.

Kadirvelu, K., Kavipriya, M., Karthika, C., Radhika, M., Vennilamani, N., Pattabhi, S. (2003). "Utilization of various agricultural wastes for activated carbon preparation and application for the removal of dyes and metals ions from aqueous solutions".Bioresource Technology, 87(1), 129-132.

Khodaie, M., Ghasemi, N., Moradi, B. and Rahimi, M. (2013). "Removal of Methylene Blue from Wastewater by Adsorption onto $ZnCl_2$ Activated Corn Husk Carbon Equilibrium Studies". Journal of Chemistry, Article ID 383985, 6 pages. http://dx.doi.org/10.1155/2013/383985

Lorenc-Grabowska, E., & Gryglewicz, G. (2007). "Adsorption characteristics of Congo Red on coal-based mesoporous activated carbon". Dyes Pigments, 74, 34–40.

Malik, P. K. (2003). "Use of activated carbons prepared from sawdust and rice-husk for adsorption of acid dyes: a case study of acid yellow 36," Dyes and Pigments, vol. 56, no. 3, pp. 239-249.

Namasivayam, C. and Kavitha, D. (2002). "Removal of Congo Red from water by adsorption on to activated carbon prepared from coir pith, an agricultural solid waste." Dyes Pigments, 54(1), 47-58.

Namasivayam, C. and Yamuna, R.T. (1992a). "Removal of Rhodamine-B by biomass slurry from aqueous solution. Water Air and Soil pollution, 65(1-2), 133-139.

Namasivayam, C. and Yamuna, R.T. (1992b). "Removal of Congo Red from aqueous solution by biomass slurry." Journal of Chemical Technology and Biotechnology, 53(2), 153-157.

Namasivayam, C., and Kanchana, N. (1993). “Removal of Congo red from aqeous solution by waste banana pith.” Journal of Science and Technology, 1(1), 33-42.

Namasivayam, C., Dinesh Kumar, M., Selvi, K., Ashruffunissa Begum, R., T. Vanathi, T., Yamuna, R.T. (2001b). “Waste coir pith-a potential biomass for the treatment of dyeing wastewaters.” Biomass and Bioenergy, 21(6), 477-483.

Namasivayam, C., Kanchana, N., Yamuna, R.C. (1993). “Waste banana pith as adsorbent for the removal of Rhodamine-B from aqueous solution.” Waste Management, 13(1), 89-95.

Namasivayam, C., Radhika, R., Subba, S. (2001a). “Uptake of dyes by a promising locally available agricultural solid waste: coir pith.” Waste Management, 21(4), 381-387.

Nasuha N, Hameed BH, Din ATM.(2010). “Rejected tea as a potential low cost adsorbent for the removal of methylene blue”. J Hazard Mater 175:126-32.

Rajeshwarisivaraj, Subburam, V. (2002). “Activated parthenium carbon as an adsorbent for the removal of syes and heavy metal ions from aqueous solution.”Bioresource Technology, 85(2), 205-206.

Rauf M.A., Shehadeh I., Ahmed A. and Al-zamly A. (2009). “Removal of Methylene Blue from Aqueous Solution by Using Gypsum as a Low Cost Adsorbent”. World Acad. Sci. Eng. Technol., 31,604–609.

Saha, P. (2010). “Assessment on the Removal of Methylene Blue Dye using Tamarind Fruit Shell as Biosorbent.” Springer Science +Business Media B.V., 213, 287–299.

Shitu A. and Ibrahim A. (2014). “Removal of Methylene Blue Using Low Cost Adsorbent: A Review”. Res. J. Chem. Sci. Vol. 4(1), 91-102.

Singh, D.K., Srivastava, N. (2001). “Basic dye removal from wastewater by adsorption on rice husk carbon.” Indian Journal of Chemical Technology, 8(2), 133-139.

APPLICATION OF BIO COAGULANT ON DRINKING WATER TREATMENT

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ABSTRACT

Removal of turbidity is essential for treatment of surface water and is often carried out with coagulation using metal salts as aluminium sulphate. Natural coagulants have bright future and are concerned by many researchers because of their abundant source, low price, environment friendly, multifunction, and biodegradable nature in water purification. This study focused on the evaluation of plant-based natural coagulant sources, processes, effectiveness and relevant coagulating mechanisms for treatment of river and pond water. The raw water samples were collected from the Bhairab River near Fulbarigate and pond near the Khan Jahan Ali Hall, KUET.

In this study, Sajna seeds were selected as bio coagulant. The optimum dose for the sajna seeds coagulant was found as 32 and 24 mg/l for the river and pond water, respectively. It is found that the turbidity removal efficiencies of the coagulants are varied from 96.0 to 96.5%, 90.8 to 86.3% with compared to alum coagulation for river and pond water, respectively. The color removal efficiencies of the coagulants are varied from 83.6 to 86.6%, 77.1 to 81.2% with compared to alum coagulation for river and pond water, respectively. It is also observed that the turbidity and color removal efficiency linearly decreases with increasing values initial values of raw water for both river and pond water. This study showed the performances of bio-coagulant such as Sajna seeds are used for the treatment of pond and river water. It is concluded that the turbidity and color removal efficiencies are satisfactory for the coagulant which is significant for use as a coagulant in water treatment purpose. Linear correlations for the turbidity and color removal efficiencies are also proposed.

Such bio-coagulants have found a high degree of significance for use as a coagulant in water treatment purpose. The main advantages of using natural plant based coagulants as water treatment material are apparent; they are cost-effective, unlikely to produce treated water with extreme pH and highly bio-degradable. The use of bio-coagulant would be a possible alternative to chemical coagulant for the same treatment of drinking water in rural areas and developing country like Bangladesh. Hence, it is concluded that these natural coagulant such as Sajna seeds could be used as coagulant for surface water treatment purpose.

Keywords: *Coagulation, Bio-coagulant, Turbidity removal, Color removal, Water treatment.*

1. INTRODUCTION

Water is essential for human survival. It has been reported that the total amount of water in the world is about 1400 million cubic km and remains constant. Apparently, more than 97% of this total volume is seawater of the rest 22% is ground water and 97% is ice locked away in the glaciers and the polar ice cap. This obviously leaves less than 1% of the supply of fresh water (Gleick, 1996).Most of the fresh water is polluted. In many developing counties, access to clean and safe water is a crucial issue. Pollution has increased alarmingly, in both developed countries (groundwater severely threatened by industrial and agricultural waste) and poor countries (domestic or agricultural waste in aqueous medium without treatment, poor waste management).This qualitative and quantitative degradation of water resources becomes a big problem in the water sector especially for developing countries. This problem is critical in Bangladesh. About more than 80% of people in Bangladesh lack clean, safe water. One of the problems with treatment of surface water is large seasonal variation of turbidity. Chemical coagulation is one of the most popular and effective methods for suspended particle and turbidity removal. However, these reagents may exert a negative impact on health as applied to drinking water treatment because they leave harmful monomer, aluminum, and unwanted side products in effluent, especially for excessive usage (Srinivasan and Viraraghavan, 2002). More than 99% of the coagulants used in drinking water treatment fall into the aluminum series. Even though they possess good particle removal efficiency, these coagulants may contaminate drinking water via aluminum residue, which has been recognized as a factor in Alzheimer's disease (Mclachlan, 1995).

1.2 Objectives of The Study

The main objectives of the study are given as follow:

- To choose suitable bio-coagulant for the treatment of surface water for drinking purpose.
- To study the turbidity removal capacity of the selected bio-coagulant.
- To study the color removal capacity of the bio-coagulant.
- To check the efficiency of the bio-coagulants with respect to traditional alum ($K_2\ [SO_4].Al_2\ [SO_4]_3.24H_2O$) coagulation.

2. METHODOLOGY

Firstly, the raw water samples were collected from the Bhairab River and KUET pond (near Khan Jahan Ali Hall). SAJNA (*M. oleifera))* seeds were taken as locally available bio-coagulant. The following tasks were performed:

- Collection of raw water sample from different areas of the Bhairab River and KUET pond.
- Selection of SAJNA (*M. oleifera)* as bio-coagulant.
- Preparation of bio-coagulant.
- Determination of water quality parameters (turbidity, color, pH and conductivity) of collected sample.
- Performing of Jar test (coagulation) for both seeds for both river water and pond water sample.
- Determination of optimum dose for the turbidity and color removal capacity for the selected bio-coagulants.
- Analyzing the test results and plotting relevant graphs.
- Analyze the efficiency of Sajna seeds as bio coagulants with respect to traditional chemical alum coagulant.

2.1 Selection of Coagulants

There are different types of naturally available bio-coagulant like Sajna or Drumstick Seed (*Moringa oleifera)*,Neem seed (*Azadirachta indica*) organic PAC (Polyaluminium chloride),*Acanthocereus tetragonus*, Aloevera leaf, Chitosan, Anionic polymer, Cationic polymer, Non-ionic polymer, *Cicer arietinum*, *Delonixregia*, *Dolichosl lablab*, PG-M (hybride type), *S.potatorum* (seeds of nirmali trees), guar plant (*Cyamopsis tetragonoloba*), tamarind tree (*Tamerindous indica*), fenugreek (*Trigonella* *foenum*), Redsorrel plant (*Hibisicus sabdariffa*), *Strychnos potatorum*, *Cactus* species, *Phaseolus vulgaris*, maize seed, tannin, gum arabic, *Prosopis juliflora* and *Ipomoea dasysperma* seed gum, as coagulants. *Moringa oleifera* or locally named Sajna seeds were selected as bio-coagulant due to their availability in Khulna district and cost effective. Alum is selected as chemical coagulant. It is a common coagulant available in local market and cheaper than other chemical coagulants.

2.2 Collection of Raw Water Sample

The raw water samples were collected from the Bhairab River located at Fulbarigate of Khulna and pond near the Khan Jahan Ali Hall at Khulna University of Engineering & Technology, Khulna. Raw water was collected from different locations of the sources in order to maintain varying turbidity. The river water sample is turbid in whole the year due to high amount of silt carried by the river and also due to the low depth of river in some places water is super turbid.

Figure 1: Typical map of Bhairab River

Table 1: The source and time of sample collection

Source	Date	Time	Temperature	Remarks
KUET Pond ($22^0$54'03.0" N $89^0$29'58.0" E)	2.2.2017	10 am	25.0^0 C	P1
	5.2.2017	10.30 am	26.5^0 C	P2
	7.2.2017	11.40 am	27.5^0 C	P3
	24.4.2017	5.00 pm	33.0^0 C	P4
	25.4.2017	4.30 Pm	33.5^0 C	P5
Bhairab River ($22^0$53'56.4" N $89^0$31'06.8" E)	3.2.2017	5.00 pm	25.5^0 C	R1
	4.2.2017	5.00 pm	27.0^0 C	R2
	8.2.2017	9.00 am	28.5^0 C	R3
	23.4.2017	5.30 pm	32.5^0 C	R4
	24.4.2017	10 am	33.0^0 C	R5

2.3 Preparation of Bio-Coagulant

The collected seed was vigorously washed thoroughly tap water. The seeds were naturally sun dried for 2-3 days. Then the outer cover the seed kernels were removed and the kernels were converted into powder using a blender. The prepared powders were used for each batch run. The jar test operations using different coagulants were carried out in different turbidity ranges. Turbidity was measured before and after treatment.

Figure 2: Sajna (*Moringa oleifera*) seeds and prepared powder

2.4 Test for Physical and Chemical Properties of Raw and Treated Water

At first the physical and chemical properties such as pH, color, conductivity and turbidity of the raw water were tested by pH meter sension-156, conductivity meter sension-5 and turbidity meter, respectively. Then the indicated doses (Table 3.2) for each coagulant were applied in the 6 nos. of beakers containing 500 ml of raw water. The filled jars were then placed on the gang stirrer, with the paddles positioned identically in each beaker. The first beaker was left as a blank one and increasing dosages of the first coagulant was added to subsequent beakers. Coagulants were injected as quickly as possible, below the liquid level and about halfway between the stirrer shaft and beaker wall. The mixing speed was increased to 100 rpm for 3minutes (rapid mix). The mixing was reduced to 20 rpm and continued the slow mix for 20 minutes. The mixer was turned off and allowed settling to occur. After settling for a period of time of 1-hour supernatant appearance was noted. The jars were removed from the gang stirrer and the physical and chemical properties (i.e. turbidity, pH, conductivity and color) were tested again. Then the contents were emptied and thoroughly the beakers were cleaned. The above procedure was repeated for all collected samples, but substituting for the blank the dosage selected as providing the desired level of performance in the first series of test.

Table 2: Indicated doses for each coagulant

Coagulant	**Indicated doses for each coagulant (mg/l)**					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Sajna	0	8	16	24	32	40

Figure 3: Jar Test set

3. RESULTS AND DISCUSSION

This represents the experimental results of physical and chemical properties such as color and turbidity of treated water sample after the application of Sajna seeds as coagulant. Jar test is carried out to determine the optimum dose and removal efficiency of turbidity and color. This will also describe the merits of natural or bio-coagulant over chemical coagulant.

3.1 Physical and Chemical Properties of Treated Water

Water samples collected from both Bhairab River and pond (near the Khan Jahan Ali Hall at Khulna University of Engineering & Technology, Khulna) were treated using bio coagulant. For Bio-coagulation, Sajna seeds were used. The doses were varied from 0 to 40 with an increment of 8 mg/l for the Sajna seeds. Table 3 and Figure 4 show the variation of the turbidity of the river water after coagulation for the Sajna seeds coagulant, whereas Table 4 and Figure 5 show the variation of the turbidity of the pond water after coagulation for the same coagulant. It was seen that the optimum dose for the sajna seeds coagulant was found as 32 and 24 mg/l for the river and pond water, respectively.

Table 3: Variation of turbidity after each dosing of bio-coagulation with Sajna seeds (River Water)

Sample No.	**Initial Turbidity (NTU)**	**Turbidity after coagulation for indicated Sajna seeds doses (mg/l)**					
		0	8.0	16.0	24.0	32.0	40
R1	234	87.6	70.2	57.2	39.3	19.5	27.2
R2	288	92.4	73.3	61.2	45.3	27.7	34.5
R3	327	97.3	82.2	69.1	52.7	31.9	37.8
R4	447	120.7	91.7	75.2	53.5	44.8	48.2
R5	533	133.5	98.6	81.3	62.3	55.3	62.1

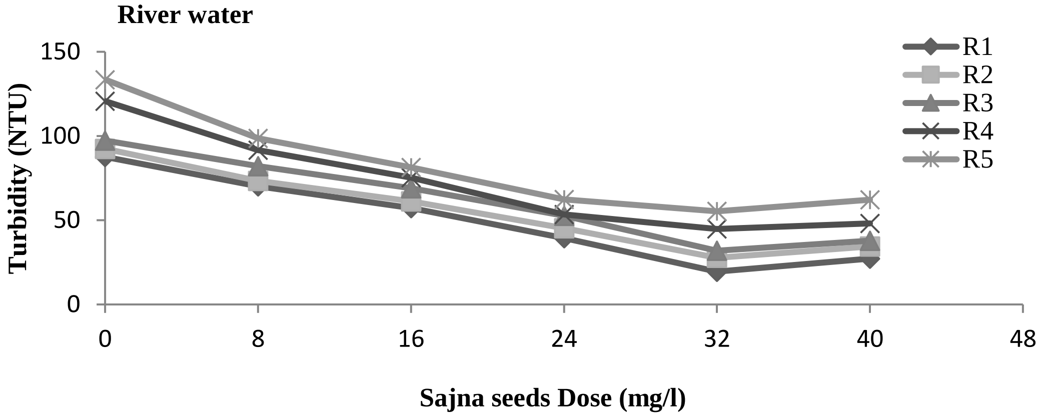

Figure 4: Variation of turbidity after bio-coagulation with Sajna seeds (River Water)

Table 4: Variation of turbidity after each dosing of bio-coagulation with Sajna seeds (Pond Water)

Sample No.	**Initial Turbidity (NTU)**	**Turbidity after coagulation for indicated sajna seeds doses (mg/l)**					
		0	8.0	16.0	24.0	32.0	40
P1	62	39.7	30.2	21.6	9.8	17.3	20.6
P2	79	59.6	38.5	31.7	13.3	24.2	31.3
P3	113	75.5	59.4	37.2	23.6	30.6	35.2
P4	148	81.9	64.9	48.9	31.3	37.7	43.9
P5	185	89.6	70.3	52.4	40.5	45.1	51.2

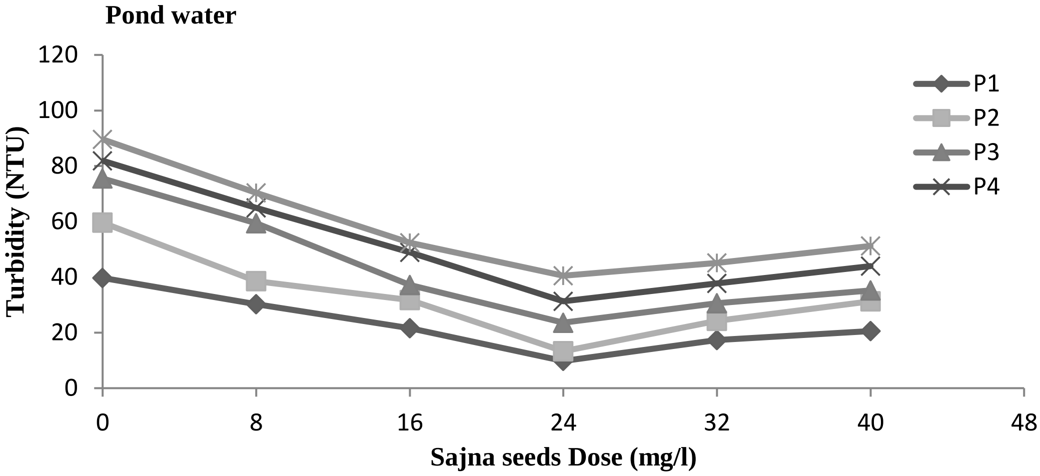

Figure 5: Variation of turbidity after bio-coagulation with Sajna seeds (Pond Water)

Table 5 and Figure 6 show the variation of the color of the river water after coagulation for the Sajna seeds coagulant, whereas Table 6 and Figure 7 show the variation of the color of the pond water after coagulation for the same coagulant. It was seen that the optimum dose for the Sajna seed coagulants were found as 32 and 24 mg/l for the river and pond water, respectively.

Table 5: Variation of color after each dosing of bio-coagulation with Sajna seeds (River Water)

Sample No.	Initial Color (Pt-Co)	Color after coagulation for indicated Sajna seeds doses (mg/l)					
		0	8.0	16.0	24.0	32.0	40
R1	407	252	210	173	146	88	116
R2	439	267	231	191	156	113	126
R3	488	287	268	220	184	134	147
R4	556	367	286	232	198	160	177
R5	674	443	320	276	227	201	236

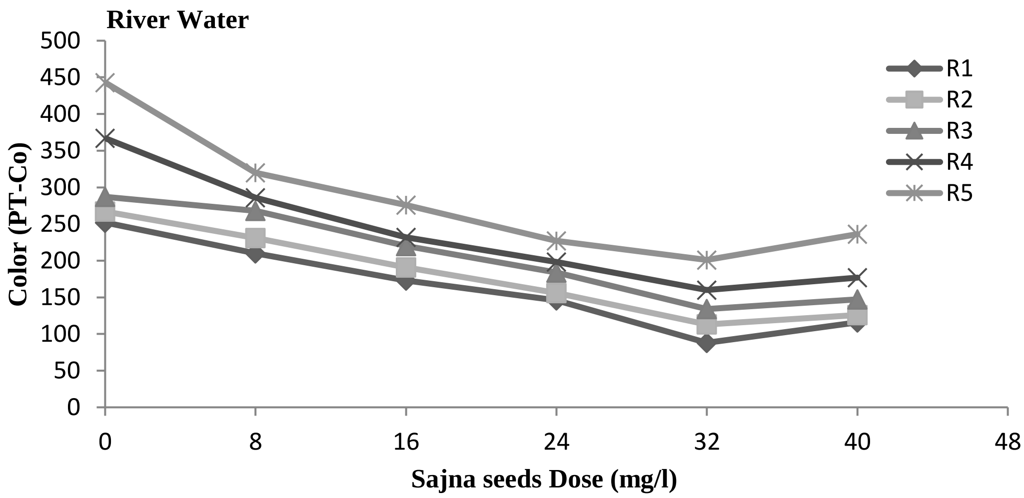

Figure 6: Variation of color after bio-coagulation with Sajna seeds (River Water)

Table 6: Variation of color after each dosing of bio-coagulation Sajna seeds (Pond Water)

Sample No.	Initial Color (Pt-Co)	Color after coagulation for indicated Sajna seeds doses (mg/l)					
		0	8.0	16.0	24.0	32.0	40
P1	170	92	76	59	37	53	68
P2	210	107	82	67	48	61	72
P3	270	131	95	78	62	69	78
P4	315	163	121	93	75	79	86
P5	332	178	136	102	89	92	101

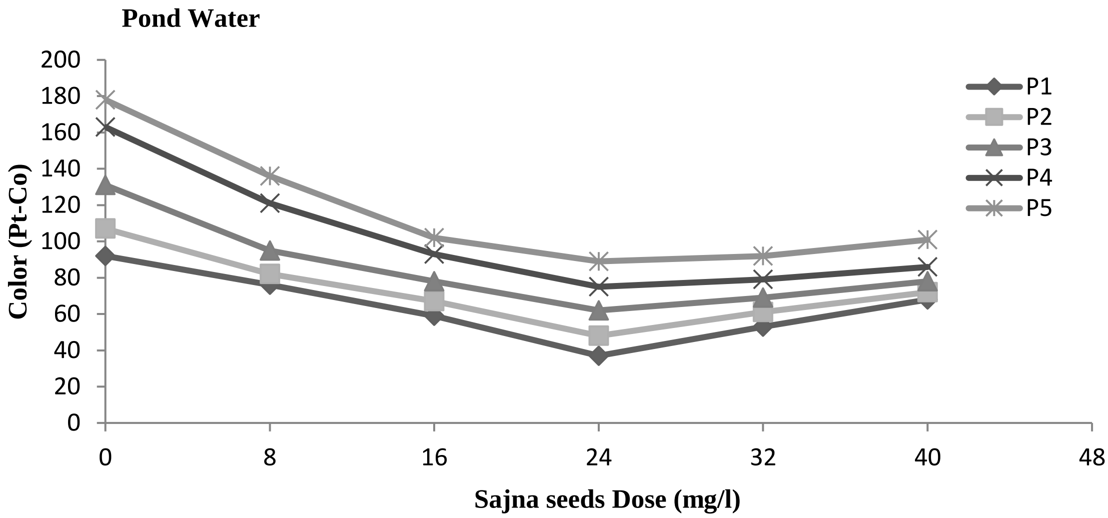

Figure 7: Variation of color after bio-coagulation with Sajna seeds (Pond Water)

3.2 Turbidity and Color Removal Efficiency of Coagulant

Turbidity and color removal efficiency of three coagulants alum, Sajna seeds were calculated from the values found in experiment.

$$Removal\ Efficiency\ (\%) = \frac{(A-B)}{A} \times 100 \tag{1}$$

Where, A = Initial value of raw water sample
B = Final value after the coagulation

It is found that the turbidity removal efficiencies of the coagulant are varied from 96.0 to 96.5%, 90.8 to 86.3% with compared to alum coagulation for river and pond water, respectively. The color removal efficiencies of the coagulants are varied from 83.6 to 86.6%, 77.1 to 81.2% with compared to alum coagulation for river and pond water, respectively.

Figure 8 show the variation of the turbidity removal efficiency for coagulants for river water respectively. It is seen that the efficiency linearly decreases with increasing initial turbidity. Linear correlations for the turbidity removal efficiency are proposed by Equations (2) to (5) for the all coagulants.

$$Sajna\ (river\ water): \quad y = 92.717 - 0.0064x; \quad R^2 = 0.93 \tag{2}$$
$$Alum\ \ (river\ water): \quad y = 96.707 - 0.0077x; \quad R^2 = 0.92 \tag{3}$$
$$Sajna\ (pond\ water): \quad y = 86.689 - 0.051x; \quad R^2 = 0.84 \tag{4}$$

$$Alum\ \ (pond\ water):\qquad y = 93.665 - 0.0181x;\quad R^2 = 0.95 \tag{5}$$

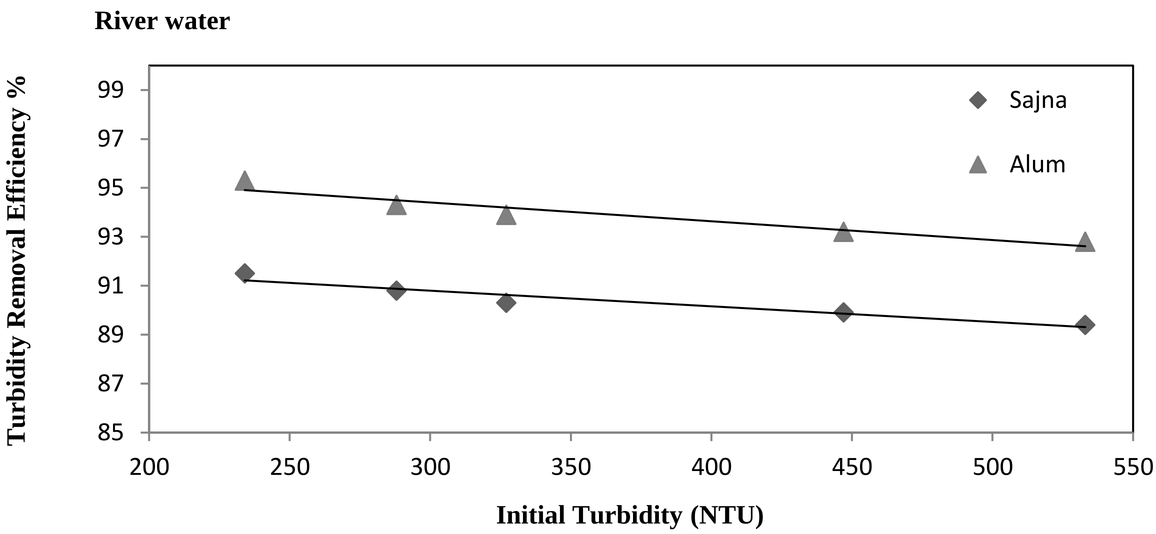

Figure 8: Variation of the turbidity removal efficiency for the coagulants (River water)

Figure 9 show the variation of the color removal efficiency for coagulants for river water. It is seen that the color removal efficiency linearly decreases with increasing initial color for both river and pond water. Linear correlations for the color removal efficiency are proposed by Equations (8) to (11) for the all coagulants.

Sajna (river water):	$y = 81.748 - 0.0137x;\quad R^2 = 0.92$	(8)
Alum (river water):	$y = 98.820 - 0.0235x;\quad R^2 = 0.91$	(9)
Sajna (pond water):	$y = 82.222 - 0.0219x;\quad R^2 = 0.86$	(10)
Alum (pond water):	$y = 97.605 - 0.0080x;\quad R^2 = 0.97$	(11)

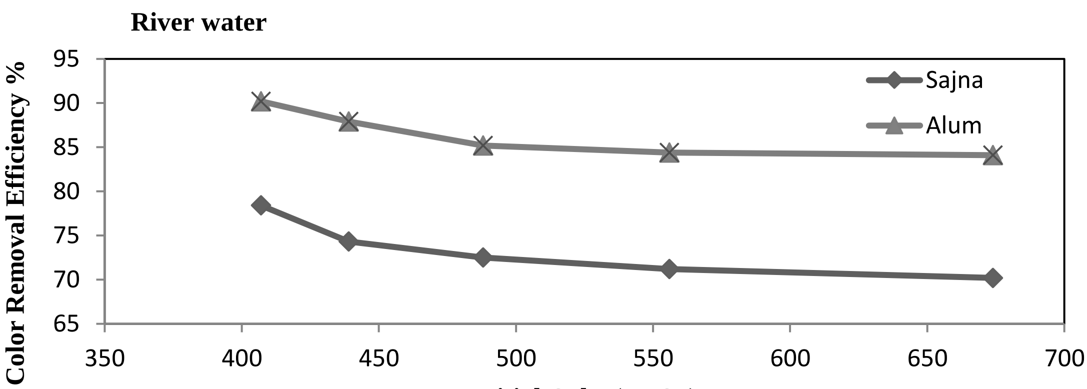

Figure 9: Variation of the color removal efficiency for the coagulants (River water)

4. CONCLUSIONS

This study showed the performances of bio-coagulant such as Sajna seeds which are used for the treatment of pond and river water. The optimum doses for the Sajna seeds coagulant was found as 32 and 24 mg/l for the river and pond water, respectively. The turbidity removal efficiencies of the coagulants are varied from 86.3 to 96% with compared to alum coagulation. It is found that the turbidity and color removal efficiencies (>70%) are satisfactory for the coagulant which is significant for use as a coagulant in water treatment purpose. The use of bio-coagulant would be a possible alternative to chemical coagulant for the same treatment of drinking water in rural areas and developing country like Bangladesh. Hence, it is concluded that these natural coagulant such as Sajna seeds could be used as coagulant for surface water treatment purpose.

4.1 Further Studies

Further studies are outlined as follows:

- In this study, performance study of bio-coagulant such as Sajna seeds are performed as coagulant. Similar research could be conducted using other easily available natural bio-coagulants.
- Some physical and chemical properties of water samples such as pH, turbidity, color and conductivity are analyzed. Some other important physical and chemical properties such as total solid, total dissolved solid, total suspended solids and Total coliform could also be analyzed.
- In this study, bio-coagulants are used for the treatment of drinking water only. Similar research could be conducted for industrial waste water treatment using bio-coagulant.

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REFERENCES

Ali, E. N., Muyibi, S. A., Salleh, H. M., and Alam, M. J. 2009. *Moringaoleifera* Seeds as Natural Coagulant for Water Treatment.Thirteenth International Water Technology Conference, P. 163-168.

Amagloh, F., and Benang, B. 2009. Effectiveness of *Moringaoleifera* seeds as Coagulant for Water Purification. African. Journal of Agric, Vol. 4 (1), P.119-123.

Antov, M.G., Šciban, M.B., and Petrovic, N.J. 2010. Proteins from Common Bean (Phaseolus Vulgaris) Seed as a Natural Coagulant for Potential Applicationin Water Turbidity Removal, Bioresour. Technol,Vol. 101, P. 2167–2172.

Antov, M.G., Šciban, M.B., and Prodanovic, J.M. 2012. Evaluationofthe Efficiency of Natural Coagulant Obtained by Ultrafiltrationof Common Bean Seed Extract in Water Turbidity Removal, Ecol. Eng, Vol. 49, P. 48–52.

Arnoldsson, E., Bergman, M., Matsinhe, N., and Persson, K. P.2008.Assessment of Drinking Water Treatment using *MoringaOleifera* Natural Coagulant. VATTEN, Vol. 64, P. 137–150.

Bakare, B. F. 2016. An Investigation of MoringaOleifera Seed Extract as a Natural Coagulant in Water Treatment. World Congress on Engineering and Computer Science, Vol. 2.

Crittenden, J.C., Trussell, R.R., Hand, D.W., Howe, K.J., and Tchobanoglous, G.2005. Water Treatment Principles and Design, 2nd Ed. John Wiley & Sons, Inc. Hoboken, New Jersey.

Gassenschmidt, U., Jany, K.D., Tauscher, B., and Niebergall, H.1995. Isolation andCharacterization of a flocculating protein from *Moringa oleifera* Lam. Biochimicaetbiophysicaacta, Vol. 1243. P. 477–481.

Ghebremichael, K.A., Gunaratna, K.R., Henriksson, H., Brumer, H., and Dalhammar, G. 2005. A Simple Purification and Activity Assay of the Coagulant Protein from *Moringaoleifera* Seed. Journal of Water Research, Vol. 39, P. 2338-2344.

Gleick, P. H., 1996. Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, Vol. 2, P.817-823.

Hellsinga, M. S., Kwaambwab, H.M., Nermarkc, F. M., Nkoanec, B. B.M., Jacksond, A. J. M. J., Wasbroughe, M. J.,Bertsg, F. I.,Porcarh,L.,and Renniea, A. R.2013. Structure of flocs of latex particles formed by addition of protein from*Moringa* seeds. Elsevier Journal of Colloids and Surfaces A: Physicochemical and Engineering Aspects.

Libanius, M. 2008. Fundamentals of Quality and Water Treatment. 2nd Ed. Campinas. Atom Ed, P. 444.

Lilliehöök, H. 2005. Use of sand filtration on river water flocculated with *Moringaoleifera*. Division of sanitary engineering, department of civil and environmental engineering, luleå, University of technology.

Magaji, U. F., Sahabi, D. M., Abubakar, M. K., and Muhammad, A. B. 2015. Biocoagulation Activity of *Moringaoleifera* Seeds for Water Treatment. The International Journal of Engineering and Science, Vol.4, P.19-26.

McLachlan, D. R. C. 1995. Aluminum and the risk for Alzheimer's disease, ActaCosmol, Vol. 6, P. 223–275.

Miller, S.M., Fugate, E.J., Craver, V.O., Smith, J.A., and Zimmerman, J.B. 2008. Toward Understanding the Efficacy and Mechanism ofOpuntia Spp. as a Natural Coagulant for Potential Applicationin Water Treatment. Environmental Science Technology, Vol. 42.

Muyibi, S. A., and Alfugara, A. M. S.2003. Treatment of Surface Water with *MoringaOleifera* seeds and alum – a comparative study using a pilot scale water treatment plant. International Journal of Environmental Studies, Vol. 60(6), P. 617–626.

Nandini, M., and Sheba, M. C. 2016. Emanating Trends in the Usage of Bio-coagulants in Potable Water Treatment: a Review. International Research Journal of Engineering and Technology, Vol. 3, (11), P. 970-974.

Ndabigengesere, A., Narasiah, S.K., and Talbot, B.G. 1995. Active Agents and Mechanism of Coagulationof Turbid Waters using. Water Research, Vol. 29, (2), P. 703-710.

Okoli,C., Boutonnet, M., Jaras, S., and Kuttuva, G. R. 2012. Protein-functionalized magnetic iron oxide nanoparticles: time efficient potential-water treatment. Journal of Nanoparticle, Vol.14, P. 1194-1203.

Richter, C.A. 2009. Water Methods and Treatment Technology. 1st Ed. São Paulo. Ed Blucher, P.333.

Rico, T. E. F., Santos, L. M., Reis, E. M., Silva, F. F., andZonetti, P. C. 2010. Treatment of Tannery Wastewater using Seeds of *Moringa* (*MoringaOleifera L.*). Agro Magazine Environment, Vol. 4, (2), P. 96-101.

Saharudin, N. F. A., and Nithyanandam, R.2014. Effluent Treatment by using Natural Coagulant. 2nd Eureka.

Schwarz, D. 2000. Water Clarification using *Moringaoleifera*. Technical Information W1e, Gate Information Service.Eschborn, Germany.

Sikkema, J., Bont, J. A. M., and Poolman, B. 1995. Mechanisms of Membrane Toxicity of Hydrocarbons. Journal of Microbiol, Vol. 59, P. 201-222.

Srinivasan, P. T., and Viraraghavan, T. 2002. Characterization and Concentration Profileof Aluminum during Drinking Water Treatment. Water SA, Vol. 28, P. 99–106.

Srinivasan, P. T., Viraraghavan, T., and Subramanian, K. S.1999. Characterization and concentrationProfileof Aluminum during Drinking Water Treatment. Water SA, Vol. 25, P. 47–56.

THE SEED OF BURMESE GRAPE (BACCAUREA RAMIFLORA) AS LOW-COST BIO-ADSORBENT FOR REMOVAL OF METHELYNE BLUE FROM WASTEWATER

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ABSTRACT

Treatment of the industrial wastewater containing dyes is becoming the concern of many conservationists. As dye containing effluent from industries has biological and environmental hazards, techniques for the removal of dyes from waste has been growing rapidly. Bio-adsorbent from divergent sources has been used as promising agent for removing the contaminants in wastewater due its availability, low-cost, biodegradability and nontoxicity. In this study the capacity of Burmese grape seeds as a low-cost bio-adsorbent for the removal of methylene blue from aqueous solution was explored. Batch adsorption experiments were performed with varying process parameters (pH, contact time and initial dye concentration) at ambient temperature. UV-vis spectrum analysis was performed to determine the change in concentrations of dye. Changes in adsorption capacity with varying pH was noticed and maximum sorption of methylene blue was found to be at pH 8. The adsorption rate was rapid for first 10 minutes of contact time and at 40 minutes the equilibrium condition was achieved and no further change was observed in concentrations with contact time. Kinetic studies showed good correlation coefficient (R^2=0.999) for a pseudo-second order kinetic model over the selected range of contact time (10-40 minutes). The removal mechanism was described by Langmuir isotherm model with a good fit (R^2=0.983). Maximum sorption capacity was calculated by Langmuir isotherm model and found to be163.93 mg/g. So, the results showed that if the process variable can be optimized, Burmese grape seeds can be a very effective adsorbent and have the potential to remove a significant amount of dye from industrial wastewater.

Keywords: *Dye, Burmese grape, Bio-adsorbent.*

1. INTRODUCTION

Rapid growth of textile industries in Bangladesh has led to economic growth but caused a serious problem to the adjacent water sources such as rivers. The disposal of dye waste water into fresh water as an effluent from textile industries causes severe damage to the aquatic environment (Hassaan et al. 2017; Gita et al. 2017). Furthermore, these dyes cause allergic reactions, dermal irritation and genetic mutation as a result of their toxic property (Daciana 2010).Several physico-chemical methods like coagulation/flocculation, membrane separation, electrochemical process, adsorption, ion exchange, irradiation, biological treatment and many others are used for removing dyes from wastewater (Chidambaram et al. 2015; Verma et al. 2012; Nidheesh et al. 2018; Gupta, 2009; Mohammed et al. 2014).Among these, adsorption is as an efficient and cost effective process as its initial cost and energy consumption is far less than other processes.

In recent years many adsorbents are used to remove dye from wastewater such as activated carbon, alumina composite, activated clay, kaolin, bentonite, red mud and many others (Adaket al. 2005; Kannan et al. 2001; Özcan et al. 2005; Nandi et al. 2008). Though they work very well the cost of these adsorbents are quite high. To make the process cost effective recently the focus of researchers is devoted to bio-adsorption process bio-adsorbents are found in vast amount. Moreover, bio-adsorbents are more selective and can reduce the dye concentration to ppb level (Mustafa et al. 2014). Some of the reported bio-adsorbents arejute fibre carbon (Senthilkumaar et al. 2005), coconut husk based activated carbon (Tamai et al. 1996), baker yeast (Yu et al. 2009), wheat straw (Batzitas et al. 2009), living biomass (Yu et al. 2000), algal biomass (Vilar et al. 2007) etc.

In this study, for the first time the feasibility of Burmese grape seed powder as bio-adsorbent for removal of methylene blue was investigated. Burmese grape (Baccaurea ramiflora) is a plant belongs to the family phyllanthaceae, most commonly cultivated in Burma, Bangladesh and India. The flesh of the fruit is eaten and the seeds are thrown away. These seeds can be used as potential adsorbent for dye removal. The implementation of this bio source must bring obvious social and economic benefit.

The research results on the removal of methylene blue from wastewater using Burmese Grape seeds are presented in this work. The effects of various parameters of adsorption such as contact time, initial pH, and dye concentration were monitored and optimal experimental conditions were determined. Moreover, the kinetic study based on pseudo second order kinetic model was done and the isotherm data were analysed using Langmuir isotherm model. The adsorption property of Burmese Grape seeds towards methylene blue is executed for the first time and this defines the novelty of this work.

2. EXPERIMENTAL METHODS

2.1 Adsorbent and Chemicals

Burmese Grape seeds were collected from local market and all other chemicals were of analytical grade. 100ppm methylene blue solution was prepared using methylene blue and diluted further using distilled for adsorption experiments. 0.1 mole/L HCl and 0.01 mole/L NaOH were used to adjust Ph.

2.2 Adsorbent Preparation

The collected Burmese Grape seeds were washed repeatedly with distilled water to remove dust and insoluble impurities. The seeds were air dried for 2 days and followed by microwaving at 600Hz for 4 minutes to ensure the removal of water. Then the seeds were grounded to fine particles for using in adsorption experiments.

2.3 Equilibrium Adsorption Studies

2.3.1 Effect of pH

This investigation was done to determine the optimum P^H. for methylene blue removal from water using seed of Burmese Grapes. In this study, 0.01 g of adsorbent was contacted with 50Ml 10 ppm dye solutions for 40 minutes for different PH.(5, 6, 7, 8 and 9). The PH. value was adjusted using HCl and NaOH solution. The mixture was centrifuged to separate the adsorbent and the supernatant solutions were analysed using UV-vis spectrophotometer.

2.3.2 Effect of Contact Time

Methylene blue removal capacity using the seeds was determined as a function of time to determine the optimum contact time. For this purpose, 50 Ml 20ppm methylene blue solution was contacted with 0.01 g adsorbent. The samples were collected at different time intervals (10, 20, 30, 40, 50 minutes) from the solution and centrifuged to separate the adsorbent with a view to analysing the samples.

2.3.3 Effect of Initial Concentration

It is well known fact that the adsorption capacity of adsorbent changes with the initial concentration of dye. To investigate this 0.01 g of adsorbent was contacted with methylene blue solutions, concentration ranging from 5 to 70 at regular intervals for 40 minutes. Then the treated water was centrifuges and analysed.

For adsorption experiments the removal capacity and adsorption capacity were calculated by equation 1 and 2 respectively,

$$\text{Removal percentage} = (C_0 - C_e)/C_0 \times 100\%$$

$$\text{Adsorption capacity} = (C_0 - C_e) \times V/m$$

where C_0 and C_e is initial concentration(mg/L) and equilibrium concentration(mg/L) respectively, V is the volume of solution(L) and m is the mass of adsorbent(g).

3. RESULTS AND DISCUSSION

3.1 Effect of pH.

Figure 1 illustrates the effect of Ph on methylene blue removal using Barmese Grapes seed as adsorbent. There was a rapid increase in the adsorption capacity with the increase of Ph from 5 to 8 and later decreased at 9. At Ph 8, the adsorption capacity was highest with the value of 34.8 mg/g. At lower Ph the surface of the adsorbent was surrounded by H^+ ions and these ions blocked the dyes from being captured by the adsorbent. At higher Ph the competition was decreased as the number of H^+ ions decreased with the increase in Ph.

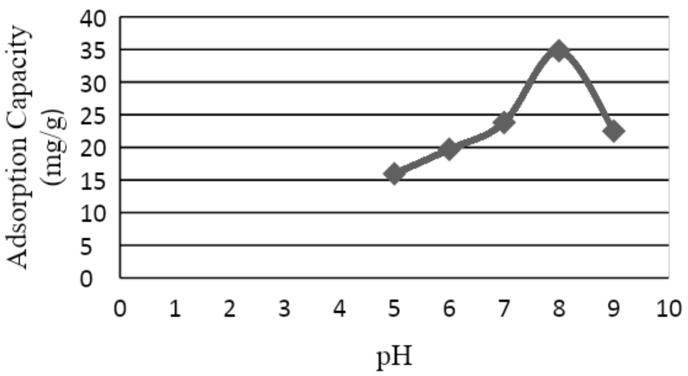

Figure 1: Effect of pH on the adsorption of methylene blue

3.2 Effect of Contact Time and Adsorption Kinetics

From figure 2, it can be seen that the adsorption rate was higher for first 10 minutes. Then the adsorption rate decreased with time as the available surface for dye was reducing with time. At 40 minutes the equilibrium condition was found and no further change was observed with time. Therefore, 40 minutes was chosen as the optimum adsorption time for dye removal.

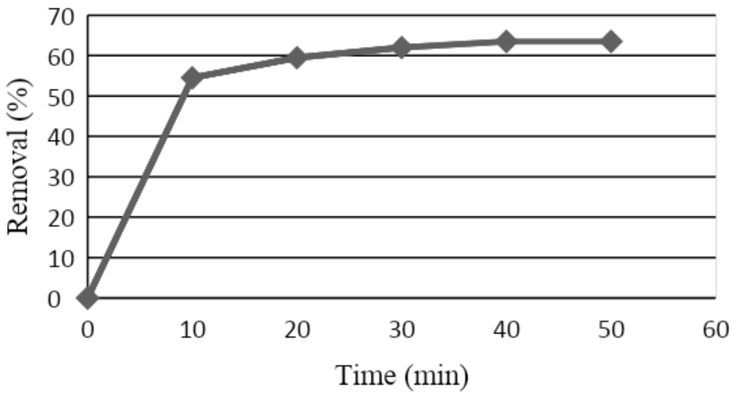

Figure 2: Effect of time on adsorption of methylene blue

Pseudo second order equation was used to analyse the kinetics of the adsorption process

$t/q_t=(1/k_2q_e^2)+(t/q_e)$

where q_t and q_e are the adsorption capacity (mg/g) at time t and at equilibrium respectively, and K_2 is the pseudo-second-order equilibrium rate constant (L mg^{-1} min^{-1}). The graphical interpretation of the data for pseudo second order kinetic model is shown in figure 3. A good fit of data (R^2=0.999) was observed which indicates that the adsorption process followed pseudo second order model and the process was chemisorption. The value for $k_2$and q_e were determined from the slope and intercept of the plot shown in fig. 3. The theoretical value of adsorption capacity (q_e) at equilibrium was 66.67 mg/g which is quite near to the value 63.5 mg/g, found from experimental procedure.

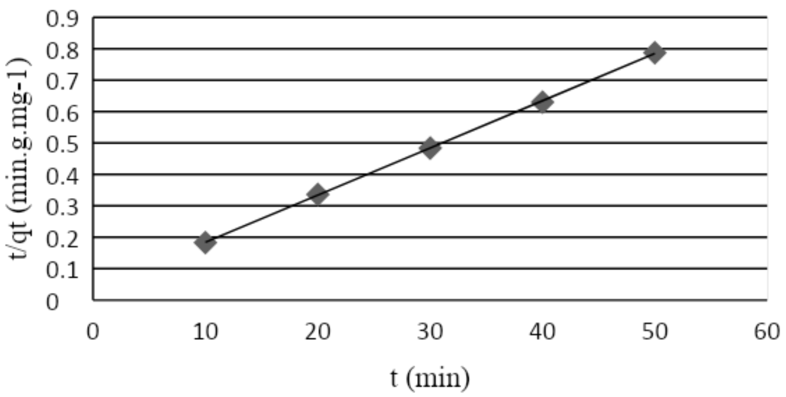

Figure 3: Pseudo-second order plot

3.3 Effect of Initial Concentration and Adsorption Isotherm

The effect of initial concentration of dye on adsorption performance was evaluated by varying the dye concentration. From figure 4 it can be inferred that the adsorption capacity increases with initial concentration to a certain point and after that point there was no change in adsorption capacity with the change in initial dye concentration. This can be explained by the fact that the concentration gradient increases with the increase in initial concentration and this forces the adsorbent to capture more dye before reaching equilibrium. After a certain point the adsorption capacity reaches to its peak point. After that increase in initial concentration does not affect the adsorption capacity. The maximum adsorption capacity reaches at dye concentration of 60 mg/L and the experimental value is 148.5 mg/g.

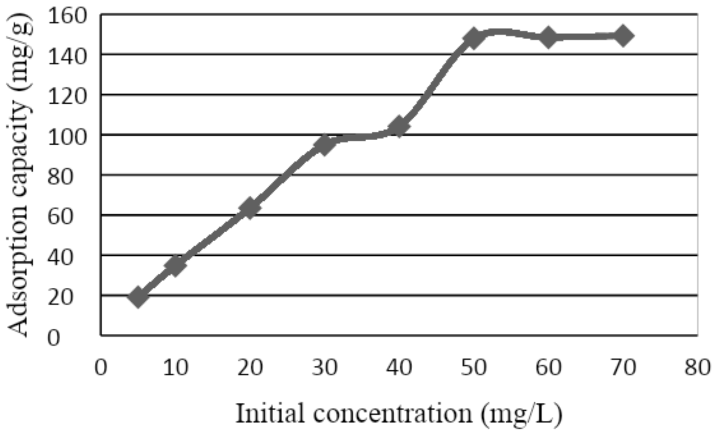

Figure 4: Effect of initial concentration on adsorption capacity

In this study the adsorption isotherm was analysed using the Langmuir isotherm, which is most commonly used. The linear form of Langmuir isotherm is expressed by,

$1/q_e=1/q_m+(1/C_e)(1/K_L q_m)$

where K_L is the Langmuir constant, $C_e$is equilibrium concentration of dye solution(mg/L), $q_e$is adsorption capacity(mg/g) at equilibrium and q_m is the maximum adsorption capacity(mg/g). Figure 5 shows that experimental data fitted well with the Langmuir isotherm model as the regression value was close to unity (R^2=0.983). The value of q_m was found to be 163.93 mg/g, which is closer to the maximum adsorption capacity determined experimentally.

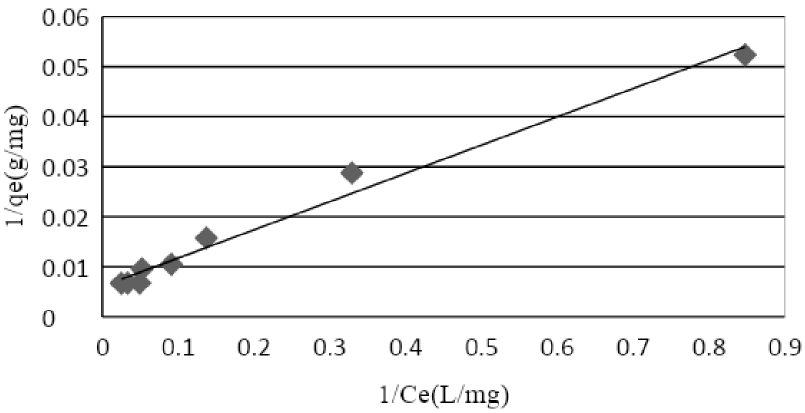

Figure 5: Adsorption isotherm

3.4 Comparison With Other Bio-adsorbents

Comparison of different bio-adsorbents on removing methylene blue is shown in table 1. Previously various bio-adsorbents were used to remove dye such as dead fungus Aspergillus niger and dead Streptomyces rimosus while their adsorption capacity were 18.54 mg/g and 34.34 mg/g respectively. Study reported the use of algal waste with the adsorption capacity of 104 for removing methylene blue. Fruit peels were also used for the same purpose. Among the shown adsorbents Burmese grapes show the highest adsorption capacity of 163.93 mg/g, which implies the feasibility of using this in large scale.

Table 1: Adsorption capacities of bio-adsorbents

Adsorbents	Adsorption capacity (mg/g)	Sources
Algal waste	104	Vilar et al. 2007
Unmodified baker's yeast	51.5	Yu et al. 2009
Green alga Ulva lactuca	40.2	Sikaily et al. 2006
The brown alga Cystoseira barbatula Kutzing	38.61	Caparkaya, et al. 2008
Dead Streptomyces rimosus	34.34	Nacera et al. 2006
Dead fungus Aspergillus niger	18.54	Fu et al. 2000
Posidonia oceanica (L.) fibres	5.56	Ncibi et al. 2009
Caulerpa racemosa var. cylindracea	5.23	Cengiz et al. 2008
Orange peel	18.6	Annadurai et al. 2002
Banana peel	20.8	Annadurai et al. 2002
Oak saw dust	29.94	Ferrero et al. 2007
Burmese grape seed	163.93	This study

CONCLUSIONS

Removal of dyes from industrial effluents by bio-adsorbent has been growing soberly due to its large availability and low cost. Besides, this branch offers an embarking opportunity to transform waste to useful materials. Adsorption of methylene blue from aqueous solution by Burmese grape seeds has been explored in this study. Effectiveness of Burmese grape seeds for the removal of methylene blue from aqueous solution was sumptuous. It panoplies higher adsorption capacity than traditional bio-adsorbents at optimum condition. Adsorption process shows pH sensitivity and pH 8 was found to be the optimum pH for maximum removal. Equilibrium was achieved after 40 minutes of contact time while first 10 minutes shows expeditious adsorption. Kinetic study shows that the adsorption process followed pseudo second order kinetics while the isotherm study suggests that the isotherm data fit with Langmuir isotherm. Maximum adsorption was found to be 163.93 mg/g .The potential use of Burmese grape seed for dye removal is established through this study. Yet there is scope of further works such as finding its adsorption capacity after alkaline treatment, it can be concluded that the locally available, low cost Burmese grape seed can be used for methylene blue removal from wastewater in an eco-friendly manner.

REFERENCES

Adak A, Bandyopadhyay M, Pal A. Removal of crystal violet dye from wastewater by surfactant-modified alumina. Sep PurifTechnol 2005;44(2):139–44.

Akshaya Kumar Verma, Rajesh Dash, PuspenduBhunia (2012) A Review on Chemical Coagulation/Flocculation Technologies for Removal of Colour from Textile Wastewaters, Journal of Environmental Management 93(1):154-68. DOI: 10.1016/j.jenvman.2011.09.012

A. El Sikaily, A. Khaled, A. El Nemr, O. Abdelwahab, Removal of methylene blue from aqueous solution by marine green alga Ulva lactuca, Chem. Ecol. 22 (2) (2006) 149–157.

Chidambaram Thamaraiselvan& Michael Noel (2015) Membrane Processes for Dye Wastewater Treatment: Recent Progress in Fouling Control, Critical Reviews in Environmental Science and Technology, 45:10, 1007-1040, DOI: 10.1080/10643389.2014.900242

DacianaIlicaLeucea (2010) The effects of azo dyes on human health, Industriatextilă 61(6):304-309

D. Caparkaya, L. Cavas, Biosorption of methylene blue by a brown alga Cystoseira barbatula Kutzing, Acta Chim. Slov. 55 (2008) 547–553.

F.A. Batzias, D.K. Sidiras, E. Schroeder, C. Weber, Simulation of dye adsorption on hydrolyzed wheat straw in batch and fixed-bed systems, Chem. Eng. J. 148 (2009) 459–472.

F. Ferrero, Dye removal by low cost adsorbents: hazelnut shells in comparison with wood sawdust, J. Hazard. Mater. 142 (2007) 144–152.

Gupta VK (2009) Application of low-cost adsorbents for dye removal: a review. J Environ Manag 90:2313–2342

G. Annadurai, R. Juang, D. Lee, Use of cellulose-based wastes for adsorption of dyes from aqueous solutions, J. Hazard. Mater. B92 (2002) 263–274.

H. Tamai, T. Kakii, Y. Hirota, T. Kumamoto, H. Yasuda, Synthesis of extremely large mesoporous activated carbon and its unique adsorption for giant molecules, Chem. Mater. 8 (1996) 454–462.

J.X. Yu, B.H. Li, X.M. Sun, J. Yuan, R.A. Chi, Polymer modified biomass of baker's yeast for enhancement adsorption of methylene blue, rhodamine B and basic magenta, J. Hazard. Mater. 168 (2009) 1147–1154.

Kannan N, Sundaram MM. Kinetics and mechanism of removal of methylene blue by adsorption on various carbons—a comparative study. Dye Pigment2001;51(1):25–40.

Mohamed A. Hassaan, Ahmed El Nemr. Health and Environmental Impacts of Dyes: Mini Review. American Journal of Environmental Science and Engineering. Vol. 1, No. 3, 2017, pp. 64-67. doi:10.11648/j.ajese.20170103.11

Mohammed MA, Shitu A, Ibrahim A (2014) Removal of methylene blue using low cost adsorbent: a review. Res J ChemSci 4(1):91–102

Mustafa T.Yagub, TusharKantiSen, SharmeenAfroze, H.M. Ang (2014) Dye and its removal from aqueous solution by adsorption: A review. Advances in Colloid and Interface Science.Volume 209, Pages 172-184

M.C. Ncibi, A.M.B. Hamissa, A. Fathallah, M.H. Kortas, T. Baklouti, B. Mahjoub, M. Seffen, Biosorptive uptake of methylene blue using Mediterranean green alga Enteromorpha spp., J. Hazard. Mater. 170 (2009) 1050–1055.

Nandi B, et al. Kinetic and equilibrium studies on the adsorption of crystal violet dye using kaolin as an adsorbent. Sep SciTechnol 2008;43(6):1382–403.

Özcan AS, Erdem B, Özcan A. Adsorption of Acid Blue 193 from aqueous solutions onto BTMA-bentonite. Colloids Surf A PhysicochemEng Asp 2005;266(1):73–81.

P Nidheesh, Minghua Zhou, Mehmet A. Oturan. An overview on the removal of synthetic dyes fromwater by electrochemical advanced oxidation processes. Chemosphere, Elsevier, 2018, 197 (210-227.),10.1016/j.chemosphere.2017.12.195. hal-01721053

Samchetshabam Gita, AjmalHussan , Choudhury, T. G. Impact of textile dyes waste on aquatic environments and its treatment.Environment and Ecology 2017 Vol.35 No.3C pp.2349-2353 ref.16\

S. Cengiz, L. Cavas, Removal of methylene blue by invasive marine seaweed: Caulerpa racemosa var. cylindracea, Bioresour. Technol. 99 (2008) 2357– 2363.

S. Senthilkumaar, P.R. Varadarajan, K. Porkodi, C.V. Subbhuraam, Adsorption of methylene blue onto jute fiber carbon: kinetics and equilibrium studies, J. Colloid Interface Sci. 284 (2005) 78–82.

V.J.P. Vilar, C.M.S. Botelho, R.A.R. Boaventura, Methylene blue adsorption by algal biomass based materials: biosorbents characterization and process behaviour, J. Hazard. Mater. 147 (2007) 120–132.

Y. Fu, T. Viraraghavan, Removal of a dye from an aqueous solution by the fungus Aspergillusniger, Water Qual. Res. J. Can. 35 (1) (2000) 95–111.

Y. Nacera, B. Aicha, Equilibrium and kinetic modelling of methylene blue biosorption by pretreated dead Streptomyces rimosus: effect of temperature, Chem. Eng. J. 119 (2006) 121–125.

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ASSESMENT OF WATER QUALITY IN AN URBAN RIVER USING POLLUTANT LOAD CONCEPT

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ABSTRACT

The present study attempts to examine the water quality of Moyur river at Khulna in Bangladesh, using the concept of pollutant load and comparing the results with water quality index. Six points were selected along the river and particular collections were carried out at a specified point. Nitrate, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total dissolved solids (TDS), turbidity, fecal coliform, pH were measured at six selected stations along the river using standard methods. The results showed that the water quality index score ranges between 21.59 to 32.62. The water classification, therefore, ranges from very bad to bad. Flow measurement were also carried out which enabled the calculation of the polluting load. The pollutant load value were calculated with respect to some parameters like $BOD_{5,}$ TDS and Nitrate. The estimated pollutant load value for BOD_5 likely ranges between 2.63 kg/hr to 32.07 kg/hr. Also the pollutant load value for TDS and Nitrate ranges between 0.078 kg/hr to 1.13 kg/hr and 0.31 kg/hr to 16.47 kg/hr,respectively.The calculation of the pollutant load showed a constant disposal of contaminats into the river, which indicates that the quality of the river is continuously decressing. This information could not be found by only analysing the water quality index. The use of the calculation of pollutant load for Moyur river is, therefore, a tool for assessment of pollution that can provide more appropriate information for the water resources management.

Keywords: *Flow, Pollutant load, Urban river, Water quality index.*

1. INTRODUCTION

Water is an essential requirement of human and industrial developments and it is one the most delicate part of the environment (Das and Acharya, 2003). But the quality of water is very important for both human and industrial development. With the passage of time, development of communities, and increased use of water resources, pressures upon controlling water resources and detection of abnormal changes in water quality conditions have increased (Sánchez *et al.*, 2007). Population growth, environmental pollution from discharge of urban and industrial sewage, and run-off have increased pollution and limited available water resources (Simeonov*et al.*, 2003; Sánchez *et al.*, 2007). As the quality of water is a major concern of now-a days, water quality monitoring of the water resources are absolutely necessary regularly to assess the quality of water for health, ecosystem, industrial use, agricultural use and domestic use.

Water quality index (WQI) is one of the most effective tools to communicate information about the quality of water to the concerned citizens. WQI is defined as a rating reflecting the composite influence of different water quality parameters. This index was developed from a mathematical relationship that transforms the result of various analysis of physical, chemical and microbiological parameters into a single number. This simplifies the quality evaluation of the fresh waters (Maane*et al.*, 2010). To ensure water quality the use of the WQI has been widely accepted over a very long period. WQI is calculated from the point of view of the suitability of surface water for human consumption (Atulegwu and Njoku, 2004). Although the water quality index is widely used to determine water quality but there is a question which can be raised so easily if flow measurement has any significance to evaluate water quality? In this respect, an alternative way to evaluate the effects of pollution in rivers is the use of the concept of pollutants load. The volumetric organic load, for example, is a fundamental parameter for the design of biological reactors for treating sewage and industrial effluents (Metcalf and Eddy, 2013). For the monitoring of water resources, the use of more widespread pollutant load is related to the calculation of the mass of suspended solids transported by water. This measure is an important indicator of soil loss and also the basis for the design and control of dams (Richards, 1998). According to this author, the knowledge of a load of suspended solids has a greater significance when compared to the concentration of these species. Many researchers have addressed this issue in a similar manner. The pollutant load concept has been considered by many authors as a tool for evaluating the impact of pollution in rivers. A study about the pollution of Lake Taihu in China using parameters such as chemical oxygen demand (COD), ammonia, total nitrogen and total phosphorus were evaluated in terms of the pollutant load. (Zhang*et al*., 2012). The concept load used to evaluate the runoff of pollutants due to various land uses and occupation in Chongqing in China. The application of the concept of the load was used to check which activity has more intensely influenced the pollution of waters in that locality. (Wang *et al.*, 2013). Recently a study had occurred to prioritize investments in pollution control on the Great Barrier Reef in Australia. The authors used the concept of load to evaluate which watersheds had the greatest influence on the pollution of reefs and used it to improve the effectiveness of programs for environmental protection. (Brodie*et al*., 2016). Finally, an application of the pollutant load concept had occured to study benzene series in an urban environment. (Li *et al*., 2019). Based on these studies, we can observe that the pollutant load concept has been considered by many authors as a tool for evaluating the impact of pollution in rivers.

The Moyur River in Khulna is one of the important channels of the Bhairab-Rupsa River system located in the south-west part of Bangladesh. This river has been increasingly polluted due to the disposal of municipal wastewater as well as various organic and inorganic waste materials from nearby market areas. Many research works had been carried out addressing the gradual degradation of water quality in Moyur River. However, the variation of pollutant load with river flow regime is yet to be addressed. In this context, the current study had been undertaken to compare the water quality index with the concept of pollutant load in Moyur River and evaluate the methodologies for more substantial information.

2. METHODOLOGY

2.1 Sample Collection Location

The Moyur River is one of the important channels of the Bhairab-Rupsa River system located in the south-west part of Bangladesh and in the downstream of the well-known Ganges delta (Rahman, Das, Roy and Akbar, 2013). The length of the Moyur River is nearly 100 km north of the coast line of the Bay of Bengal. The Moyur River is located at 22°47′ to 22°50′ N latitudes and 89°31′ to 89°34′ E longitudes in the north-south direction, geographically. The river originates from the Beel Dakatia (a large wetland) and meets with the Rupsha River. The total length of the river is 11.42 km and it has a basin area of 40 km2 with more or less a flat elevation varying from 2.7 m to 3.9 m (Roy, Datta, Adhikari, Chowdhury and Roy, 2005), The surface study of the basin area is classified as deltaic deposits which are composed of tidal deltaic deposits, deltaic silt deposits and mangrove muddy deposits with soils of sand, silty clay and clay in texture. The sub-surface studies are also characterized by a varied mixture of sand, silt and clay.

Figure 1: Location map of the water sampling spots in the Moyur River

2.2 National Sanitation Foundation Water Quality Index

As per NSFQWI, nine parameters have been used for calculating the water quality index which include dissolved oxygen (DO, mg/ L), biochemical oxygen demand (BOD_5, mg /L), nitrate (NO^{3-}, mg/ L), phosphate (PO^{4-}, mg/ L), fecal coliform bacteria (CFU/100 mL), turbidity (NTU), total solids (TS, mg /L), temperature change from 1 mile upstream (˚C), and pH. Following the guidelines of NSFQWI, weighting factor of each parameter had been used. For weighting factor determination, scientists were asked to graph the level of water quality ranging from 0 (the worst) to 100 (the best) from the raw data, (e.g. pH values 2–12), first. The curves drawn had been averaged to get the weighting curve for each parameter. Results of the nine parameters had been compared to the curves and a numerical value "Q-value," is obtained. The Q-value was then multiplied by a "weighting factor," based on the importance of that water quality with regards to the hydro-geological setup of the study area. The nine resulting values were then aggregated to obtain an overall WQI.

The NSFWQI ranges are divided by five quality classes (Table 1). Each of the NSFWQI parameters has its own weighting factor (Wi) which describes the importance of the effect of each parameter in the calculation. The weighting factor for each parameter has been described below:

Dissolved oxygen (DO) 0.17, Turbidity 0.08, Fecal coliform (FC) 0.15, Suspended solids (SS) 0.08, pH 0.12, Temperature 0.1, Total phosphates (TP) 0.1, Biochemical oxygen demand (BOD_5) 0.1, Ammonia nitrogen (NH3-N) 0.1.

Table 1: Water quality rating as per NSFWQI

WQI Value	Rating of Water Quality
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality

2.3 Flow Measurement and Calculation of Load

With regard to the flow measurement a current meter (Model 802 electromagnetic current meter) was used at sampling point one to six. First, the water velocity and depth was measured at many points along the margins. The water velocity data is collected from the current meter using a software called CDU Express. Then, the water flow was determined by multiplying the average velocity of the channel by the cross-sectional area of flow.

Figure 2: Experimental set up for Model 802 Water Flow Meter

Finally, after the determination of the concentration and flow data, it was possible to perform the calculation of pollutant load F according to Equation 1.

$$F = Q * C \quad (1)$$

Where, F is the load (g/ h or Kg/ h)
Q is the flow rate (L/ h)
C is the concentration (g/ L or Kg/ L)

3. RESULTS AND DISCUSSION

3.1 Water Quality Index (WQI)

Biochemical Oxygen Demand (BOD_5) is an important indicator of the water quality and the extent of pollution in the watershed areas. At every sampling points from 1 to 6 the value of BOD is extensively high (Table 2). It means that the disposal of municipal domestic waste or other toxic wastes are too high in the watersheds. As the value of BOD_5 is too high the natural oxygen that had been replenished by the plankton was inadequate with regards to microbial oxidation of biodegradable organic matters and thus the value of Dissolved Oxygen got less at every sampling points (Table 2). The pH at most of the points in the stream was found to be in the range of 6.6 to 7.36. The point with the highest pH was point 6 having a pH of 7.36. The other point with slightly higher pH values are 3, 4, and 5 with pH values of 7.19, 7.10 and 7.20, respectively. The rest of the points of pH values are less than ranges of seven.

As the value of Fecal coliform (FC) are also too high that means the amount of waste present in the river water is too much contaminated with faecal sludge and that's why there is a lot of pathogenic bacteria present in water which is found in human and animal excreta. Nevertheless, nitrate ion in water is undesirable. High nitrate levels were found at points 1, 3 and 4 with values of 1mg/L, 1.3 mg/L and 1.9 mg/L, respectively. The results of other points do not exceed 1 mg/L but it is also harmful for natural water. Total dissolved solids had concentration range between 600 and 3600 mg/L. The observed high concentration of dissolved solids in the surface water is an indicator to the fact that there are anthropogenic activities and the run- off includes high suspended material. The turbidity is linked to suspended solids in that the higher the turbidity the higher the suspended solids. The points with higher turbidity values are 4 (22.0 NTU), 5 (20.4 NTU) and 1(20.7 NTU), while the rest of the points had a turbidity less than 20 NTU but it's also higher and harmful for in total environment of any natural resources.

The results of the WQI showed that water quality at point 1 is classified as "very bad" and at points 2 to 6 as "bad" (Table 1). The score of WQI ranges between 0 to 40. Overall, the scores were below 40, which indicate that the land use and occupation on this watershed likely affect the water quality.

Table 2: Measurement results for parameters

Parameter Sampling points						
	1	**2**	**3**	**4**	**5**	**6**
BOD_5 (mg/ L)	240	198	228	222	196	264
DO (mg/ L)	2.58	2.80	2.86	3.13	2.87	3.10
pH	6.6	6.98	7.19	7.10	7.20	7.36
FC	400	600	900	800	500	600
Nitrate (mg/ L)	1.0	0.9	1.3	1.9	0.8	0.5
TDS (mg/ L)	900	3600	600	800	1400	1300
Turbidity (NTU)	20.7	17.1	19.1	22.0	20.4	18.7

Note: DO=Dissolved oxygen BOD_5=Biochemical oxygen demand FC=Fecal coliform TDS=Total dissolved solids.

3.2 Pollutant Load

The pollutant load values were calculated with respect to some parameters such as BOD_5, TDS, and nitrate. The concept of pollutant load involves the mass of a pollutant that is discharged into the water for a period of time (Metcalf and Eddy, 2013). The measurements of concentrations previously considered for WQI scores computing and the flow measurements were used to obtain the pollutant load values. As can be seen in figure 3, the highest value of flow is 2.41 cubic meter per second which is at sampling point 4 and the lowest value of flow is 0.166 cubic meter per second which at point 6. These flow measurements were done on the sunny day. If the measurement were taken at a rainy day may be then there will be some variation in results. These measurements of water flow allowed us to compute the pollutant load transported by the river. With regard to the figure 4 the average pollutant load for BOD_5ranges between 2.63 kg/hr. to 32.07 kg/hr. From this pollutant load value of BOD_5 we can say that there are a lot of existences of biodegradable waste in the water which is harmful for total environment of river water and its ecosystem. As the value of BOD_5 is too much that means a lot of industrial waste, municipal waste that generated in the city is released into the Moyur River. Similarly, analysing the pollutant load for total dissolved solids in figure 5 ranges between 0.078 kg/hr.to 1.13 kg/hr. which represents the availability of too much salts, some organic materials and a wide range of other things from nutrients to toxic materials that may cause death of many aquatic life forms. Again the pollutant load for nitrate in figure 6 ranges between 0.31 kg/hr. to 16.47 kg/hr. The presences of excess nitrogen can be harmful to ecosystem. It also happened for the contamination of sewage and industrial waste.

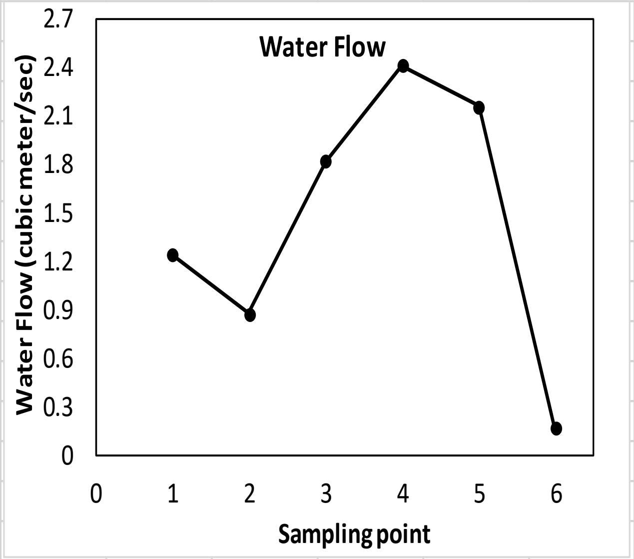

Figure 3: Flow Measurement

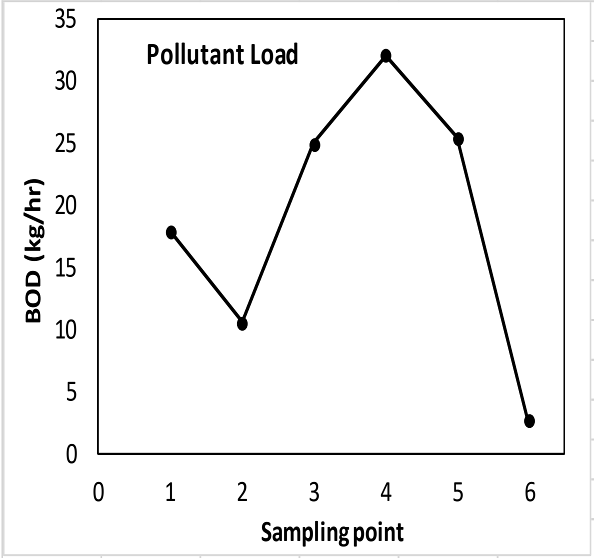

Figure 4: Pollutant load for BOD

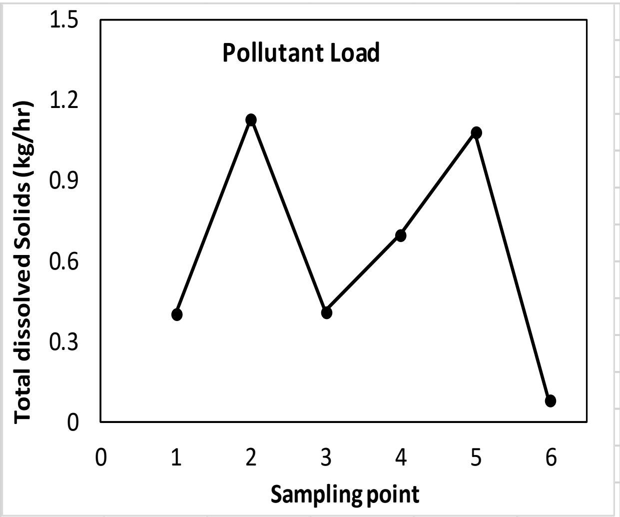

Figure 5: Pollutant load for TDS

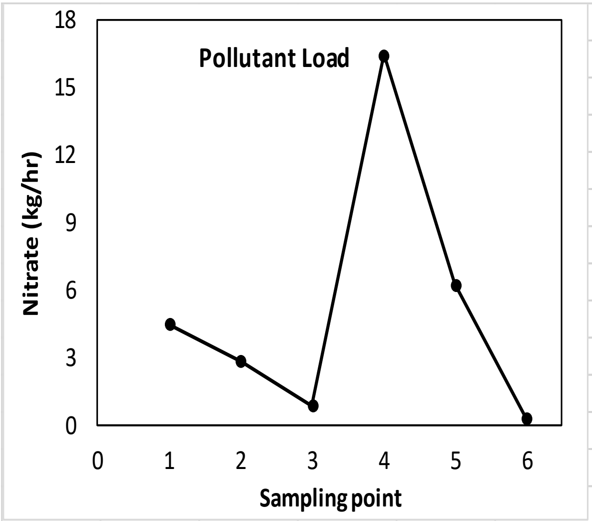

Figure 6: Pollutant load for Nitrate

Overall, it can be concluded that there is high value of pollutant load at some sampling points while it is less in other points. In some cases, the value of WQI and the value of Pollutant load did not match up at the same sampling points which mean that sometimes the WQI value cannot be able to show the exact information for the water bodies. That's why the calculation for pollutant load is needed for appropriate information for any water bodies.

4. CONCLUSIONS

The results obtained in this study showed that the monitoring of Moyur River by pollutant load concept is more representative of the environmental impacts. The river is increasingly polluted by various types of wastes which comes from various sources and deposited in the river basin, which could be detected by the pollutant load values. The highest pollutant load value of biodegradable organic matters had been found 32.07 kg/hr as biochemical oxygen demand (BOD_5), 1.13 kg/hr as total dissolved solids (TDS) and 16.47 kg/hr as nitrate, respectively which is highly threatening for ecosystem by reducing the dissolved oxygen levels significantly. On the other hand, the water quality index seemed to be not so effective to express the progressive contamination in the watershed. Sometimes the water quality index value and the value of pollutant load did not match up. That means very often the water quality index value is not enough to express the quality of water to provide the outmost situation of inland water bodies. The WQI value provide information about surface water quality and the pollutant load concept provide the information about suspended load which is transported by water at a specific time. As a whole, the use of the calculation of load for Moyur River is, therefore, a tool for assessment of pollution that can provide more appropriate information for the management of this water resource.

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REFERENCES

Atulegwu, P.U. and J.D. Njoku, . (2004). The impact of biocides on the water quality. *Int. Res. J. Eng. Sci. Technol., 1*, 47-52. .

Brodie, J. E.; Lewis, S. E.; Collier, C. J.; Wooldridge, S.; Bainbridge, Z. T.;Waterhouse, J. et al. . (2017). . Setting ecologically relevant targets for river pollutant loads to meet marine water quality requirements for the Great Barrier Reef, Australia: A preliminary methodology and analysis. *Ocean & Coastal Management, v. 143*, 136-147.

Das, J. and B.C. Acharya,. (2003). Hydrology and assessment of lotic water quality in Cuttack city,India. Water, Air, Soil Pollut.,150:. *DOI: 10.1023/A:1026193514875*, 173-175.

Li, C.; Li, S.; Yue, F.; Liu, J.; Zhong, J.; Yan, Z. et al. (2019). Identification of sources and transformations of nitrate in the Xijiang River using nitrate isotopes and Bayesian model. *Science of the Total Environment, v. 646,* , 801-810,.

Maane-Messai, S.; Laignel, B.; Motelay-Massei, A.; Madani, K.; Chibane,. (2010). Spatial and temporal variability of water quality of an urbanized river in Algeria: The case of Soummam Wadi. *Water Environment Research, v. 82, n.*, 742-749.

Metcalf, L.; Eddy, H. P. (2013). *Wastewater Engineering: Treatment and Resource Recovery*. New York: McGraw-Hill Education.

Rahman, M., Das R., Roy, K. and Akber, M. A. (2013). “Evaluation of dry season water quality of Mayur River flowing through the western fringe of Khulna City,. *Proceedings of the 4th International Conference on Water and Flood Management (ICWFM-2013),*, 17-25.

Richards, R. P. (1998). Estimation of pollutant loads in rivers and streams: A guidance document for NPS programs. *Denver: USEPA*, 108.

Roy, M.K., Datta, D.K., Adhikari, D.K., Chowdhury, B.K. and Roy P.J. (2005). Geology of the Khulna City Corporation,. *Life and Earth Science, 1*, 57- 63.

Sánchez E, Colmenarejo MF, Vincente J et al. (2007). Use of the water quality index and dissolved oxygen defcit as simple indicators of watersheds pollution. *Ecol Indic 7:*, 315–328.

Simeonov V, Stratis JA, Samara C et al . (2003). Assessment of the surface water quality in Northern Greece. *Water Res 37:World Health Organization (1998) Guidelines for drinking water quality, 2nd edn. WHO, Geneva*, 4119–4124.

Wang, S.; He, Q.; Ai, H.; Wang, Z.; Zhang, Q. (2013). Pollutant concentrations and pollution loads in stormwater runoff from different land uses in Chongqing. *Journal of Environmental Sciences, v. 25, n. 3,*, 502-510,.

Zhang, R.; Qian, X.; Yuan, X.; Ye, R.; Xia, B.; Wang, Y. (2012). Simulation of water environmental capacity and pollution load reduction using QUAL2K for water environmental management. *International journal of environmental research and public health, v. 9, n. 12,*, 4504-4521.

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ECOLOGICAL IMPACT OF WATER AND SEDIMENT CONTAMINATION IN PASSUR RIVER ADJACENT TO SUNDARBANS

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ABSTRACT

Sundarbanss, the world's largest mangrove forest has a unique ecosystem of greate ecological and economical significance supporting marine biodiversity as well as providing livelihood for many people in this region. In this study the ecological risk of the Sundarbans is analysed through evaluating pollution assessment in Passur river water and the river bed sediment. The studied water quality parameters such as pH (6.7), hardness, BOD_5 (1.8 mg/l), alkalinity, Cl^- (135 mg/l) etc. showed no serious pollution in river water. The ecological risk in the concentration of six trace elements (Pb, Cd, Ni, Zn, Fe, Cu) in the Passur river sediment were inspected revealing that the sediment is moderate to severely contaminated with Cd (1.5 mg/kg), Fe (3.1%) and Ni (36.2 mg/kg). High concentration values of Cd and Ni suggest the risk of eco-toxicity for organisms living in the sediment. Pollutant load index for all of the three sampleas were founed to be 1.40, 1.23 and 1.35, respectively which are larger than the limiting value 1 which indicates deterioration of sediment. Risk index (RI) of these three sample of sediment analysis are 846, 223 and 446, respectively.Sediment sample 1 has high risk possibilty, sediment sample 2 poses moderate risk with the limiting range of RI ($150 \leq RI \leq 300$), sample 3 represents considerable risk with limiting range of ($300 \leq RI \leq 600$). Using simulation-based @Risk software, the values of Risk Index (RI) show certainity around 90%. Among the trace metals Cd has shown higher potential ecological risk factor (Er^i) indicating greater ecological imbalance causing serious harm on aquatic flora and fauna. Silt (75.8%) is the dominating grain size of the Sundarbans soil. Ecological impacts of the Sundarbans upon dredging was also briefly described. Conservaion of natural resources is of prime concern to maintain the biodiversity of the Sundarbans forest.

Keywords: *Water quality parameter, Trace element, Ecological risk, Passur river, Sundarbans forest.*

1. INTRODUCTION

The Sundarbans is one of the largest mangrove forests in the world covering about 10,200 km2 area (88000'-89055'E and 21030'-22030'N) of the south-west of Bangladesh (60%) and south-eastern region of India (40%). The forest is formed in the delta of Bay of Bengal formed by the confluence of three important rivers- the Ganges, Brahmaputra and Meghna (Ahmed et al., 2010). The Passur is an important river flowing close to the south-western boundary of Bangladesh is a distributary of Ganges which continues as the extension of the Rupsha river, meets the Shibsha river within the Sundarbans and near the sea it flows as the Kunga river. It is considered as the deepest river of the country and its entire length is affected by tides. In the confluence of the Passur river and the Mongla river lies the second largest port of the country called the Mongla sea port. This water resource is affected by anthropogenic activities threatening the river ecosystem along with the mangrove forest.

Ecosystem is a community of living organisms interacting together with the nonliving components of the environment. Sundarbans has a unique ecosystem providing habitation for 453 faunal wildlife, including 290 bird, 120 fish, 42 mammal, 35 reptile and eight amphibian species (Iftekhar and Islam, 2004). The formation and justification of mangrove food chain is unique, roled by both marine and terrestrial components but due to loss of biodiversity the marine status is at risk affecting the ecology of Sundarbans (Manna *et al*., 2010). The quality of Sundarbans ecosystem is degrading due to over exploration of natural resources and different anthropogenic activities including industrial discharges, port activities, ship breaking, use of fertilizer and pesticides in agriculture and shrimp aquaculture.

Water quality parameters determine levels of contaminants and pollution in river ecosystem. Different anthropogenic sources in/near the river stream cause water pollution by changes in the water quality parameters. Therefore, monitoring its water quality is important for aquatic biodiversity. Nevertheless, trace elements degrade the quality of aquatic ecosystem due to their toxicity and accumulation threatening biodiversity and risking human health thereby (Ahmed *et al*., 2010, Wu *et al*., 2017). Sediment can act as a sink for metals in the environment (Kumar *et al*., 2016) and is useful source of information on environment and geotechnical status of marine pollution (Uluturhan et al., 2011).

The study of water quality parameters and metal contamination in the bed sediment of Passur river near the Sundabans will help to develop strategies for better conservation and utilization of natural resources. This study aims at analysing the ecological impact of Passur river water and sediment quality on the Sundarbans ecosystem.

2. METHODOLOGY

2.1 Study Area

The water samples were collected in the month of September from three stations in the Passur river near Mongla port keeping GPS reference points with a distance of at least 1km between two successive stations. Samples were collected in acid-washed plastic bottles.

Table 1: Details of water sampling location

Sample No	Latitude	Longitude
WS1	22°29'18"	89°35'18"
WS2	22°29'20"	89°35'23"
WS3	22°29'16"	89°35'22"

A river bed sediment sample was also collected near Mongla port using an acid-washed plastic spatula, sealed in plastic bag and stored at 4°C until analysis.

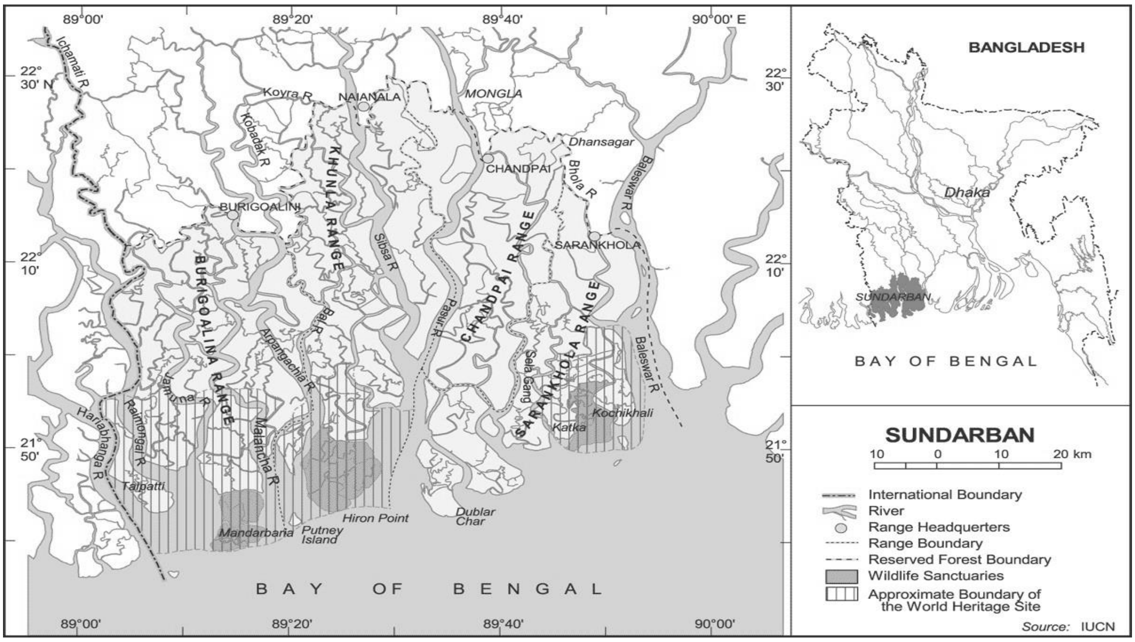


Fig 1: Map showing the Sundarbanss (Rahman *et al*., 2010)

2.2 Analysis of River Water & Bed Sediment

Laboratory water quality parameters were determined following the standard methods. PO_4^-, Fe, Mn, were analysed using UV Spectrophotometer (DR-2700, HACH, USA). Conductivity was analysed using conductivity meter (Sension-156) and pH was analysed using pH meter (pH -5011). The sediment sample was sieved and 50gm of the sample passing #200 sieve (0.075mm) was taken for hydrometer analysis to know the grain size distribution of the fine grained sediment sample. ASTM 152-H hydrometer was used for this analysis and the Sodium Hexametaphosphate was used as the dispersing agent. ASTM Standard sieves were used for grain size analysis.

2.3 Assessment of Pollution

In order to assess the quality of sediment, different indices are used worldwide. In this study Pollution load index was used. It is calculated by multiplying the contamination factors (CF) of the elements and deriving the n-th root of the multiplication (Tomlinson *et al*., 1980). The equation for calculating PLI is as follows:

$$PLI = (CF_1 \, X \, CF_2 \, X \ldots\ldots X \, CF_n)^{1/n}$$

Where, CF is the ratio of concentration of each element to the background values of sediments. Here due to the absence of background values, UCC values can be used. PLI = 1 represents presence of baseline level of pollutants and PLI > 1 represents deterioration of the sampling site.

Potential ecological risk index (RI) was used to assess the degree of contamination by the following equation:

$$RI = \sum_{i=1}^{n} Er^i = \sum_{i=1}^{n} Tr^i \times CF^i$$

Where, Er^i is the potential ecological risk factor of an individual element, Tr^i is the biological toxic factor of an individual element and CF^i is the single element contamination factor (Hakanson, 1980).

To assess the toxicity level Mean ERM Quotient (M-ERM-Q) method was used which was obtained as follows:

$$M\text{-}ERM\text{-}Q = \frac{\sum_{i=1}^{n} \frac{C_i}{ERM_i}}{n}$$

where C_i is the concentration of element i, ERM_i is the ERM values for the element i and n is the number of elements. According to the classification of M-ERM-Q: M-ERM-Q < 0.1 indicates 9% probability of toxicity, 0.11 ≤ M-ERM-Q < 0.5 indicates 21% probability of toxicity, 0.51 ≤ M-ERM-Q < 1.5 indicates 49% probability of toxicity and M-ERM-Q > 1.5 indicates 76% probability of toxicity (Long *et al*., 2000).

3. RESULTS AND DISCUSSION

3.1 Water Quality Analysis

To assess the level of acceptance the findings of this study in table 1 were compared with the certified values in table 2. The values obtained from the study were very much close to the expected limiting values. Though BOD_5 values were within the acceptable limit but appeared quite high. The DO values were quite lower as the living organisms in the river used up large amount of oxygen. The Cl^- values were found to be lower as the study was conducted in rainy season. The Fe contents are higher may be due to different anthropogenic activities especially wastewater discharges, sewage sludge, mining and mineral processing.

Table 1: Water quality parameters in three different stations

Samples	pH	Hardness	DO	BOD_5	Alkalinity	Cl^-	$PO4^-$	EC	Fe	Mn
WS1	7.4	125	5.8	2.8	115	110	0.00	299	0.33	0.4
WS2	6.6	95	5.1	1.4	100	70	0.29	214	0.13	0.4
WS3	6.9	105	5.6	1.9	105	90	0.26	267	0.27	0.45

Table 2: Certified values in the reference materials

Parameters	Unit	EQS	CCC	WQS
pH	—	6.5-8.5	6.5-8.5	7-8.7
Hardness	mg/L	—	—	—
DO	mg/L	≥5	—	≥5
BOD_5	mg/L	≤3	—	—
Alkalinity	mg/L	—	—	—
Cl^-	mg/L	—	230	150
PO_4^-	mg/L	—	—	—
EC	µs/cm	—	—	—
Fe	mg/L	—	1	1
Mn	mg/L	—	—	1*

*Formula used: WQG ≤ 0.0044 hardness + 0.605

EQS = Environmental Quality Standards (JEQ)

CCC = Criterion Continuous Concentration (USEPA)

WQS = Water quality Standard (BCMOE, 2019)

3.2 Sediment Analysis

Another researcher undertook a s study where the concentration of heavy metals in the river bed sediments of Passur river were determined (table 3).

Table 3: trace element concentration in bed sediment of Pussur river (Rahman *et al*., 2010)

Samples	**Pb (mg/kg)**	**Cd (mg/kg)**	**Ni (mg/kg)**	**Zn (mg/kg)**	**Fe (%)**	**Cu (mg/kg)**
S1	12.2	2.5	32	50.43	2.78	29.25
S2	16.15	0.8	37.40	64.81	3.16	18.30
S3	13.12	1.30	39.32	62.78	3.34	23.25

3.2.1 Metal Contamination Analysis

The Pollution load index for all of the three samples are more than 1 (S1=1.40, S2=1.23, S3=1.35) indicating deterioration of sediment over the period. The CF values are low for Pb, Ni, Zn, low to moderate for Cu and considerably higher for Cd indicating sever contamination. In comparison with other literature data of mangrove forest over the world, concentration of Fe is remarkably higher representing higher contamination (Islam *et al*., 2017). Port activities and ship breaking are the possible sources for Fe contamination in this region.

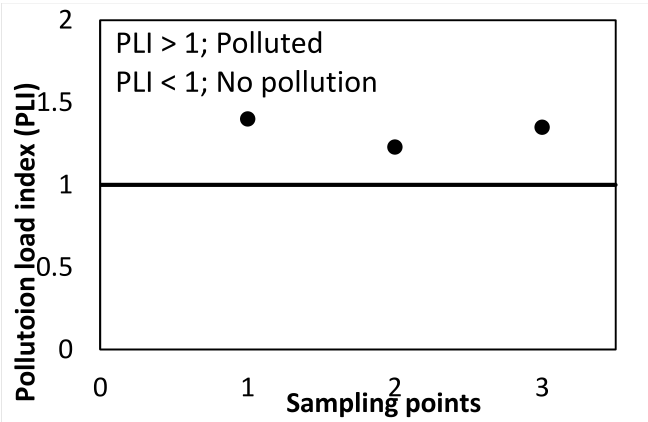


Figure 1: PLI values for bed sediment samples

Table 4: Certified values in reference materials

Standards (mg/kg)	**Pb**	**Cd**	**Ni**	**Zn**	**Fe***	**Cu**
TEL	30.24	0.68	15.9	124	—	18.7
PEL	112	4.21	42.8	271	—	108
ERL	46.7	1.2	20.9	150	—	34
ERM	218	9.6	51.6	410	—	270
UCC	17	0.09	47	67	3.92	28

* The concentration of Fe is given in percentage
TEL = Threshold effect level (CCME, 1999)
PEL =Probable effect level (CCME, 1999)
ERL= Effect range low (NOAA, 2012)
ERM = Effect range medium (NOAA, 2010)
UCC = Upper Continental Crust (Rudnick and Gao, 2014)

According to sediment quality guidelines, no element shows concentration above PEL. Cd, Ni and Cu fall above TEL values where Cd and Ni exceeds both the TEL and ERL values and can possess threat to the organisms. Pb, and Zn are not considered as threats to the ecology. Cd concentration is reported to be very high compared with the UCC value. Comparing with these values the Sundarbans sediment is low to moderately contaminated with these elements whereas Cd concentration is remarkably higher and moderate to severely contaminated in the sediment of Sundarbans. Cd is non-essential element and in excess amount hampers photosynthesis and plant growth, alters mineral uptake, produce oxidative stress in plants (Benavides et al., 2005). In fauna Cd can decrease growth and reproduction capability. If enter in foodchain can affect liver, kidneys, placenta, lungs, bones and brain (Jaiswal et al., 2018). Cd exposure can cause anosmia, cancers, cardiac failure, cerebrovascular infarction, osteoporosis, emphysema, proteinuria, and cataracts (Lalor, 2008). Fe is an important mela as micronutrients for life process in plants and microorganisms but excess amount may have negative toxic biological effect on the biota of the Sundarbans. Excessive Fe uptake in plants can cause alteration of enzymatic activities, plant necrosis or death and colonies disintegration as well as roots abscission at (Jucoski et al., 2015). Overexpose to Fe can affect liver, gills, testis and intestines of fishes.

Table 5: Pearson correlation matrix for elements in the sediment

Metals	Pb	Cd	Ni	Zn	Fe	Mn
Pb	1.00					
Cd	-0.86	1.00				
Ni	0.47	-0.85	1.00			
Zn	**0.77**	-0.99	**0.93**	1.00		
Fe	0.42	-0.82	**0.99**	**0.90**	1.00	
Mn	-0.94	-0.98	-0.75	-0.94	-0.71	1.00

Bold correlations are significant at $p < 0.01$

To analyse the transport behaviour of the elements a correlation has been established shown in table 5. Strong positive correlation between Fe, Zn, Ni and Pb represents that they are of similar origin and controlled by pretty much the same factors. All of the elements are strongly negatively correlated with Cd and Mn representing that these two metals have less influence on accumulation of other trace elements (Islam et al., 2017).

3.2.2 Ecological Risk Assessment

Table 6 indicates that the ER^i values for all the samples are within the expected values ($ER^i < 40$) and posse low potential ecological risks except Cd which is high ($160 < ER^i < 320$) to very high ($ER^i > 320$) and may pose high ecological risk. The RI values found out be moderate ($150 \leq RI \leq 300$) for S2 and considerable ($300 \leq RI \leq 600$) for S3 and is of high risk for S1 (Zhao *et al*., 2012). The values of M-ERM-Q for all three samples falls in the range of 0.11-0.5 which indicates 21% probability of toxicity (long *et al*., 2000).

Table 6: Sediment contamination based on ecological risk assessment

Samples	Er^i					RI	M-ERM-Q
	Pb	Cd	Ni	Zn	Cu		
S1	3.58	833	3.40	0.75	5.22	846	0.23
S2	4.85	267	3.98	0.97	3.27	280	0.22
S3	3.86	433	4.18	0.93	4.15	446	0.24
Tri	5.0	30.0	5.0	1.0	5.0		

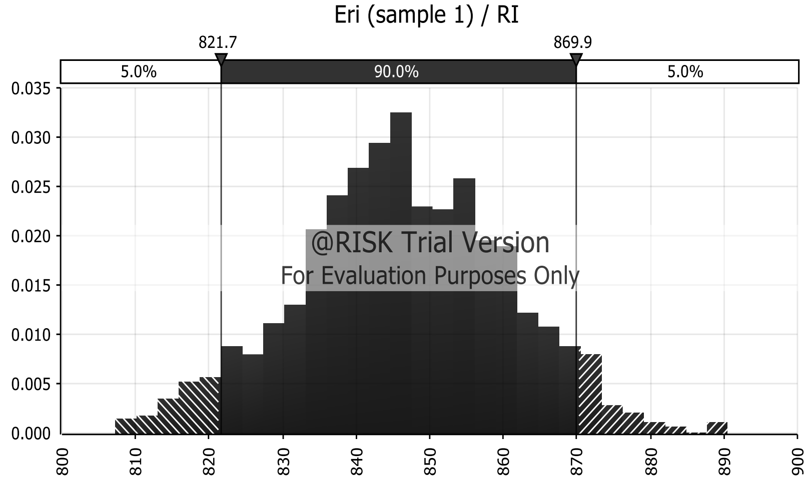
A simulation-based approach was also adopted to assess the probability of risk occurrence. Fig 2 illustrates 90% possibility of the outcome to occur in all of the three samples revealing that the RI values have significant influence on possible risk occurrence of trace element accumulation on sediments in this region.

Frequent accidents of cargo vessels carrying oil, coal, cement, chemical elements and other harmful materials near the Sundarbans have huge negative impact on the Sundarbans aquatic flora and fauna. The tide-influenced depositional system helps the oil to reach the forest and affect the trees and enter into the Sundarbans food-cycle. To facilitate the navigation of water vehicle, dredging has been occurred now a days. It greately impacts on aquatic flora and fauna. Dredging can cause bank erosion leading to vegetation disturb and fish population alteration. Fishes experience higher mortality rates due to injuries, physiological stressors, disorientation, abrasions and infections and even death (The Daily Star, 2016). Dredging increase turbidity, reduce light availability putting the organisms living under water, fishes, especially dolphins and the aquatic ecology as a whole in a threat. Sediment dredging increases the amount of salinity on the roots of the plants. There was a significant reduction in seed germination with increasing salt stress. Increasing soil salinity significantly retarded stem and root elongation. (Bhatt et al., 2008). Disposal of dredged sediment in the Sundarbans forest can also affect the vegetation and the wildlife.

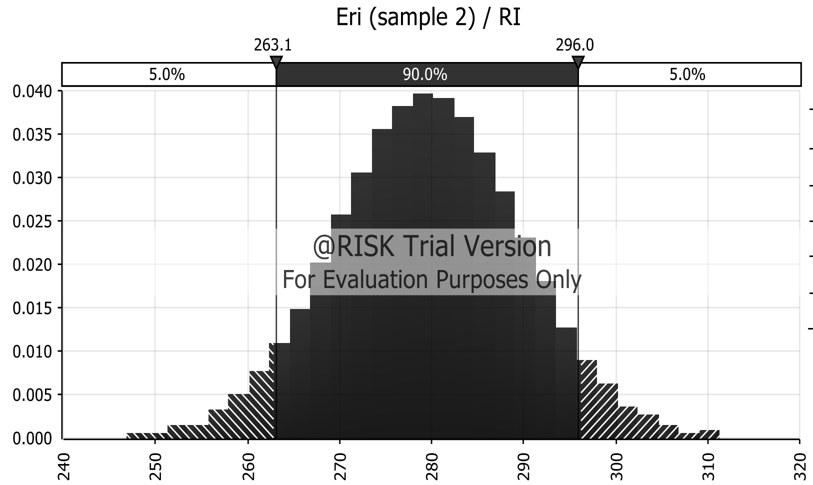
3.2.3 Grain Size Analysis

Fig 3 shows that the sediment sample collected in this study contain silt mostly. The percentages of silt and clay are higher than sand. Sediment grain size decreases with increase in metal content

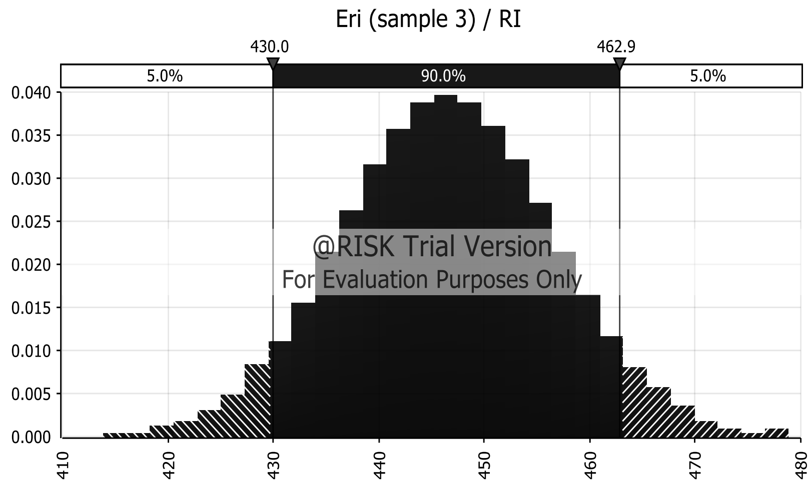
(Maslennikova e*t al*., 2012). The mean size indicates that the sediments are deposited at moderately low energy condition (Ramanath *et al*., 2009). Fig 3 represents the textural characteristics of the Passur river bed sediment which is primarily silty loam or silty clay loam revealing that silt is the dominating grain size in the Sundarbans soil.



Eri (sample 1) / RI	
Minimum	807.389
Maximum	890.317
Mean	848.304
Std Dev	14.240
Values	1000



Eri (sample 2) / RI	
Minimum	246.374
Maximum	311.266
Mean	279.627
Std Dev	9.993
Values	1000



Eri (sample 3) / RI	
Minimum	413.853
Maximum	478.846
Mean	446.466
Std Dev	9.996
Values	1000

Fig 2: Percentage (90%) of certainty of ecological risk in sediment samples S1, S2, S3 respectively.

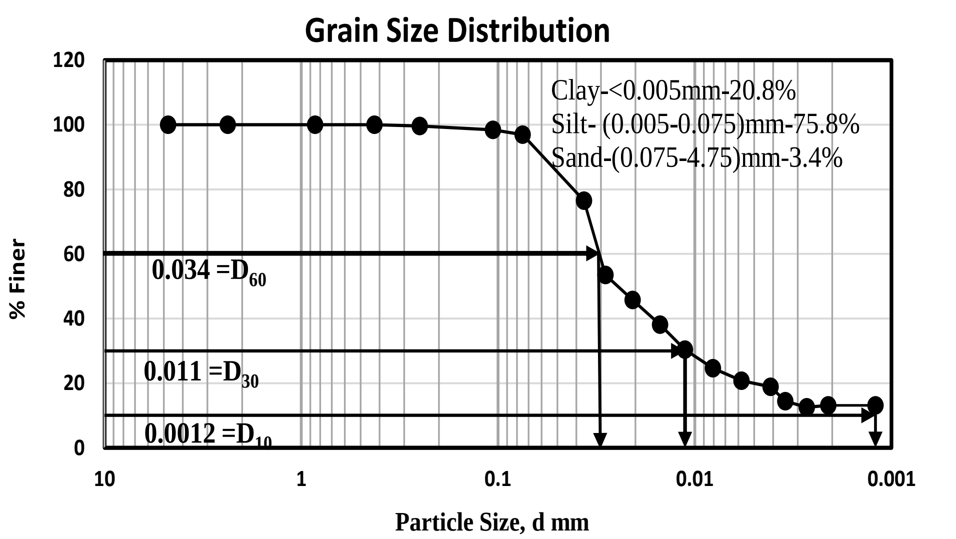


Fig 3: Grain size distribution curve of the Passur river bed sediment sample

Gradation curve indicates that the amount of silty sand is large enough than clay and fine sand. The size of clay particle is <0.005mm and the gradation curve indicates the percent finer of clay is 20.8%. The amount of silt is large (75.8%) and contains huge amount of trace metals. Coefficient of uniformity is 3.09 which is less than the limiting value 4 to 6. So it is classified as poorly graded soil. Also the Co-efficient of curvature is 2.97 which is in betweem 1 to 3.

4. CONCLUSIONS

In this study, water quality parameters for Passur river were determined. The study findings indicated no serious pollution of the river water. The Passur river bed sediment near Sundarbans is rich in silt content. The ecological risk in the concentration of six trace elements (Pb, Cd, Ni, Zn, Fe, Cu) in the collected river bed sediment had been analysed. The concentration values for Cd (1.5 mg/kg), Fe (3.1%) and Ni (36.2 mg/kg) were high which suggests that the sediment is moderate to severely contaminated with these trace metals which may originated from different anthropogenic sources. The concentration of Cd and Ni are higher than the TEL and ERL reference values indicating the possible risk of eco-toxicity. Cd has higher value of potential ecological risk factor (Er^i) indicating high ecological risk and posing negative effect on aquatic flora and fauna. Dredging is also degrading the aquatic ecosystem causing harm to aquatic flora and fauna and the disposal of dredged materials in the Sundarbans could hamper vegetation growth in the forest area.

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REFERENCES

Ahmed, K., Yousuf, M., Haque, R. and Mondol, P. (2011). Trace element concentrations in some macrobenthic fauna of the Sundarbans mangrove forest, south west coast of Bangladesh. *Environ. Monit. Assess.*, 177, 505–514.

BCMOE. (2019). *British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture*. Water Protection & Sustainability Branch, Ministry of Environment & Climate Change Strategy.

Benavides, M. P., Gallego, S. M., Tomaro, M. L., (2005). Cadmium toxicity in plants. Brazilian Journal of Plant Physiology, 17: 21–34.

Bhatt., J.M., Patel., D.A., Bhatti., M.P., Pandey., N.A. (2008). Effect of soil salinity on growth, water status and nutrient accumulation in seedling of Ziziphus Mauritiana (Rhamnaceae). *Journal of Fruit and Ornamental Plant Research*, 16, 383-401.

CCME (Canadian Environmental Quality Guidelines). (1999). Canadian sediment quality guidelines for the protection of aquatic life: mercury, zinc, lead, copper, chrome and cadmium. In: *Canadian Environmental Quality Guidelines, 1999*. Winnipeg, Canadian Council of Ministers of the Environment.

Haider, Q. (2016, October 22). Adverse effects of river dredging on the aquatic ecosystem. *The Daily Sta*r.

Hakanson, L., (1980). An ecological risk index for aquatic pollution control: a sedimentological approach. *Water Res*. 14, 975–1001.

Iftekhar, M. S. and Islam, M. R. (2004*)*. Managing mangroves in Bangladesh: A strategy analysis. *Journal of Coastal Conservation*. 10 (1): 139–146.

Islam, M. A., Al-Mamun, A., Hossain, F., Quraishi, S. B., Nehar, K., Khan, R., Das, S., Tamim, U., Hossain, S. M. and Nahid, F. (2017). Contamination and ecological risk assessment of trace elements in sediments of the rivers of Sundarbans mangrove forest, Bangladesh. *Marine Pollution Bulletin.*

Jaiswal, A., Verma, A. and Jaiswal, P. (2018). Detrimental Effects of Heavy Metals in Soil, Plants, and Aquatic Ecosystems and in Humans. *Journal of Environmental Pathology, Toxicology and Oncology*, 37(3):183–197.

JEQ (Japan Environment Quarterly). *Environmental Quality Standards for Water Pollution*. Ministry of Environment, Government of Japan, Japan.

G de O. Jucoski, J., Cambraia, C. Ribeiro, J.A. de Oliveira, S.O. de Paula, M.A. Oliva. (2013). Impact of iron toxicity on oxidative metabolism in young *Eugenia uniflora* L. plants, *Acta Physiol. Plant,* 35: 1645-1657.

Kumar, A., Ramanathan, A.L., Prasad, M.B.K., Datta, D., Kumar, M. and Sappal, S.M. (2016). Distribution, enrichment, and potential toxicity of trace elements in the surface sediments of Sundarbans mangrove ecosystem, Bangladesh: a baseline study before Sundarbans oil spill of December, 2014. *Environ. Sci. Pollut. Res*. 23, 8985–8999.

Lalor, G. C. (2008). Review of cadmium transfers from soil to humans and its health effects in the Jamaican environment. Sci Total Environ., 400:162–72.

Long, E. R., MacDonald, D. D., Severn, C. G., Hong, B. C. (2000). Classifying probabilities of acute toxicity in marine sediments with empirically derived sediment quality guidelines. *Environ. Toxicol.* 19, 2598–2601.

Ma, X., Zuo, H., Tian, M., Zhang, L., Meng, J., Zhou, X.,Manna, S., Chaudhuri, K., Bhattacharyya, S.and Bhattacharyya, M. (2010). Dynamics of Sundarbans estuarine ecosystem:Eutrophication induced threat to mangroves.*Saline Systems*, 68: 1–16.

NOAA (National Oceanic and Atmospheric Administration). (2012). National Oceanic and Atmospheric Administration, USA (Chapter 173–204 WAC, 1991/95, WA Dept. of Ecology).

Rahman, M. M., Rahman, M. M. and Islam, K. S. (2010). The causes of deterioration of Sundarbans mangrove foreste cosystem of Bangladesh: conservation and sustainable management issues. *AACL Bioflux*, 3.

Rahman, M.T., Rahman, M. S., Quraishi, S. B., Ahmad, J. U., Choudhury, T. R. and Mottaleb, M. A. (2011). Distribution of Heavy Metals in Water and Sediments in Passur River, Sundarbans Mangrove Forest, Bangladesh. *J. Int. Environmental Application & Science*, 6 (4): 537-546.

Ramanathan, A.L., Rajkumar, K., Majumdar, J., Singh, G., Behera, P.N., Santra, S.C. and Chidambaram, S. (2009). Textural characteristics of the surface sediments of atropical mangrove Sundarbans ecosystem, India. *Indian J. Mar. Sci.*, 38 (4), 397-403.

Rudnick, R.L., Gao, S. (2014). *Composition of the continental crust*. In: Treatise on Geochemistry, second ed., 1–64 (Chapter 4).

Wu, H., Liu, J., Bi, X., Lin, G., Feng, C.C., Li, Z., Qi, F., Zheng, T. and Xie, L. (2017). Trace elements in sediments and benthic animals from aquaculture ponds near a mangrove wetland in southern China. *Mar. Pollut. Bull*.

Uluturhan, E., Kontas, A. and Can, E. (2011). Sediment concentrations of trace elements in the Homa Lagoon (Eastern Aegean Sea): assessment of contamination and ecological risks. *Mar. Pollut. Bull.*, 62, 1989–1997.

U.S. EPA (Environmental Protection Agency). (1994). *National Recommended Water Quality Criteria.* U.S. Environmental Protection Agency, Washington, D.C., USA.

Zhao, S., Feng, C., Yang, Y., Niu, J. and Shen, Z. (2012). Risk assessment of sedimentary elements in the Yangtze Estuary: new evidence of the relationships between two typical index methods. *J. Hazard. Mater.* 241–242, 164–172.

Investigation of Irrigation Water Quality & Soil Fertility Condition Around Bhadra River at Khulna

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ABSTRACT

This paper is an attempt to analyze the water quality of Bhadra River in Khulna district for irrigation purpose. The farmers residing in the western fringe of Khulna city in Bangladesh, use the sewage-fed water of the Bhadrariver for irrigation as good quality surface water is not available as well as higher cost in groundwater irrigation. The present study was undertaken to evaluate the suitability of this river water for irrigation during the wet season since this period is more sensitive to crop agriculture in the study area. A total of five water samples from five different stations, were collected and analyzed for pH, EC, TDS, major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}). Chemical data were used for calculation of SAR for better understanding the suitability of river water for irrigation use. In wet season the observed average value for water pH 6.94; EC 1726 (μs/cm); TDS 1300(mg/l); Na^+245 (mg/l), CI^-374 (mg/l); Ca^{2+}45.93 (mg/l); Mg^{2+}23.60 (mg/l); SO_4^{2-}4.2 (mg/l), NO_3^-0.52 (mg/l); SAR 41.55. The results revealed that river water was found to be safe for irrigation with regards to EC and TDS but SAR indexexceeded the allowable limits. Nevertheless, Na^+cation and Cl^-anion exceeded the acceptable limits for irrigation. Soil salinity intrusion is also an increasing problem in the coastal areas of Bangladesh. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. Laboratory analyses for soil samplesobtained an average value of pH (8.52), P (11.42 μg/g), Zn (1.33μg/g), Cu (3.16 μg/g), K (0.22 meq/100g), Ca (26.60 meq/100g), Mg (5.90 meq/100g) and N (0.103 %). Comparedto standard values it was found that Zn and Kwere within the range of standard value. However, the nutrients of soil such as P, Ca, Mg and Cu exceeded the acceptable limit for soil fertility.

Keywords: *Irrigation, Salinity, Suitability, River water, SAR.*

1. INTRODUCTION

Water is the most common substance on earth. It covers more than 70 percent of earth's surface. It fills the ocean, rivers and lakes and is the ground and in the air we breathe. Water is everywhere. Regardless of language or culture, all living beings share this basic need for their survival. Water plays an important role in the world economy. Approximately 70% of the freshwater used by humans goes to agriculture. Fishing in salt and fresh water bodies is a major source of food for many parts of the world. Much of long distance trade of commodities (such as oil and natural gas) and manufactured products is transported by boats through seas, rivers, lakes and canals. Large quantities of water, ice, and stream are used for cooling and heating, in industry and homes. Water water excellent solvent for a wide variety of chemical substances, as such it is widely used in industrial processes, and cooking and washing. The most important use of water in agriculture is for irrigation, which is a key component to produce enough food. Irrigation takes up to 90 % of water withdrawn in some developing countries and significant proportions in more economically developed countries (In the United states, 30% of fresh water usage is for irrigation).

Bangladesh is an irrigated agriculture based country and is dependent on adequate water supply of usable quality. As the crop yield is directly related to the quality of water used for irrigation, an assessment of groundwater suitability for irrigation is essential for the growth of food production and poverty eradication. Coastal Bangladesh, covering about 3.22 million ha, of which 2.00 million ha are cultivated land (SRDI, 2001), used to have great potential for agricultural development, but increasing salinity, mainly in the soil's root zone, is the largest limitation factor (Rahman *et al.*, 1993). Previously, water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available (Islam and Shamsad, 2009). However, salinity increase have been one of the major problems for traditional agricultural practices in coastal Bangladesh for several decades (Rahman *el al.*, 2011).

Salinity is a global problem. The continuous loss of arable land due to irrigation in arid and semi-arid regions of the world, over exploitation and mismanagement contribute to global change in a way which currently appears to draw much less concern in the media and the general public than the accumulation of greenhouse gases: Carbon dioxide, methane and others, in our atmosphere and putative temperature increase and climate changes associated with them. Nevertheless, the advancement of desertification by salinization and its threatening of global agriculture can be readily quantified (Smedema & Shiati, 2002).

Dumuria upazilla, in Khulna district is in the south west coastal region of Bangladesh where saline water intrusion is the most severe where farmers mostly cultivated a single rice crop in the wet season under rainfall conditions. The use of groundwater as sole source of irrigation remains a risky venture, owing to the possible intrusion of saline water from the river into the coastal aquifers if the water level of aquifers is lowered because of excessive withdrawal of water for irrigation. However, even in monsoon season, there are times when pro longed drought condition persists and farmer are at stake in choosing which source of water to use as irrigation water. Therefore, a detailed investigation regarding the irrigation water quality and their salinity hazard classification has to be done for the monsoon season in the area, particularly for the available water resources including surface water and shallow groundwater. As most of people of these districts are dependent on agriculture and fisheries, keeping these mind, the objectives of the research were to assess the hydrochemistry of surface water and groundwater of the area in the monsoon season, to evaluate the suitability of irrigation water quality of different sources of Dumuria upazilla of Khulna district in Bangladesh.

2. METHODOLOGY

2.1Sampling, Preservation, and Preparation of Water Sample

Prior selecting the water sampling sites from a well-studied reconnaissance survey, samples were collected from 5 sampling stations based on the characterizing features of the locations along the river. Samples were collected from the midstream of the river by using an engine boat and following the guidelines of standard methods. Samples for cationic and anionic analyses were collected in separate 500 ml PET bottles. Then samples were carried to the laboratory and tested immediately.

Location	Longitude	Latitude
Site 1	89^{0}24’54.09”	22º47’37.4”
Site 2	89^{0}25’4.53”	22º47’47.8”
Site 3	89^{0}25’19.05”	22º48’.3.5”
Site 4	89^{0}25’34.2”	22º48’27.4”
Site 5	89^{0}24’48.4”	22º48’52.3”

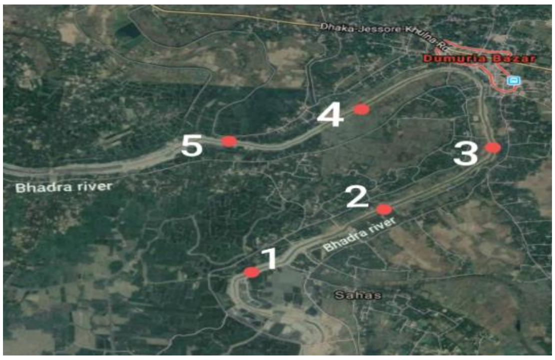

Figure-1: Location of study area.

2.2 Laboratory Measurements

Na, K, Ca, Mg, NO_4, SO_4, PO_4 were analyzed following the standard procedures. Titrimetric methods were used for determining Ca, Mg and Cl ions. K was measured by direct use of flame photometer, NO_3^-, SO_4^{2-} and PO_4^{3-} were measured by using spectrophotometer. TDS was measured by keeping the water sample in oven for 24 hours at 105°C. Physical properties of water DO, pH, EC were measured by DO meter, pH meter and Conductivity meter, respectively.

2.3 Data Analysis for Water Sample

Different water quality parameters like EC, TDS classes were used in the study to assess the quality of the water. In agriculture, water quality is an important criterion for the development of a successful and sustainable irrigation Scheme. In order to assess the suitability of the river water for irrigation use, various parameters like EC, SAR index were measured to assess the suitability of water for using in irrigation. Besides, every water quality parameter was compared to their respective standard value to assess their suitability for irrigation.

2.4 SAR Index Determination

The Sodium adsorption ratio (SAR) is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural Irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil.
The formula for calculating the sodium adsorption ratio (SAR) is:

$$SAR = \frac{Na}{\sqrt{0.5(\mathrm{Ca} + \mathrm{Mg})}}$$

Where Na, Ca, Mg are in mg/1.

2.5 Sampling, Preservation and Preparation of Soil Sample

Total 2 soil samples were collected at 0-15 cm depth from three different locations of Bhadra river basin at Dumuria in Khulna district. Samples were collected with plastic packets. After collecting, the soil samples were air-dried and then a composite sample was prepared by mixing unit samples. Then samples were used for chemical analysis.

2.6 Experimental Methodology

The soil pH was measured by pH meter. K (potassium) was measured by flame photometer. Ca, Mg, Cu, Zn and P were measured by soil extraction method. Then the soil parameters were compared with their respective standard value to assess soil quality.

3. RESULTS AND DISCUSSIONS

3.1 Water Quality of Bhadra River Water

Bhadra River is coastal river. Due to the unequal precipitation and mixing of sea water, the river water quality varies throughout the year. Here in the wet season, water quality parameters were analysed.

Table 3-1: Tested Results of Bhadra River Water Quality Parameters at Wet-Season

Sample No.	pH	Ec (µs/cm)	TDS (mg/L)	DO (mg/L)	Na^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)
1	6.89	1875	1320	7.6	202	44.38	21.50	308	0.60	3.0	0.71
2	6.88	2400	1530	5.6	223	44.98	21.90	340	0.40	4.0	1.05
3	6.95	1729	1210	7.2	307	47.91	23.60	468	0.51	6.4	0.92
4	7.02	1627	1200	6.9	260	44.39	25.20	396	0.65	3.5	0.74
5	6.98	1672	1240	7.3	234	47.99	25.70	356	0.43	3.9	1.03

In wet season the observed average value for water pH 6.94; EC 1726 (µs/cm); TDS 1300(mg/l); Na^+245 (mg/l), Cl^-374 (mg/l); Ca^{2+}45.93 (mg/l); Mg^{2+}23.60 (mg/l); SO_4^{2-}4.2 (mg/l), NO_3^-0.52 (mg/l); SAR 41.55.

3.1.1 Suitability of Bhadra River Water for Irrigation

On irrigated agricultural lands, salinization is one of bountiful inauspicious environmental and human induced impacts that persuade loss of production in gigantic scale. Salinization critically limits the choice of crops, deleteriously affect crop germination and yields and can provoke soils to be inappropriate to work. It is important that all appraisals regarding irrigation water quality tobe linked with the evaluation of soils to be irrigated. The suitability of river water samples for irrigation use is governed by the mineral constituent present in the water. The major physico-chemical parameters, which determine the suitability of river water for irrigation, are pH, EC, TDS, chloride, sulfate, nitrate, sodium, potassium, calcium, magnesium etc. In assessing the suitability or waters for irrigation use, water quality characteristics that affect agricultural production need to be evaluated. Irrigational suitability of the Bhadra River and its connected channel was evaluated by determining the concentration of various water quality parameters (pH, EC, TDS, chloride, sulfate, nitrate, sodium, potassium, calcium, magnesium, etc.) and SAR index.

Table 3-2: Quality evaluation of irrigation water with respect to BIWOS Standard

Parameter	Rate of Hazards	Water class
pH	5.1-6.4	No problem
	6.5-8.5	Moderate
	8.5-9.5	Sever
EC	<250	Excellent
	250-750	Good
	750-2000	Permissible
	2000-3000	Doubtful
	>3000	Unsuitable
TDS (mg/l)	<450	Good
	450-2000	Permissible
	>2000	Unsuitable
Cl^-(mg/l)	<80	No problem
	80-200	Moderate
	>200	Sever
Na^+ (mg/l)	<60	No problem
	60-180	Moderate
	>180	Sever
NO_3^- (mg/l)	<5	No problem
	5-30	Moderate
	>30	Sever
SAR	10-18	Good
	18-26	Doubtful
	>26	Unsuitable

3.1.2 Physico-Chemical Characteristics of Bhadra River Water

The obtained pH value of water was found 6.94 which is close to 7 indicates that the water is suitable for irrigation purpose. Salinity of river water that is used for irrigation is determined by EC, which is used as a surrogate measure or TDS concentration in water. According to the classifications of irrigation water based on EC and TDS, the river water was within the permissible limit. Comparing with BIWQS (DoE, 1997), the value of EC in river water is not exceeded the tolerance limit (2250 us/cm) for irrigation. Continuous use of irrigation water containing higher EC leads to formation of saline soil. The higher the EC, less quantity of water is available to plants, even though the soil appears to have plenty of moisture. The main effects of salinity on plants can include reduction in growth rate, damage of meristems in growing shoots, reductions in yield components of rice, or typical symptoms of nutritional disorders under osmotic and ionic stress. Therefore, successful use of this river water requires salt tolerant plants, good soil drainage, excess irrigation for leaching, and/or periodic utilızation of low salinity water. The chloride contents of the Bhadra River exceeded the tolerance limit (200 mg/l) for irrigation in Bangladesh (DoE, 1997). As per the chloride classification of irrigation water, the river water come under the severe category which indicates that water was not free from chloride hazard. Generally, chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. The sulfate concentration in the Bhadra River water was recorded to be very high and it was in the good to injurious category. The tendency of high sulfate concentrations is to limit the uptake of calcium by plants. This decrease in the uptake of calcium is associated with the other hand, with relative increases in the absorption of sodium and potassium. Nitrate is one of the primary macronutrients that stimulate plant growth. Inherent soil nitrogen or supplementary fertilizers are the common sources, but nitrate in the irrigation water has much the same effect as soil-applied fertilizer nitrogen and an excess will cause problems, just as too much fertilizer would.

3.1.3 SAR Index of Bhadra River Water

The degree to which the irrigation water tends to enter into cation exchange reaction in soil can indicated by the sodium adsorption ratio. Excess sodium gets adsorbed on soil particles, thus changes the soil properties and also reduces permeability. In this study, SAR 41.55 was found to exceed the tolerable range SAR 26 and thus causes big problem for irrigation.

3.2 Soil Quality of Bhadra River Catchment

Table 3-3: Nutrients level chart of soil (SRDI) Standard

Nutrients	Very low	low	Medium	Optimum	High	Very High
P(µg/g)	<7.5	7.51-15	15.1-22.5	22.5-30	30.1-37.5	>37.5
Zn(µg/g)	<0.45	0.45-9	0.91-1.35	1.35-1.81	1.81-2.25	>2.25
Cu(µg/g)	<0.15	0.15-0.3	0.31-0.45	0.45-0.6	0.61-0.75	>0.75
K(meq/100g)	<0.09	0.091-18	0.181-0.27	0.271-.36	0.361-45	>0.45
Ca(meq/100g)	<1.5	1.5-3.0	3.1-4.5	4.51-6	6.1-7.5	>7.5
Mg(meq/100)	<0.375	0.375-0.75	0.751-1.1	1.2-1.5	1.5-1.875	>1.87

Table 3-4: Nutrients level in Collected Field Soil Samples Near Bhadra River

Sample No	pH	N (%)	Zn (µg/g)	Cu (µg/g)	K (meq/100g)	Ca (meq/100g)	P (µg/g)	Mg (meq/100)
1		0.095	1.64	3.32	0.21	26.55	13.63	5.83
2		0.111	1.02	3.00	0.22	26.65	9.20	5.97
Avg.		0.103	1.33	3.16	0.22	26.60	11.42	5.90

3.2.1 Soil Fertility Based on Available Nutrients

The optimal pH range for agricultural soil in most plants is between 6.5 and 8.5. Because pH levels control many chemical processes that take place in the soil specifically, plant nutrient availability it is vital to maintain proper levels for plants to reach their full yield potential. The average obtained pH value is 8.52 which suggest alkaline soil. Zinc is essential plant micronutrient. It is important for production of growth hormones. Good root development depends on Zn. So, maintaining adequate Zn content is very necessary. The average obtained value of Zn is 1.31 which indicates that the Zn content is medium and needs to increase. Copper is essential elements in plants growth. Without adequate copper contents plants fail to grow properly. So, maintaining fair amount of copper is very essential. The average obtained value of copper is 3.16 (µg/g) which indicates a higher amount of copper present in soil. Potassium (K) is an essential nutrient for plant growth and is classified as a macronutrient due to large quantities of K being taken up by plants during their life cycle. But when the supply from the soil is not adequate, K must be supplied in a fertilizer program. The average obtained value of K is 0.22 (meq/100g) which indicates a moderate amount of K present in soil. Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. Phosphorus is one of the three nutrients generally added to soil as fertilizer. One of the main roles of P in living organisms is in the transfer of energy. Organic compounds that contain P are used to transfer energy from one reaction to drive another reaction within cells. Adequate P availability for plants stimulates early plant growth and has tens maturity. The average obtained value of P is 11.42 which indicates low amount of P present in soil. So, quantity of P needs to increase. Calcium is essential for many plant functions. It is needed for plants for cell division, Cell wall development, nitrate uptake and metabolism, enzyme activity, etc. The average obtained value of Ca^{2+} is 26.60 (meg/100g) which indicates very high amount of Ca^{2+} present in soil. Magnesium is an essential plant nutrient. It has a wide range of key roles in many plant functions, one of the magnesium's well-known roles is in the photosynthesis process, as it is a building block of the Chlorophyll, which makes leaves appear green. The average obtained value of Mg is 5.90 (meg/100g) which indicates a very high amount of Mg present in soil.

4. CONCLUSIONS

The first objective of this study was to determine the water quality of the Bhadra River and its suitability for irrigational use as the river is a major source of water for agricultural activities due to traditional practice with surface water irrigation as well as higher cost in ground water irrigation. For this study, total five river water samples were collected during wet season. Test results indicated that the Bhadra river water is suitable for irrigational uses. pH of water samples were observed to be in the normal range (6.5-8.4) irrespective of sampling months and stations, indicating that the river water was suitable for irrigation.EC, TDS, major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}), values are in tolerate limit, but SAR Index restricted the Bhadra River water for use in irrigation. The second objective of this study was to identify the soil quality and soil fertilization status of Bhadra river catchment. From the analysis of Bhadra river catchment soil data, it was found that in collected soil samples only K and Zn were within the range of standard value. But, the nutrients of soil such as P, Ca, Mg and Cu were beyond the suitable ranges.

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REFERENCES

Abrol, I., Yadav, J., & Massoud, F. (1988). Salt-affected soils and their management. Food andAgriculture Organization of the United Nations. FAO soils bulletin, 39.

Alam, M. (1990). Bangladesh in world regional geology: Columbia University Press, New York.

Banuls, J., & Primo-Millo, E. (1992). Effects of chloride and sodium on gas exchange parameters andwater relations of Citrus plants. Physiologia Plantarum, 86(1), 115-123.

Carr, M. (2013). Crop Yield Response to Water. FAO Irrigation and Drainage Paper 66 By P. Steduto,TC Hsiao, E. Fereres and D. Raes. Rome, Italy: Food and Agriculture Organization of the UnitedNations (2012), pp. 500, US $100.00. ISBN 978-92-5-107274-5. The whole report can bedownloaded from: http://www. fao. org/docrep/016/i2800e/i280e00. htm. ExperimentalAgriculture, 49(2), 311-311.

Coleman, J. M. (1969). Brahmaputra River: channel processes and sedimentation. Sedimentary Geology,3(2-3), 129-239.

Hague. S. (2006). Salinity problems and crop production in coastal regions of Bangladesh. PakistanJournal of Botany, 38(5), 1359-1365.

Kirby, J., Mainuddin, M., Mpelasoka, F., Ahmad, M., Palash, W., Quadir, M.Hossain, M. (2016). The impact of climate change on regional water balances in Bangladesh. Climatic change, 135(34),481-491.

Kotb, T. H., Watanabe, T., Ogino, Y., & Tanii, K. K. (2000). Soil salinization in the Nile Delta andrelated policy issues in Egypt. Agricultural water management, 43(2), 239261.

LaHue, G., & Ecogeomorphology, R. (2017). Saline soils and water quality in the Colorado River Basin:Natural and anthropogenic causes.

Milliman, J. D., & Meade, R. H. (1983). World-wide delivery of river sediment to the oceans. The Journalof Geology, 91(1), 1-21

Morgan, J. P., & McINTIRE, W. G. (1959). Quaternary geology of the Bengal basin, East PakistanandIndia. Geological Society of America Bulletin, 70(3) 319-342.

Mondal, M., Tuong, T., Ritu, S., Choudhury, M., Chasi, A., Majumder, P, Adhikary, S. (2006). Coastal water resource use for higher productivity: participatory research for increasing croppingintensity in Bangladesh. Environment and Livelihoods in TropicalCoastal Zones: Managing Agriculture-Fishery-Agriculture-fishery-Aquaculture Conflicts., 72-84.

Mondal, M., Tuong, T., & Sattar. M. (2008). Quality and groundwater level dynamics at two coastal site of Bangladesh: implications for irrigation development. CGIAR Challenge Program on water and Food, 7.

Petersen, L., & Shireen, S. (2001). Soil and water salinity in the coastal area of Bangladesh.BangladeshSoil Resource Development Institute.
Parida, A. K., & Das, A. B. (2005). Salt tolerance and salinity effects on plants: a review. Ecotoxicologyand environmental safety, 60(3), 324-349.
Roy, M., Datta, D., Adhikari, D., Chowdhury, B., & Roy, P. (2005). Geology of the Khulna citycorporation. J Life Earth Sci, 1, 57-63.
Rahman, M., Das, R., Hassan, N., Roy, K., Haque, F., & Akber, M. A. (2014). Environmental study onwater quality of Mayur River with reference to suitability for irrigation. International journal ofenvironmental sciences, 4(6), 1150.
Smedema, L. K., & Shiati, K. (2002). Irrigation and salinity: a perspective review of the salinity hazardsof irrigation development in the arid zone. Irrigation and drainage systems, 16(2), 161174.
Siyu, X., Zhixun, X., & Pingwu, W. (1996). Soil salinity in the irrigated area of the Yellow River inNingxia, China. Arid Land Research and Maagement, 10(1), 95-101.
Shahid, S, Chen, X., & Hazarika, M. K. (2006). Evaluation of groundwater quality for irrigation in Bangladesh using geographic information system. Journal of Hydrology and Hydromechanics,54(1), 3-14.
Warrence, N. J., Bauder, J. W., & Pearson, K. E. (2002). Basics of salinity and sodicity effects on soilphysical properties Department of Land Resources and Environmental Sciences: Montana StateUniversity, Bozeman.

ASSESMENT OF PARTICULATE MATTER AND NOISE POLLUTION AT DIFFERENT ROAD INTERSECTIONS IN KHULNA CITY

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ABSTRACT

Air is a crucial element of the atmosphere which may affect all the living creatures and the environment. Air with high particulate matter (PM) is most harmful to public health and environment. Noise is also one of the most extending environmental problem. Characteristics of airborne particulate matter and noise generated from the movement of traffic have been studied at different road intersections in Khulna City. PM and noise data were collected from five locations named as Fulbarigate, Shiromoni, Daulatpur, Shibbari More and Notun Rasta. Different fractions of PM and sound level found to be closely correlated with the number of heavy traffic as like busses, trucks, auto-rickshaws, three-wheelers and two-wheelers as counted at the study area. The maximum noise level found as 87 decibel at Daultatpur and minimum was 79 decibel at Fulbarigate. Maximum concentration of $PM_{1.0}$, $PM_{2.5}$, PM_{10} were reported at Duk Bangla as 27.0 (µg/m^3),43.0 (µg/m^3),63.0 (µg/m^3). $PM_{2.5}$ found to contribute to the total concentration of PM_{10} about 69 % at Duk Bangla location while the maximum value of $PM_{1.0}/PM_{2.5}$ ratio obtained as 0.63 at Shibbari More which indicates the dominancy of fine particles at theses locations. The highest air quality index (AQI) value was found as 67 at Duk Bangla which indicates the moderate air quality of this location whereas other four intersections exhibited the air quality according to AQI as good. Recorded noise level found to be exceeded the national standard for all monitoring locations.

Keywords: *Particulate matter, Noise pollution, Air quality index, $PM_{2.5}/PM_{10.0}$.*

1. INTRODUCTION

Air quality is degrading rapidly all over the world and as well as Noise level is becoming untolerable to human beings. These problems arise mainly for urbanization, industrialization, high density of population and increasing level of vehicular concentrations. Khulna is the third largest city of Bangladesh. It is one of the most traffic congested city with a large number of population about 0.63 million .The number of population in Khulna city is expected .990 million by 2020 (Population Stat, 2019).The rapid growth of population and industries making as increasing scenario of number of vehicles and the limited roadways causing heavy traffic concentration.Therefore the emissions from vehicles specially Particulate Matter have been identified as the most responsible pollutant causing air pollution. The traffic generated emissions are accounting more than 50% of the total PM emissions in the urban areas (Wrobel et al., 2000). About more than 30% respiratory problems are related to personal exposure to high level PM concentrations (WHO, 2000).

At present, over 600 million people living in urban areas worldwide are being exposed to dangerous levels of traffic–generated air pollutants (Cacciola et al., 2002). In developed countries, PM emissions are mainly responsible for respiratory health problems (Yang, 2002; Shendell and Naeher, 2002; Wang et al., 2003). Vehicular exhausts, emission from tire and brake wear and re-suspension of road dusts are the major sources of Ambient PM concentrations. During recent years, Khulna city is experiencing a rapid growth of industrialisation due to easily navigation transport of raw materials by Mongla Port. The government of Bangladesh has banned thousands of two-stroke three-wheelers, sometimes known as baby taxis, from the streets of Dhaka. Because of this Banning, vehicles took place in some divisional cities, also in Khulna. According to the daily air quality index (AQI) report of 29th November, 2019 the Air quality index of Khulna city was recorded as 184 which indicates unhealthy conditions. A lot of peoples are suffering from respiratory problems due to Air pollution.

Noise is derived from the Latin word “nausea” implying unwanted sound or sound that is loud, unpleasant or unexpected (Sing et al., 2004). Noise pollution is defined as form of air pollution that is an audible unwanted sound that poses a threat to a person’s health and well-being (Goines et al., 2007). In Khulna city, the noise level is also increasing rapidly specially for vehicular movements. Large amount of buses and trucks are moving through this city because of different industrial activities situated in this city. Vehicles moving between Dhaka to Khulna for passenger purpose are also responsible for generating noise. As per the December 2018 report of Department of Environment, Khulna, most of the populous places in the city have crossed the allowable limit 60dB. The noise level at Rupsha Traffic intersection was 70dB and Daulatpur, Sonadanga and Boyra bus stands stood at 73, 82 and 72 respectively. According to World Health Organization (WHO), generally 60dB sound can make a person deaf temporarily and 100dB sound can cause complete deafness. Road users in Khulna city such as drivers, helpers, shop keepers, students etc. are suffering from heart attack, bed temper, hearing problem because of noise pollution (Begum et al., 2011). In Khulna city area, there are 49 rice mills,7 jute mills and 32 other mills and lots of trucks are moving to carry their raw materials and products. In recent years, it is shown that , the roadway of Khulna city is frequently submerging with water ,as a result these road surface getting cracked easily.For this reason, the friction between trye and roads are increasing and it increases PM Mass concentrations.So improvement of traffic management system and besides roadway environment may have a direct consequences on Air quality and noise level.The objectives of this study to asses the concentration of Particulate matter and Noise level at some road intersections and to compare the value with Bangladesh National Air Quality Standards and Standard set by the government of Bangladesh.

2. METHODOLOGY

2.1 Selection of Locations

Five road intersections were selected carefully for achieving the purpose of this study. These intersection points have more populated traffic congestion than other points. The first point was Fulbarigate, which is about 6m North of Fulbarigate Police box. The second point was Daulatpur about 2m South of Akankha Tower. The third intersection point was Notun Rasta about 2m east of Mosque. Shibbari More was taken as fourth intersection point about 2m apart from Sundarban Currier Service office. Duk Bangla was taken as fifth intersection points. These points were selected very close to intersections. Description of selected locations are presented in Figure1.

2.2 Particulate Matter (PM) Monitoring

Handheld 3016 IAQ laser particle counter, a real time particulate matter monitoring equipment was used in this study. After finalizing the monitoring locations, with the help of the monitoring equipment as shown in Figure 2, PM data was measured. Air data monitoring campaigns were conducted frequently at different dates for at least 1-hour duration at every intersection point from June to September, 2019. Particulate matter concentration data were recorded per min by PM counter as per their sizes. The concentration of different PM fractions (0.3, 0.5, 1.0, 2.5, 5.0, 10.0) were recorded by this equipment.

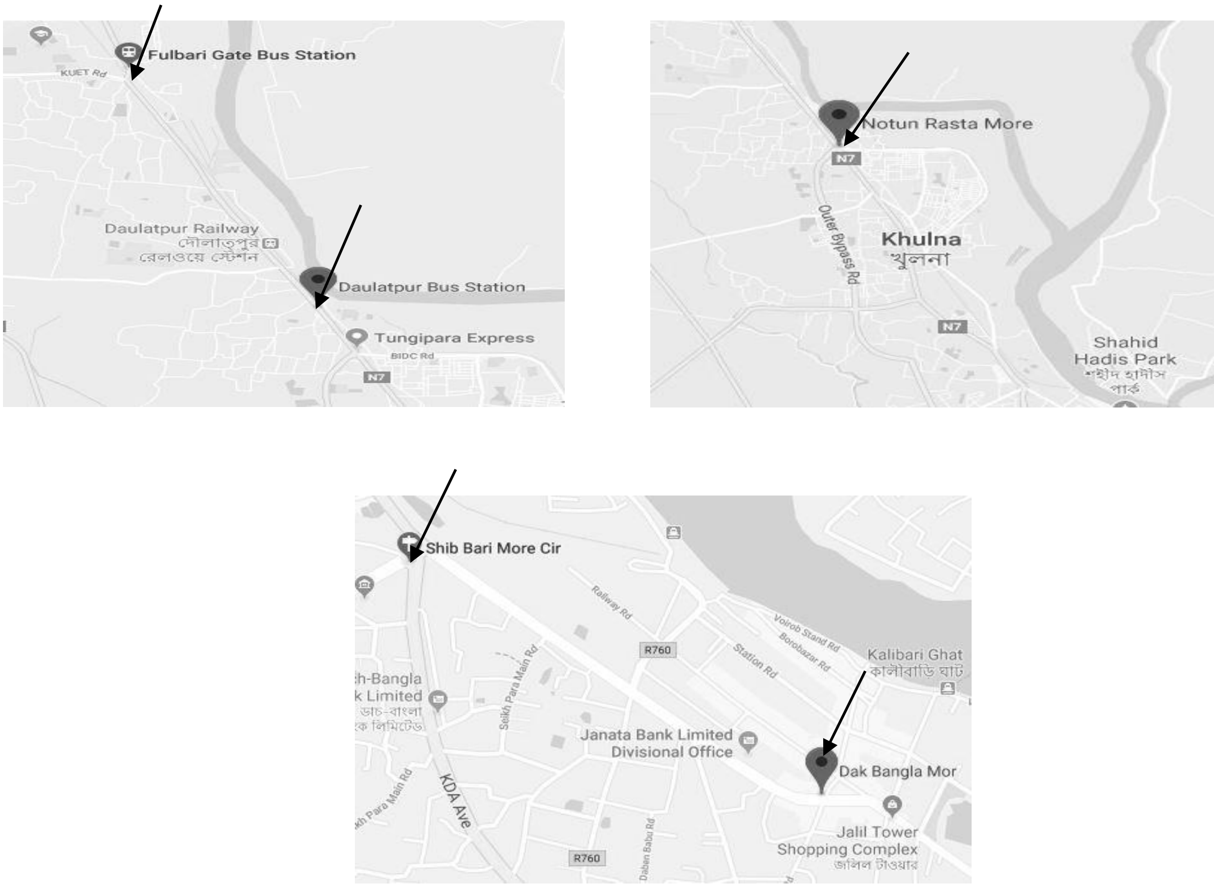


Figure 1: Monitoring locations in Map

Figure 2: Particulate Matter Monitoring at Shibbari More

2.3 Monitoring of Sound

Noise measurements were conducted with the PM concentration data at the selected locations by using a calibrated Sound Level Meter (SLM). The Sound Level Meter was placed a specified distance from the source of sound and kept it at a height of ear level shown in Figure 3. The distance between the source of sound or traffic and Sound level meter was 1.5m for all intersection points. Sound data were recorded per minute intervals from this equipment. All points from where sound data was collected at the same conditions. All intersection points were open, no obstacles to sound such as buildings, trees, poles etc. It was maintained that there was no contribution of noise from other sources. After using this collected data, the Noise level of this point was reported with the help of standard set by the government of Bangladesh.

Figure 3: Noise Data sampling by Sound Level Meter

2.4 Traffic Monitoring

From all selected intersection points, traffic data was collected simultaneously with PM concentration and Noise data by video recording of moving vehicles. Mobile camera was used for recording the movement of vehicles. After that, the video was analysed and vehicles were counted with respect to time. By using this data, the variation of PM concentration with Traffic volume was reported. At the same time variation of Noise level with traffic volume was reported.

2.5 Calculation of Air Quality Index

Air Quality Index is a communication to easily and effectively describe the air quality of a certain location. AQI values are derived from air quality data readings, which allows for more meaningful comparison of pollutants affecting air quality. The index is derived using the below depicted formula 1.

$$\textbf{AQIpollutant} = \frac{\textit{Pollutant data reading}}{\textit{Standard}} * 100 \quad \ldots\ldots \qquad ..(1)$$

3. RESULTS AND DISCUSSION

3.1 PM Mass Concentration and Air Quality Index

Average PM concentration at selected road intersections are presented in Table 1. Concentrations of $PM_{2.5}$ and $PM_{10.0}$ found within the BNAAQS for all considered intersection. Duk Bangla location found to carry the highest concentration of $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ as 26.64 µg/m^3, 43.47 µg/m^3 and 63.02 µg/m^3 consecutively. This can be happened due to the larger vehicular movement at this location. Notun Rasta location showed lowest average concentration of $PM_{1.0}$, $PM_{2.5}$ and $PM_{10.0}$ as 5.82 µg/m^3, 13.33 µg/m^3 and 34.91 µg/m^3 respectively. Highest $PM_{1.0}$/ $PM_{2.5}$ appeared at Shibbari More as 0.63 and lowest was at Fulbarigate as 0.43 indicating the contribution of $PM_{1.0}$ to the concentration of $PM_{2.5.}$ Highest $PM_{2.5}$/ $PM_{10.0}$ found at Duk Bangla as 0.69 indicates 69 % presence of fine particles in total particle concentration. Air Quality Index of 1-hr averaging PM concentration data at selected road intersections are presented in Table 2. AQI of $PM_{2.5}$ and $PM_{10.0}$ found as good for four locations named as Fulbarigate, Daulatpur, Natun Rasta and Shibbari more while the location named as Duk Bangla found to exhibit the AQI value as moderate. It can be evidenced from the larger vehicular movement at this location as tremendous amount of people used to come to this location for purchasing different goods.

Table 1: 1-hour average PM concentration at selected road intersections

Description		**Fulbarigate**	**Daulatpur**	**Notun Rasta**	**Shibbari More**	**Duk-Bangla**
PM Mass concentration (µg/m^3)	$PM_{1.0}$	6.0	7.0	6.0	15.0	27.0
	$PM_{2.5}$	14.0	15.0	13.0	24.0	43.0
	$PM_{10.0}$	36.0	39.0	35.0	41.0	63.0
PM Mass Ratio	$PM_{1.0}$/ $PM_{2.5}$	0.43	0.44	0.44	0.63	0.62
	$PM_{2.5}$/ $PM_{10.0}$	0.39	0.40	0.40	0.60	0.69

Table 2: Air Quality Index of 1-hr averaging PM concentration data at selected road intersections

Location	Standard ($\mu g/m^3$)	AQI of PM for Respective Locations				
		Fulbarigate	Daulatpur	Notun Rasta	Shibbari More	Duk Bangla
$PM_{2.5}$	65 (24h avg)	21	23	21	37	67
PM_{10}	150 (24h avg)	24	26	23	28	42
AQI	-	24	26	23	37	67
Category	-	Good	Good	Good	Good	Moderate

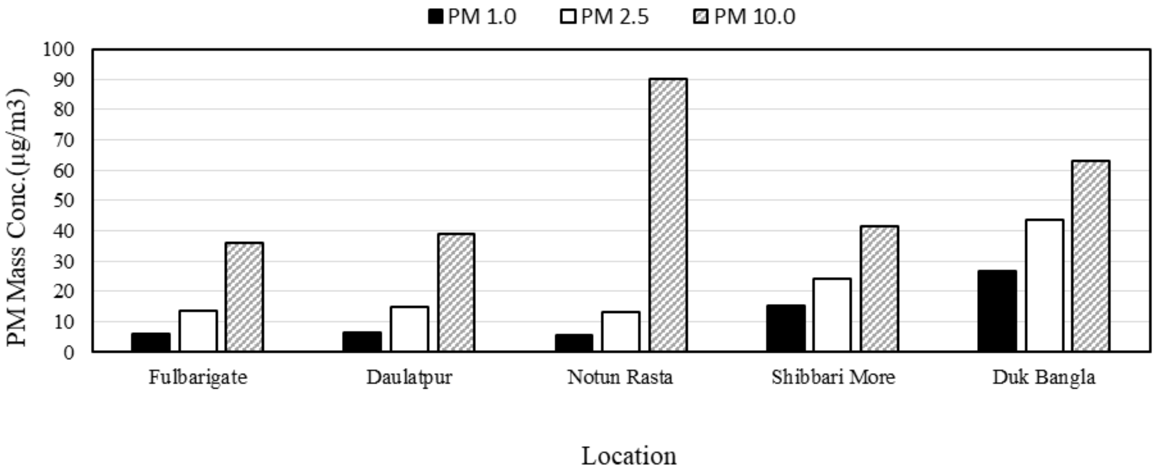


Figure 4 : PM Mass concentration at different road intersections

PM Mass concentration at different road intersections presented in Figure 4. Bar diagram represented the variation of PM Mass Concentration at five road intersection points. In the diagram it was seen that the concentration of PM_{10} at Notun Rasta is higher than other intersection points. It was due to high traffic volume and more traffic congestion. Vehicles movement at new market were very slowly because in this intersection a lot of traffic came from two sideways one of Notun Rasta –Khalispur link road and another is Notun Rasta-Sonadanga link road. Also, concentration of $PM_{2.5}$ and PM_{10} was very high at Duk Bangla because of a large number of 3W vehicles and auto-rickshaw were moving and contributing particulate matter.

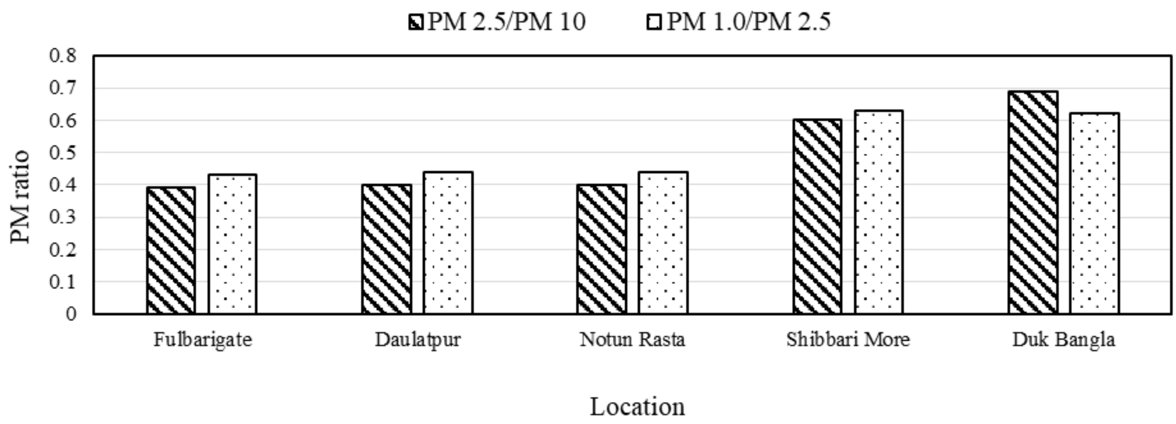


Figure 5: PM ratio at different road intersections

At four intersection points the value of $PM_{1.0}/PM_{2.5}$ was larger than the value of $PM_{2.5}/PM_{10.0}$ indicated that Particulate matter sizes less than 1 µm contributing higher than other particle sizes for polluting the air of Fulbarigate, Daulatpur, Notun Rasta and Shibbari More. At Duk Bangla location, $PM_{2.5}/PM_{10.0}$ value was higher than $PM_{1.0}/PM_{2.5}$ indicated that the particulate matter sizes less than 2.5 µm contributing more for air pollution of that intersection point.

3.2 Traffic Concentration

Vehicles moving through the intersection points were classified as 2W (motor cycle), 3W (auto rickshaw, CNG), 4W (small trucks, private cars) and HCV (large buses and trucks). Vehicles moving through all the selected road intersection points were counted manually for one-hour duration with four minutes intervals as presented in Table 3. From this data, average traffic moving at Fulbarigate, Daulatpur, Notun Rasta, Shibbari More and Duk Bangla were 84, 96, 106, 84 and 79 nos for per four minutes respectively. It was found that the number vehicles crossing Notun Rasta was highest than then other points which was the major reason of higher concentration of Particulate matter at that location. Also, the location Duk Bangla contained the average traffic flow as high which supports the higher concentration of PM at this location. Among all intersection points the amount of HCV was higher at Fulbarigate (12%) that contributes huge amount PM emissions.

Table 3: Percentages of motor vehicle plying on monitoring intersections

Location	**2W**	**3W**	**4W**	**HCV**
Fulbarigate	23%	51%	12%	14%
Daulatpur	17%	68%	9%	6%
Notun Rasta	21%	59%	7%	13%
Shibbari More	23%	57%	11%	9%
Duk Bangla	20%	52%	12%	16%

3.3 Noise Level at Five Selected Road Intersections

Noise level of five road intersections is shown in Figure 6. It was reported that the highest value of noise level belongs to Daulatpur as 85.95 dB at high value weighted A and 83.09 dB at low value weighted A. Daulatpur road intersection was also near the three-wheeler station and bus station. Large number of shops are situated near this point that contributes more sound value. Duk Bangla is one of the most congested place of Khulna city having three-wheeler stand and lots of shop in the footpath. It is also a business centre of Khulna City. Because of these reasons a large number of people are gathering there and as a result the sound level of this intersection poses higher than tolerable limit. It is seen that in each intersection points the sound value exceeds the standard value set by the government (70dB).

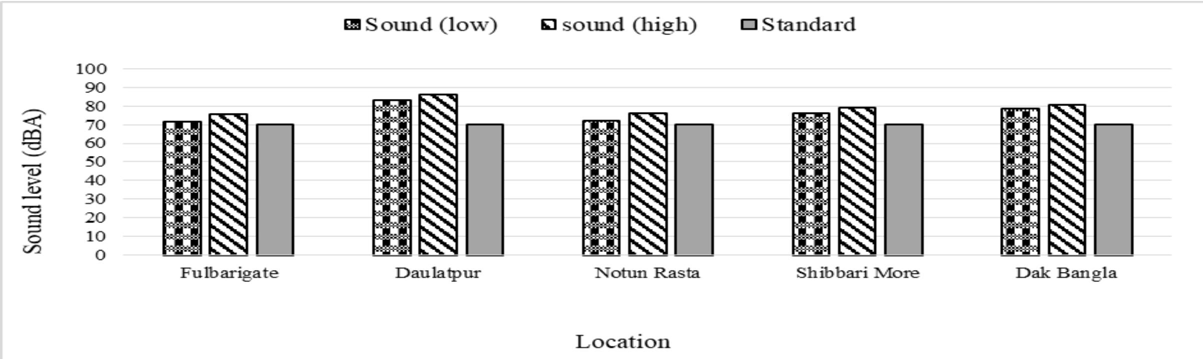
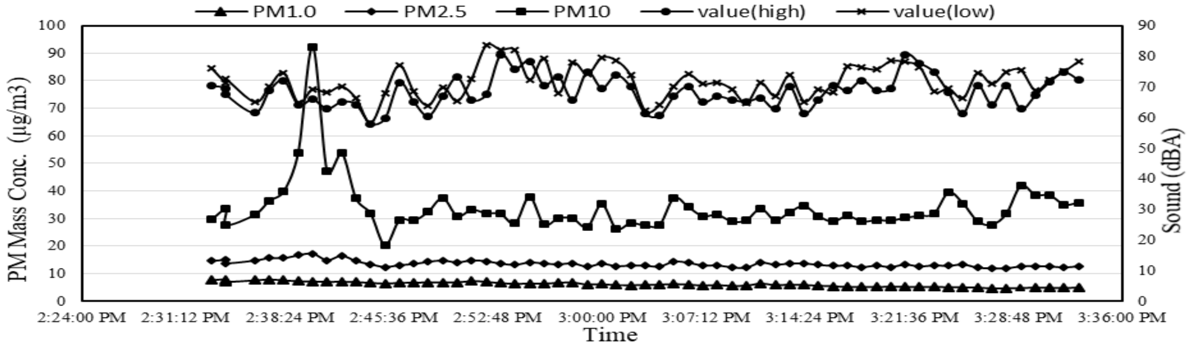


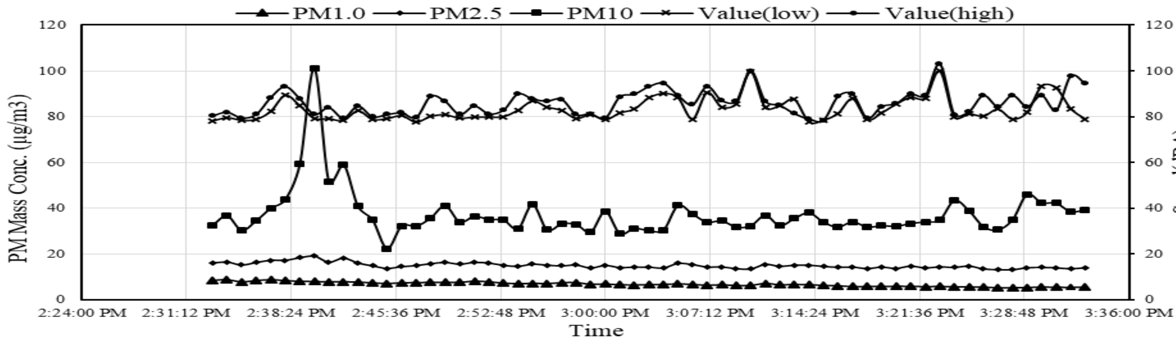
Figure 6: Variation of Noise level at road intersections

Variation of PM Mass concentration and Sound level for all monitoring locations are shown in Figure 7(a) to Figure 7 (e).

The nature of PM mass concentration and noise level curve with respect to time poses similarity. Most of the cases it is shown that, Particulate matter increasing with the increasing of noise level. Both of these data are generated from vehicular movement. PM concentration and noise level pose high pick when the concentration of vehicular movement increases. Sometimes it was observed that the concentration of PM increases abruptly specially at Fulbarigate because of occurring traffic congestion when train was crossing through Dhaka –Khulna highway. At that time Vehicular emission increases due to fuel combustion although vehicle concentration is not increased and sound data also poses peak in that curve due to sound contribution by moving train. At other road intersections, fluctuation of PM concentration and sound level was reported. The main reason for showing that fluctuation could be the gathering of people with motorized vehicle at the respective locations affecting the PM concentration and Noise level.



(a)



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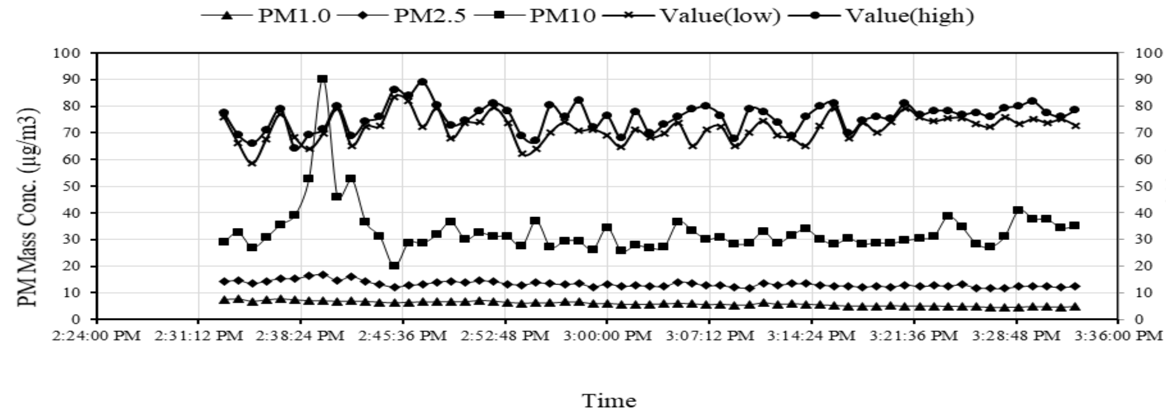

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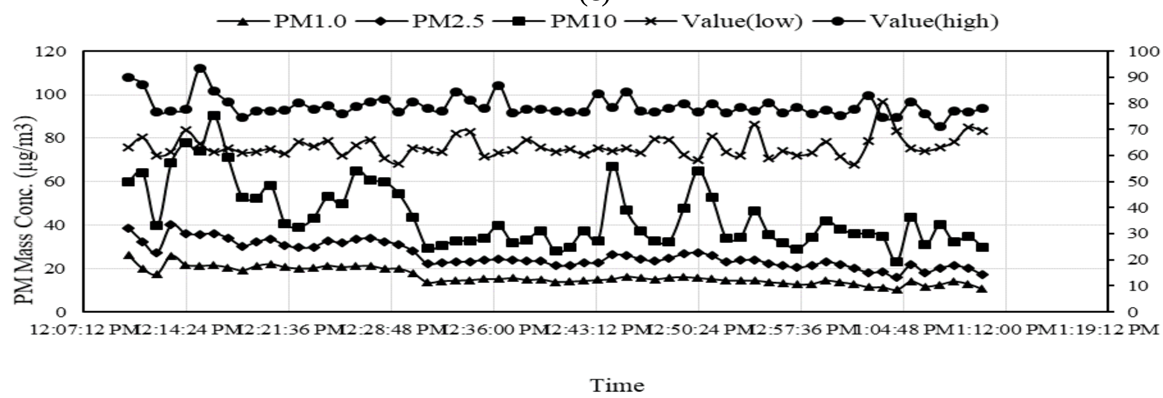

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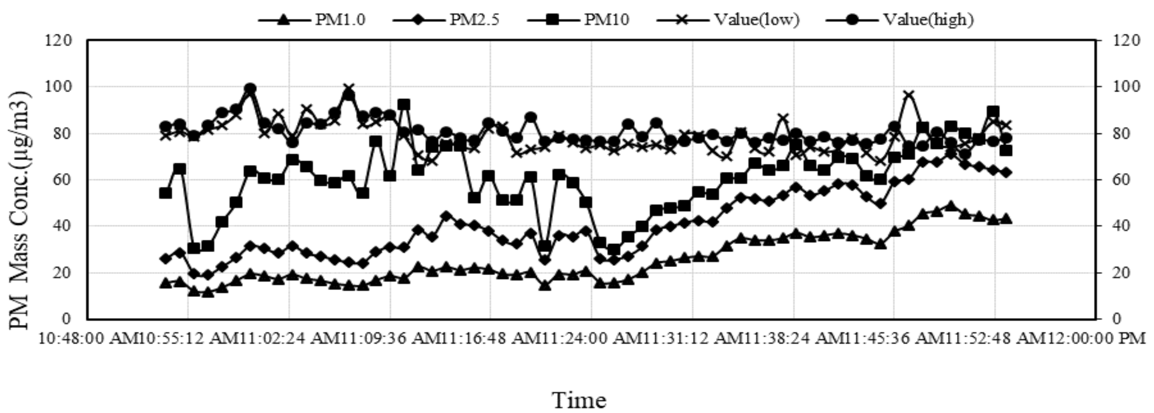

(e)

Figure 7: Variation of PM Mass concentration and Sound level; (a) Fulbarigate, (b) Daulatpur, (c) Natun Rasta, (d) Shibbari More and (e) Duk Bangla

4. CONCLUSIONS

In this present study, the concentration of PM_{10}, $PM_{2.5}$, $PM_{1.0}$ and Noise level due to heterogeneous traffic movement at five road intersection points of Khulna city was investigated. Major findings of this study are as follows:

- Maximum concentration of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} were reported at Duk Bangla as 27.0 $\mu g/m^3$, 43.0 $\mu g/m^3$, 63.0 $\mu g/m^3$.
- The maximum Noise level was 87 decibels at Daultatpur location and minimum was as 79 decibels at Fulbarigate location.
- The maximum value of $PM_{2.5}/PM_{10.0}$ ratio was 0.69 obtained at Duk Bangla and minimum value found as 0.43 found at Fulbarigate.
- The maximum value of $PM_{1.0}/PM_{2.5}$ ratio was obtained as 0.63 at Shibbari More while minimum value was found as 0.39 at Fulbarigate.
- The highest air quality index (AQI) value was found at Duk Bangla as 67 which indicates moderate air quality of this location. The condition of air quality found good for rest four locations according to the AQI of PM.

REFERENCES

Bangladesh Bureau of Statistics (BBS), (2011). *District Statistics, Khulna*, Government of Bangladesh.

Begum, B. A., Kamal, M., Salam, A. and Biswas, S. K., (2011). Assessment of Particulate Air Pollution at Kalabagan and Shisumela Area Along the Mirpur Road, Dhaka. *Bangladesh J. Sci. Ind. Res.* 46(3), 343-352,

Cacciola, R. R., Sarva, M., and Polosa, R., (2002). Adverse respiratory effects and allergic susceptibility in relation to particulate air pollution: flirting with disaster. Allergy 57, 281–286.

Goines, L. and Haglar, L. (2007). Noise Pollution: A Modern Plague. *Southern Medical journal. March; 100(3):287-293.*

Population Stat, (2019). Population Stat for Khulna, Bangladesh, Available at: https://populationstat.com, Accessed: November, 2019.

Santhanam, E., Martin, K., Goody, A., & Hicks, O. (2011). Bottom-up steps towards closing the loop in feedback on teaching: A CUTSD project. *Paper presented at Teaching and Learning Forum – Expanding horizons in teaching and learning, Perth, Australia, 7-9 February 2001.*

Sing, N. and Davarj, S. C., (2004). *Hum. Ecol*. 16(3): 181-187.

World Health Organization (WHO), 2000. Air Quality Guidelines for Europe. WHO Regional Publications, European Series No. 91, WHO Regional Office for Europe, Copenhagen.

Wrobela, A., Rokitaa, U. E., and Maenhautc, B. W. (2000). "Transport of traffic-related aerosols in urban areas. The Science of the Total Environment 257 2000 199-211.

Yang, K.L., (2002). Spatial and seasonal variation of PM10 mass concentrations in Taiwan. *Atmospheric Environment 36, 3403–3411.*