EFFECTS OF WASTE WATER FROM TEXTILE INDUSTRIES ON KARNAFULI RIVER

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ABSTRACT
Textile industry is one of the largest production sectors in Bangladesh. These industries use high volume of water and large quantity of harmful chemical compounds throughout its operation and finally dump this polluted water in nearby water bodies. In Chittagong, Karnafuli River is the victim of such incident. This study is focused to find out the negative effects of textile wastewater on Karnafuli River. The study took wastewater sample of five textile industries near Kalurghat Industrial Area and different confluence points of river Karnafuli and analysed different water parameters including pH, BOD, COD, TS, TSS, TDS, Total alkalinity, Chloride, Faecal coliform, Electrical conductivity. It also performs heavy metal tests including Na, Ca, Mg, Mn, Zn, Cu, Pb, K and Cd. All the test results are compared with few international standards along with the Bangladesh drinking & industrial effluent standards. The comparison shows that the values of TDS & TSS in the river & the value of Turbidity in the confluence points are much higher than the standard limit. The heavy metal test shows nothing remarkable. The effects of high concentration of earlier mentioned parameters on human life and aquatic life are also discussed in this study.

Keywords: Karnafuli River; chemical waste; environmental effects; BOD; COD

INTRODUCTION
Bangladesh is a developing country and behind this development, textile industries play a vital role. It is the cardinal source of foreign currency and the contribution is about 12% to GDP (Akter, 2012). Though the contribution of textile industries to our economy is axiomatic, it has some serious environmental issues. Textile industries use high volume of water throughout the process of washing fibre and finished products, bleaching, dyeing etc. It is found from a study that textile industries consume approximately 200 litres of water to produce 1 kg of textiles (Yacout et al, 2013). Approximately 2000 different chemical compounds which includes pesticides, soda, heavy metals as colour pigments (Pb, Cd, Cu, Ni etc), minerals, acids, bases, salts etc. are mixed with (Environmental Hazards of the Textile Industry, 2005) water for various operations in textile and finally dumped into nearby water bodies. This chemical wastewater is very toxic for both human beings and aquatic lives.

Chittagong, the second most populated city after the capital Dhaka in Bangladesh is situated by the river Karnafuli. Being the centre of industries, Chittagong city possesses many textile industries and most of these industries are situated near to the river Karnafuli to meet the excess demand of water. A large number of local people also depend on this River for irrigation, cultivation, navigation, fisheries and source of drinking water. The wastewater produced by the textile industries release their effluents into the river and due to this rampant pollution by these textile industries, the amount of DO (Dissolved Oxygen) is alarmingly decreasing. From a recent survey, it is found that the amount of DO in Karnafuli River is between 3.37 to 6.37 mg/litre (Bashar et al, 2015), which is well below the required limit for shallow water fish. Another study found that the present p^H range of Karnafuli River is 6.36 to 9.86, which was previously 7.01-8.24 (Ahmed et al, 2010). Therefore, the acidity of Karnafuli River is increasing day by day, which makes it difficult to use the water as irrigation purpose, drinking purpose as well as for fishes. It is also creating severe problem in ecology, as water is a big part of it. By using this polluted water, public health is now in a threat.

Textile wastewater and their effects over every living beings is of prime concern to a mass people. A number of studies are carried out in different parts of the world to assess the negative effects of textile effluents. A study entitled as "Wastewater characteristics in textile finishing mills" analysed the different sources of water pollution in textile finishing mills and characterised the processed effluents according to treatability and reusability (Isabella et al. 2008). Another study by Y.C. Ho et el. (2012) assessed the effects of several textile waste on different environmental feature. The effect on surface water, ground water, seawater and land was also described in that paper. Imtiazuddin et el. (2012) examined the textile wastewater effect on the environment by analysing TDS, TSS and heavy metal tests.

Pollution of Karnafuli River is more than ever now as the number of textile industries are increasing near the banks of river. Thus, the value of DO, BOD, COD, TSS, TDS etc. parameters are changing to a more unfavourable limit. This study on Karnafuli River is focused to analyse different water parameters and an assessment of present condition of the River water quality based upon the analysed water parameter results. It also discussed the negative effects of wastewater consumption by the people living beside the river and the potential danger to aquatic lives.

METHODOLOGY

This study is conducted over textile industries situated in Kalurghat area. Effluent from these textile industries empty into different tributaries and finally meets Karnafuli River. To assess the condition of Karnafuli River this study also analyzed sample wastewater, collected from different confluence points. To conduct the study following work plan was followed:

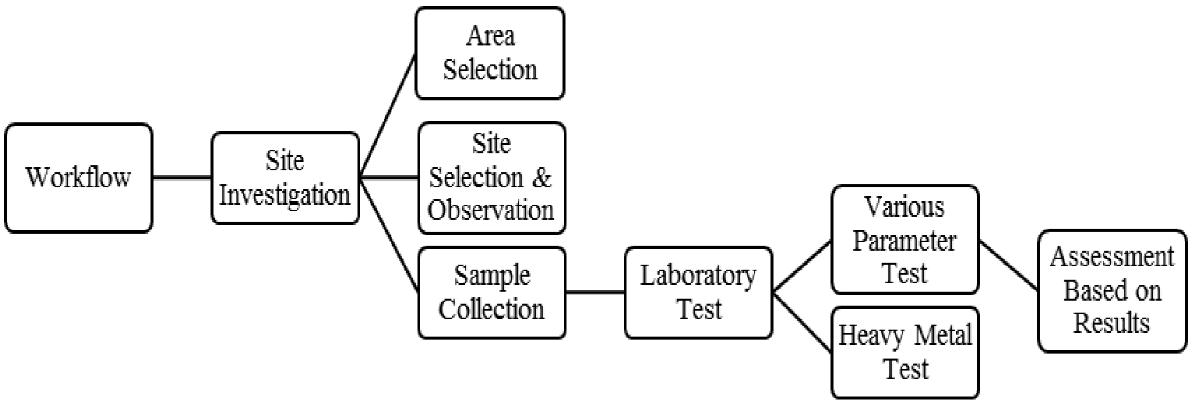

Fig. 1: Hierarchy of work plan

Kalurghat industrial area was selected to conduct the study as most of the textile industries in Chittagong is situated in that area. Eventually effluent from these textiles are explicitly emptying in Karnafuli River. A preliminary survey was carried out in Kalurghat area to assess the overall condition of textile industries. It is found that without the exception of few most of the textile industries are equipped with an effluent treatment plant (ETP). In most of the cases these ETP's were either not fully functional or required demand was not met. Moreover, it is also found from the survey that, effluents, either treated or untreated is dumped in various canals, which are running through many regions of lower income people. Kashem colony is one of them and a potential victim of many water borne disease as people living in this area use polluted water of canals because of unavailability of supply water. Assimilation capacity of these canals are almost nil because of narrow width and high concentration of textile wastewater dumping.

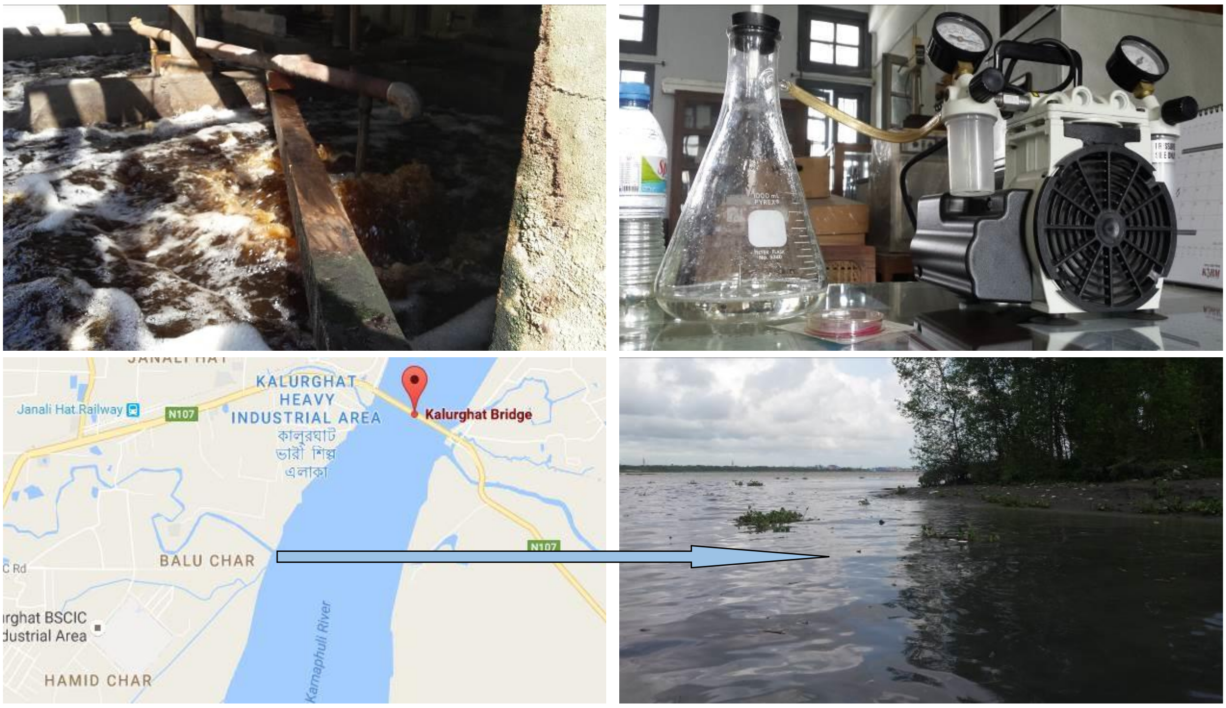

Fig 2: Wastewater collection, testing and location of Ispahani khal.

From the preliminary survey, five textile industries namely Fabion Trades, Well Group, Choice Wash, RTT Ltd and Al Hamadi Textiles were selected for sample collection. Collection of wastewater sample was carried out using plastic bottles. Proper precaution was taken while collecting sample from confluence points and different outlets following standard sampling manner. Both the effluent and influent sample of ETP were collected to analyze where it was applicable while in confluence points samples were collected in non-tidal and tidal condition and from different distance (Upstream 50m, confluence point, downstream 50 m and 100 m).

After collection of wastewater, various parameter tests including pH, BOD, COD, TS, TSS, TDS, Total Alkalinity, Chloride, Faecal Coliform, Electrical conductivity and Turbidity were conducted in Environmental lab of Civil Engineering department of CUET following American Society for Testing and Materials (ASTM) standard methods available at lab. Heavy metal tests includes Na, Ca, Mg, Mn, Zn, Cu, Pb, K and Cd. The heavy metal tests were conducted at Bangladesh Council of Scientific and Industrial Research (BCSIR), Chittagong using spectrometer. These tests determined different parameters of wastewater and represents the contemporary condition of water of textile industrial area and nearby water bodies. As the standard value of different water testing parameter is set depending upon the human and environmental compatibility, the obtained results from the lab were compared with Bangladesh drinking and industrial effluent standards, WHO drinking water standard and few other international standards to find out the effect of textile wastewater on Karnafuli River.

RESULTS AND DISCUSSION

The obtained test results of five different textile industries are tabulated in table 1, both treated and untreated effluent are tested for Fabion Trades and Well Group. Table 2 represents the standard value of different water parameters based on industrial standard, drinking standard and so on. From the comparison of test results with standard values it is found that the value of pH and DO is within the tolerable limit, so no treatment is needed here. The value of BOD for most of the textiles is within the acceptable limit considering industrial standards for Bangladesh; however, it is not satisfactory when compared to WHO drinking standards. High concentration values of TS, TSS and TDS is found in almost all the textiles in consideration. Wastewater sample of Al Hamadi textile shows unusually higher concentration values for TS (14000 mg/l) and TDS (7800 mg/l). The value of alkalinity, hardness and chloride seems acceptable considering *BIES.

Table 1: Water parameter test results of sample wastewater of different textile industries

Parameter	Unit	Untreated Effluent					Treated Effluent	
		Fabion Trades	Well Group	Choice Wash	Al Hamadi	RTT	Fabion Trades	Well Group
pH	N/A	9	8	7	8	7	8	8
DO	mg/l	4	10	7.6	9	10	8	8
BOD	mg/l	20	50	41	10	20	50	10
COD	mg/l	80	80	54	70	80	55	25
Total Hardness	mg/l as CaCO3	42	30	37	48	50	35	58
TS	mg/l	1800	1180	580	14000	540	1140	1380
TDS	mg/l	1350	800	30	7800	30	780	950
TSS	mg/l	450	380	550	6200	510	360	430
Total Alkalinity	mg/l as CaCO3	500	380	290	320	200	300	300
Chloride	mg/l	200	600	300	280	700	200	240
*FC	n/100 ml	Nil	Nil	Nil	Nil	Nil	Nil	Nil
*EC	µmohos/cm	1699	717	371	1534	1219	1062	1766
Turbidity	NTU	11.62	53.9	24.4	9.67	40.63	6.06	6.44

*FC- Fecal Coliform *EC- Electrical Conductivity

Table 2: Water parameter standards

Parameter	Unit	WHO standards	*BDS	*BIES	Canadian Standard	U.S EPA	EU-1998	IS-10500
pH		6.5-8.5	6.5-8.5	06-8.5	6.5-8.5d	6.5-8.5[d]	-	5.5-9.0[ISW]
DO	mg/l	-	4	200	7[d]	-	-	
BOD	mg/l	-	0.2	50	-	-	-	30[ISW]
COD	mg/l	-	6	4.5-8	-	-	-	250[ISW]
Total Hardness	mg/l as CaCO3	500	200-500	-	-	-		300[d]
TS	mg/l	250	150-600	600	-	-	-	-
TDS	mg/l	-	100	-	<500[d]	500[d]	-	-
TSS	mg/l	1000	1000	2100				
Total Alkalinity	mg/l as CaCO3	-	10	150	-	20[aq.]	-	-
Chloride	mg/l	-	1010	2250	-	230[aq.]	250	-
*FC	n/100 ml	5	10	25-45	-	-	-	-
*EC	µmohos/cm	0/100 ml	-	-	-	-	2500	-
Turbidity	NTU	-	-	1200	-	-	-	10[d]

[d] Drinking water quality standard; [ISW] Inland surface water quality standard; [aq] Aquatic environmental quality standard; *BDS-Bangladesh drinking standard; *BIES- Bangladesh industrial effluent standard; *FC- Fecal Coliform; *EC- Electrical Conductivity.
(Sources: Council of the European Union. 1998; DOE 1991; Federal Provincial Territorial Committee on Drinking Water. 2008; WHO. 2008 and Fundamentals of Environmental Measurements. 2014)

Heavy metal test results show nothing remarkable of Mn, Zn, Cu, Pb and Cd when compared with standard limit ECR-1997. The test results of Na, Ca, Mg and K is not compared to any standards due to unavailability of comparable sources.

Table 3: Heavy metal test results and comparison with standard values

Heavy Metals	Na	Ca	Mg	Mn	Zn	Cu	Pb	K	Cd
Test Results	15.2	13.6	12	0.14	0.08	0.11	-	5.66	-
ECR-1997	-	-	-	5	5	0.5	0.1	-	0.5
Canadian	-	-	-	-	5	-	0.01	-	0.005
U.S.EPA.	-	-	-	0.05	5	13	0.015	-	0.005
EU(1998)	-	-	-	0.05	-	2	0.01	-	0.005
IS: 10500	-	-	-	0.1	5	0.05	0.1	-	0.01

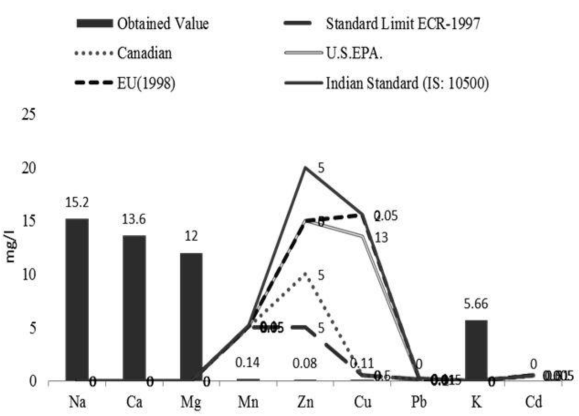

Fig. 3: Comparison of heavy metal test results

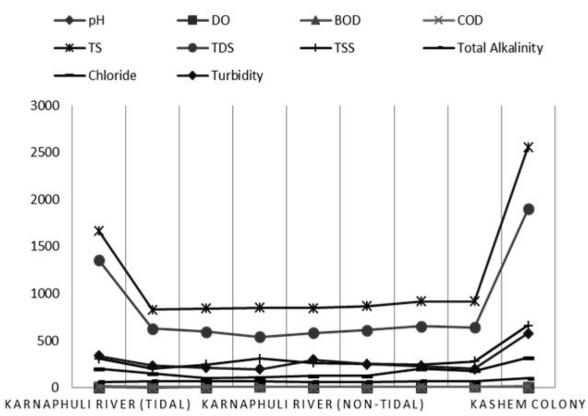

Fig. 4: Comparison of confluence point test results

Table 4: Water parameter test results of sample wastewater of confluence points

Parameter	Karnaphuli River (Tidal)				Karnaphuli River (Non-Tidal)				*KC
	u/s 50m	Confluence	d/s 50m	d/s 100m	u/s 50m	Confluence	d/s 50m	d/s 100m	
pH	7	7	7	7	7	7	7	7	8
DO	7	8.8	9.6	11	7.3	8.5	9.6	10.3	10.2
BOD	6.4	6	7	7.6	6.4	6.4	7.1	7.86	8
COD	15	10	9	12	9	9	12	10	15
TS	1670	830	843	850	846	870	920	920	2560
TDS	1360	630	596	540	582	613	655	640	1899
TSS	310	200	247	310	265	257	245	280	661
Total Alkalinity	62	70	68	68	61	64	70	68	100
Chloride	200	150	100	110	125	125	200	180	320
Turbidity	341	235	212	195	298	252	230	203	578

*KC- Kashem colony

From table 4 it is observed that the values of pH, BOD and COD in confluence points are lower than the *BIES but higher than *BDS. The value of TS and Chloride is much higher in *KC compared to the standard limits.

Effects on Karnafuli River

The present water quality of Karnafuli River is unsatisfactory, effluent of textile industries with high concentration of TDS and TSS is emptying into the River. Excess presence of these water parameters is blocking the sunlight and reducing the rate of photosynthesis in water body, thus endangering the aquatic life of Karnafuli River. Moreover, high concentration of TDS and TSS can cause physical injury and abrasion to fish skin. Water with high amount of TDS and TSS is also harmful for the nearby crop fields as undesirable accumulations in plant tissues and growth reduction might take place through consuming such water as irrigation purpose. To control the problem screening, trickling filter, sedimentation, filtration, activated sludge process, chemical coagulation etc. can be used. Turbidity is another parameter, which shows unfavorable values regarding the River water quality. Excess presence of turbidity is found both from visual experience and the test conducted in the laboratory. Due to this, less light is entered in the lower level of the River and reducing the plant productivity, thus DO is decreasing alarmingly in the River. Turbid water is also not suitable for drinking or everyday purpose as it cannot be disinfected because suspended particles hide microorganisms. To remove turbidity remedial filtration is needed and that includes flash mixing, coagulation, sedimentation and ultrafiltration. The presence of heavy metal in the river in excess amount can be detrimental and often toxic to aquatic life. Heavy metal accumulates in human body over a long period and finally results in some serious health problems like cancer. So drinking this water is not appropriate at all. Among other parameters chloride could have significant effects on ecosystem when present in excess amount, it may impact fresh water organisms and plants by altering reproduction rates, increasing species mortality and changing characteristics of the entire local system. The present study represents the picture of Karnafuli

River as a polluted one; above-mentioned effects might cause serious damage to its ecosystem and the people depend on it.

CONCLUSIONS

The preservation of ecosystem of Karnafuli River is very vital, this study found the excess presence of TSS, TS and TDS in river water. Turbid water of Karnafuli River has become a threat for aquatic life as well as for people living around the riverbanks. If measures are not taken to alleviate the present condition of Karnafuli River, it might face the fate of Buriganga River. This study observed many non-functional ETP's in textile industries, so measures should be taken to mandate an operable ETP to improve the quality of effluent. The environmental conservation act 1995 (ECA) provides that all relevant industrial to install ETP to treat their wastewater to achieve certain standards before releasing it into receiving environment. Department of Environment (DoE) is mandated to enforce this provision of law and they should take proper steps to execute it. Going on to further study on this issue, we could include other industries along with textile industries, as well as more water parameters could be tested.

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DEVELOPMENT OF BUSINESS MODEL FOR IMPROVED FAECAL SLUDGE MANAGEMENT IN DHAKA CITY

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ABSTRACT
This paper represents development of viable business model for unsewered Dhaka outlining faecal sludge handling and management. In order to create Faecal Sludge (FS) emptying demand, Dhaka Water Supply and Sewerage Authority (DWASA) will have to disconnect all illegal sewer lines from the household to the storm sewerage line by applying DWASA act 1996. DWASA, all private service provider, NGOS, household owner will cooperate in this proposed business model which may be financed by donor agencies or any other institutions interested to fund and the revenue will be earned from customer chain. The application of this business model will be able to save our environment, abate the cost of treatment plant, counterbalance the absence of sewer network, and provide relatively cheaper sanitation facilities to the people of Dhaka City.

Keywords: Business models, law enforcement, disposal, faecal sludge management, environment, low cost

INTRODUCTION
The direct disposal of excreta in open drain or storm sewer without treatment increase the pathogens within the environment and cause diarrhoea disease. The World Health Organization (WHO) estimates that 2.2 million people die annually from diarrhoea diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management (Richard, 2001).
On-Site sanitation system means where the storage are contained within the plot occupied by the dwelling and its immediate surroundings. It may be disposed of on site or removed manually for safe disposal (WHO 2006). In Dhaka city, 80% of the existing sanitation access is met by on-site manual emptying technologies. Faecal sludge management is a demand responsive service that customers request their facility to be emptied. The usual practice is to utilize the services of manual emptier. Although Vacutug services are available in other areas, but many inhabitants in are still not aware of this service. NGOs in Dhaka cities have not been getting wider response from the potential households for emptying services. The majority of household owner with septic tank does not know about the DWASA act 1996, which clarify that connection from household sewer to nearby drain or storm sewer is strictly prohibited. This is the one of the reason that the household owners do not face the overflow of their septic tanks or pits because they directly connect their sewer lines to the nearby drain or storm sewer. This kind of phenomena is a major reason for less demand of this emptying business.
The vacutug is a latrine pit exhauster made for operation in extreme conditions. It is a simple machine, comprising a vacuum tank and a pump/tug assembly. The vacuum tank is specially designed to carry sludge. It is made of different sizes (700 litre, 1000 litre & 2000 litre). The Model: MK-II & MK-IV is self-propelled where engine can propel the vehicle at suitable speed. In suction mode the vacuum pump has a free air capacity of 2,700 L/min and will fill the tank in around two to ten minutes (depending of the thickness of the sludge). It can also pressurize the tank for discharging the wastes at a high level. The vacutug MK-II & MK-IV, MK-V has proved its ability to negotiate tight turns and narrow passages throughout the trial. The vacutug has proved that it was capable of access

to some of the densest urban area where conventional systems are unable to penetrate. The MK-III is big & can be used in neighbourhood having wider road access.

The service is affordable by the urban poor who are looking forward to emptying their latrines. The capital is affordable by entrepreneurs and offers the possibility to develop/strengthen a micro-enterprise. And lastly the operational cost is easily recovered from revenue generated.

METHODOLOGY

In developing countries urban sanitation access is achieved mostly through on-site sanitation systems. The faecal waste from the on-site sanitation facilities rarely reaches a treatment facility for safe reuse or disposal because the households have an illegal connection of their sewers connected into a nearby drain or storm sewer drain; in general safe management of faecal waste downstream of the household is severely neglected. DWASA will disconnect the all illegal links to the storm sewerage line by applying DWASA act 1996 and it will increase not only FS emptying demand but also provide a facility to treat the faecal wastes in a treatment plant. An extensive awareness programs like the use of social mobilization campaign, mass media, word of mouth, local TV channel, miking, billboard, documentary film etc. will be carried by DWASA. These activities will create the public awareness about the benefits of the paid service in contrast with the danger of disposal into the drain, canal and land, and its hazardous impacts to water, air and the environment in general. By doing this we will be able to have a business regarding the emptying of pits and septic tanks. In order to make the business viable, we need to have a monetary authority. The method of the emptying has shown by the following-

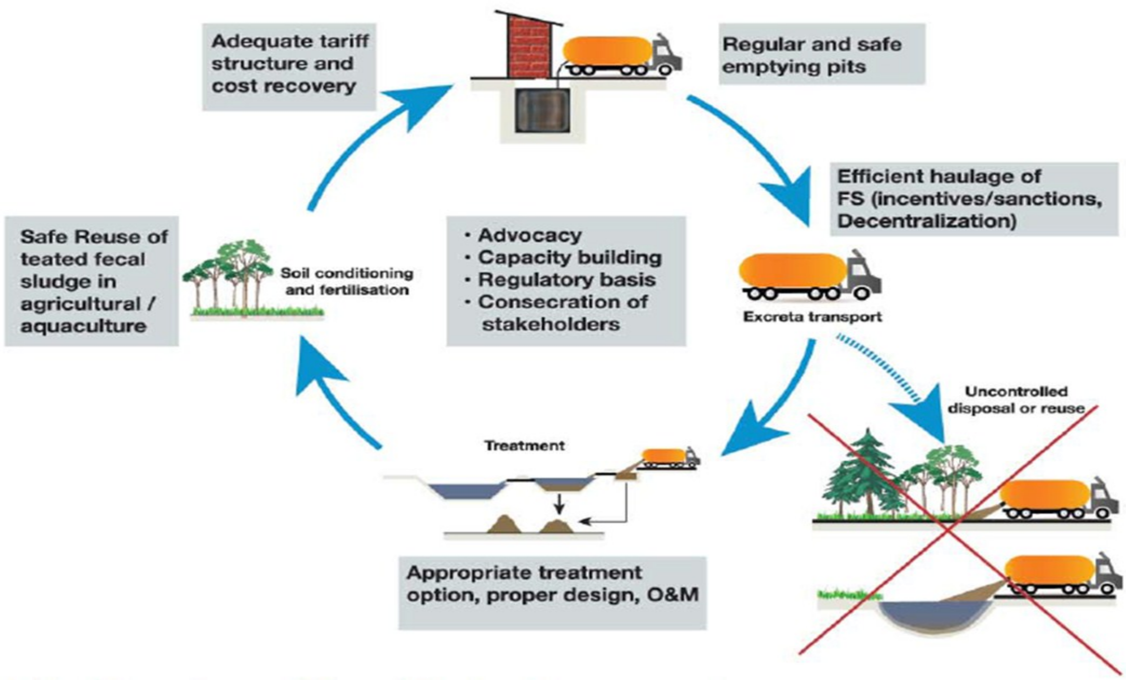

Fig. 1: Operational method of Vacutug

Presently DWASA does not have separate sewer division to look after the emptying service and dumping zone of wastes. So we are proposing a separate sewer division to DWASA for making the business viable.

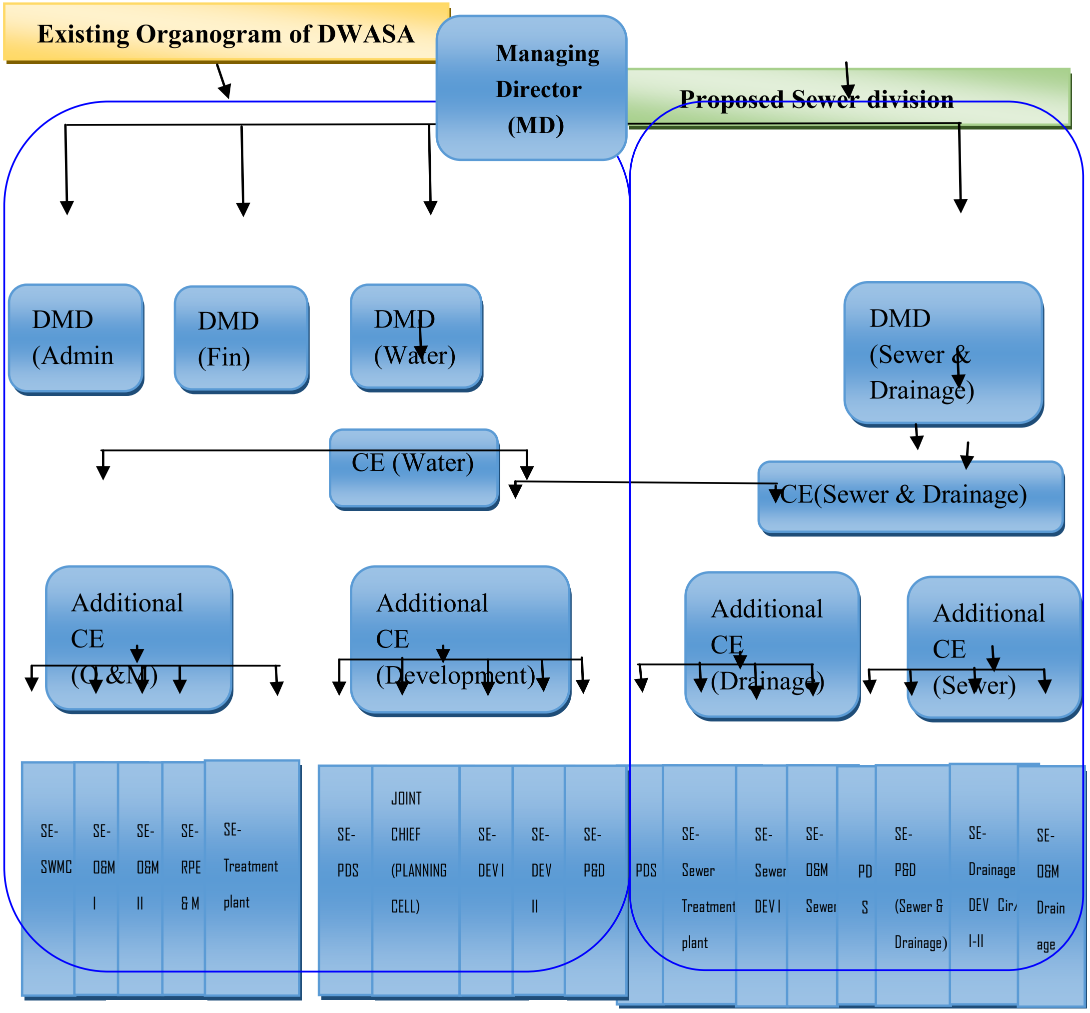

Fig. 2: Proposed New Sewer Division for DWASA

Table. 1: Advantage and disadvantage of Vacutug in general

Advantages	**Disadvantages**
Removes waste safely for both workers and public health	Slow speed encourages local dumping(Model MK-I & II)
Low odor technology	Capital cost is high
Faster to empty than either manual or sludge gulpher	Accessibility problem
Reduces social stigma on workers	Maintenance cost is potentially high

There are five potential faecal sludge derived product groups were identified: dry sludge as fuel for combustion; biogas from anaerobic digestion of sludge; protein derived from sludge processing to be used as animal feed; dried sludge for use as a component in building materials; and treated sludge as a soil conditioner or organic fertilizer.

Business Model Option 1

DWASA will provide de-sludging vehicles (Model: Vacutug MK-VI) to the service provider as per contract agreement with them on hire basis. Large Vacutag vehicle is inaccessible in Slum and narrow street area. So, DWASA will also provide baby vacuum trucks instead of Vacutug as de-sludging vehicle.

Fig 3: Vacutug MK-VI with Baby Trucks

The private service providers deal directly with household and DWASA will monitor the work. The DWASA will ensure the safe disposal of FS to Sewerage treatment plant (STP) or transfer station. All private service providers or NGOs will be the enlisted service provider under DWASA. The tariff for emptying charge will be fixed by household owner and enlisted service provider. The FS inspector will supply the list of enlisted service providers to the each of household owners. The condition of the septic tank or pit will be checked by the inspector on a regular basis. He will inform the household owner to emptying his septic tank and pass him a time frame if septic tank or pit becomes filled up by two third of its volume. If within this time frame, household owner unable to clean his septic tank and if the septic tank sludge spill out, then DWASA will clean the septic tank with his own initiative and cost of emptying will be billed to the household owner with the water bill.

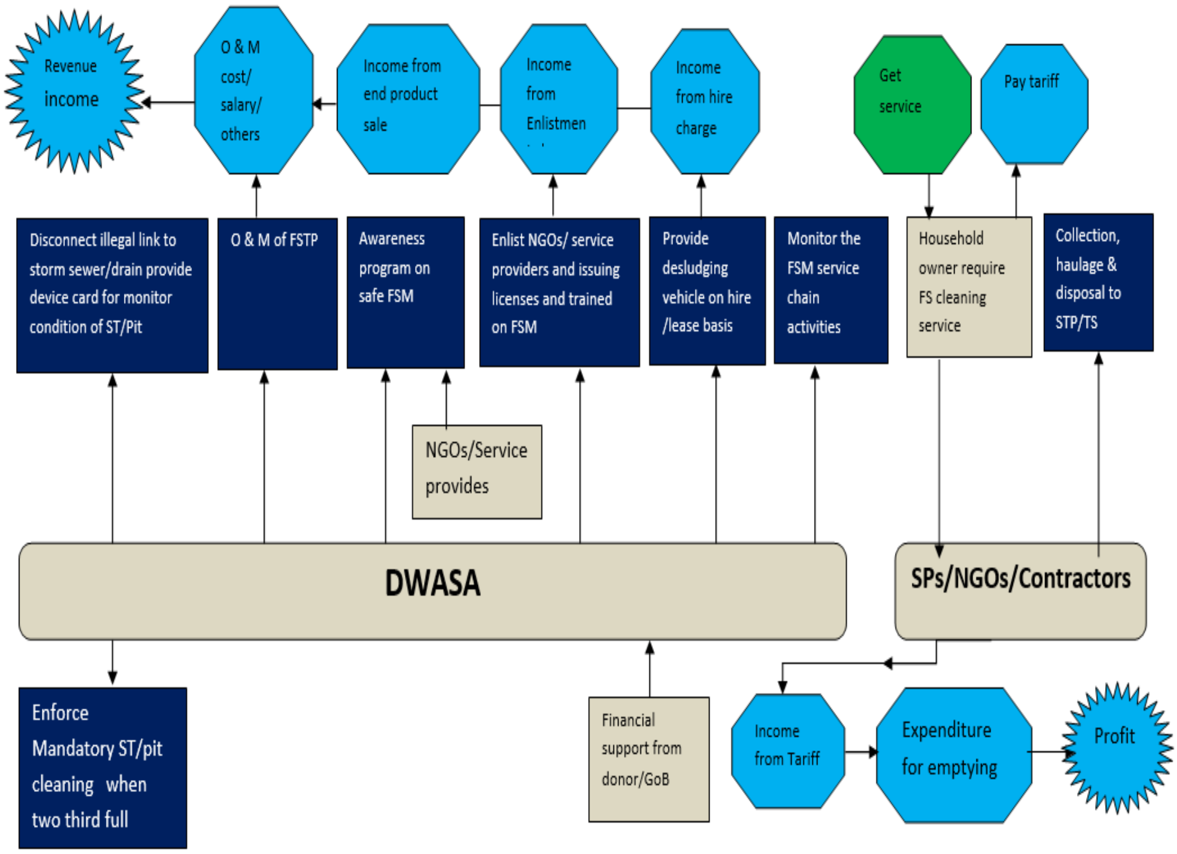

Fig. 4: Business Model Option 1

Business Model Option 2

The DWASA may engage contractors (private company and NGO) and provide them license on a yearly basis for FS management. One FS yearly contractor will be selected for each sewerage zone on the open bidding system. The contractors will haulage septic tank sludge to a special facility located

STP or transfer station managed and run by DWASA. DWASA will provide de-sludging vehicles (Model: Vacutug MK-VI) to the contractor as per contract agreement with them on hire basis. Linking of latrines directly with the open and/or covered drainage system (storm sewerage) should be disconnected by applying DWASA role 1996 including an awareness program (Option 1 model) to increase the demand of FSM business. The FS inspector will visit the household septic tank/pit on a regular basis. He will inform by written to the household owner for make arrangement for emptying his septic tank when it becomes filled up by two third of its volume. A stipulated time and date will be fixed by household owner and DWASA will take initiative by issuing a work order to the contractor for cleaning his septic tank septic tank or pit. The cost of emptying will be billed to the household owner with the water bill. The contractor will be paid from DWASA revenue as per the contract signed with DWASA. The lessons learn from Dhaka City Corporation's_yearly road maintenance contract could be applied.

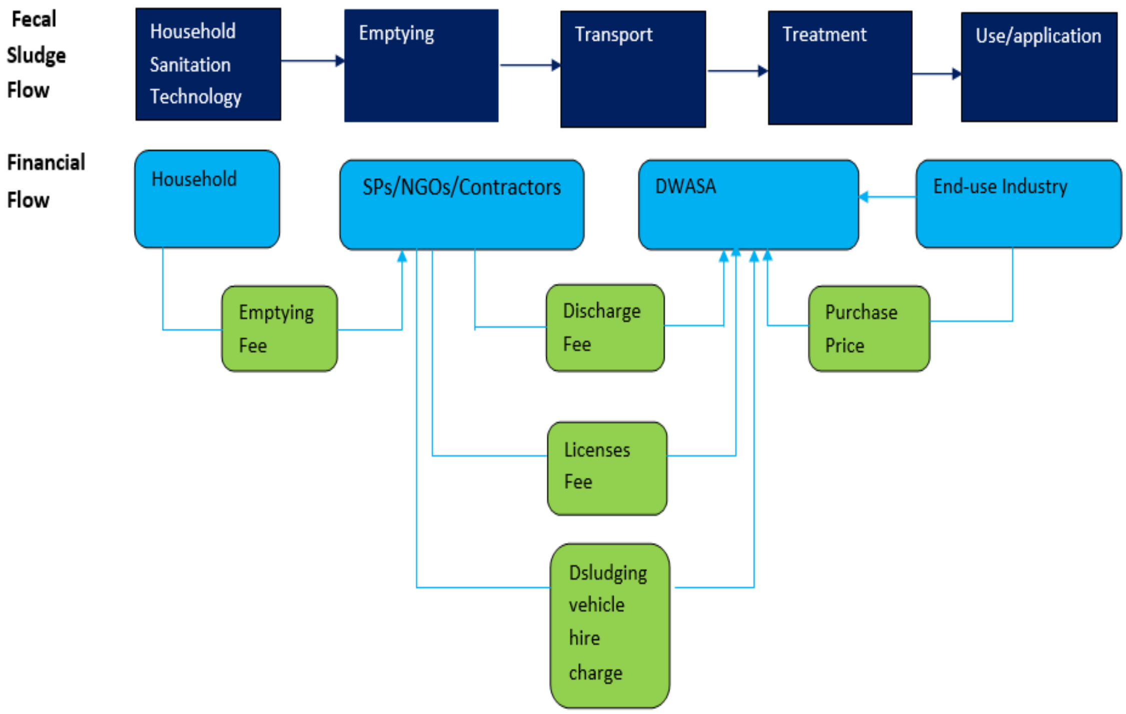

Fig. 5: Business Model Option 2

MODEL EFFECTS & DISCUSSIONS

For an improved and sustainable faecal sludge management service in DWASA, these two business models are highly recommended for prevention of direct deposition of faecal sludge in the environment. The mechanical emptying process is fast, efficient and minimizes health hazard. The settlement of sludge in lower level septic tank also reduce the cost of purification. Lastly, Business models of Faecal sludge management also creates huge employment sector for the people which needs to be within a closed loop where the collection, transport, treatment and use should be in order to protect environment and health of the people. The sustainable faecal sludge management system needs to be economically viable, socially acceptable, technically & institutionally appropriate in order to make the environment and natural resources in healthy condition.

CONCLUSIONS

In business model option 1, enlisted service provider & DWASA both are involved in the customer service. Household owner and enlisted service provider will fix the tariff for emptying charge which will be collected by DWASA from service provider. But, in business model option 2, enlisted contractors (NGOs & private company) will complete the full work of FS management without any work involvement of DWASA according to DWASA's work order. DWASA will take the cost of emptying which will be billed to the household owner with the water bill and the contractor will be paid from DWASA revenue as per the contract signed with DWASA. FSM is an important and significant element of urban sanitation in many poor and rapidly-growing countries beyond the short-term capacity of most. Either as a long term solution or, at least, as a short-run intervention, improved management of faecal sludge is likely to play an important role in managing public and environmental health and the environment more widely for many years to come. While many cities aspire to provide networked sanitation for all but it is too costly to construct a sewerage network in a developing country. In Bangladesh we have a high density of population where it is very difficult to construct a sewerage network and we should save our environment as well. Our current practise is to use combined sewer system which affects our water bodies in a dangerous way. In this paper we have proposed a sewer division to DWASA by this DWASA can monitor the sewer system in an eco-friendly way. Here we have showed the way of collecting the containment to re-use/disposal. By enforcing the law DWASA can create the emptying necessity from the households. Regarding this business there will be a huge employment opportunity for the people of our country .By using the above emptying method we can empty our faecal wastes in a hygienic way as well as can run the emptying business.

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Bangladesh Government Rules and Regulation book

COMMUNITY BASED APPROACH FOR SOLID WASTE MANAGEMENT IN KHULNA CITY

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ABSTRACT
Generation of solid waste (SW) is a major problem in urban areas, thus its management is one of the important obligatory functions to not only urban local authority but also for the inhabitants. The citizens expressed their concerns about the waste management system in KCC and associated problems that they are encountering. Waste generation in Khulna City Corporation is around 455 tons of municipal solid waste/day and generation rate is now 0.75 Kg/capita/day on an average. Existing public utility services and facilities are not adequate to meet the demand of disposing these massive amount of wastes and that's why several problems are arising. There are some deterrents in the KCC's solid waste Management system, arising from both the city corporation authority and the citizen of different levels. With a view to address the problem from through community participation, this paper intends to evaluate the potential of community based solid waste management approach in context of Khulna city.

Keywords: Solid Waste; solid waste management; community based solid waste management

INTRODUCTION
For most of the cities in developing countries also for the countries which are comparatively developed, massive production and solid waste disposal is a substantial reason for the environmental degradation. According to the KCC Ordinance, 1984, KCC is responsible for collection, transportation, and treatment of solid waste in Khulna City (Murtaza, 2002). But having problems and constraints with availability of resources, administrative constraints and other relevant, the organization has not been able to manage well entirely the whole task of solid waste disposal. And as such, it has become a major concern for the city authorities as well as the city dwellers since the problem relating to the solid waste disposal directly and indirectly affect the health and hygienic conditions of the city people. Waste generation rate of KCC is now 0.50 kg/cap/day producing around 950 tons of wastes, where about 36.84% being uncollected (Riyad, 2014). The rubbishes, which remain uncollected, are dumped in open spaces, street and drains, clogging the drainage system, which create serious environmental degradation and treats to health. Public awareness, political determination and public participation are essential for the successful implementation of the legal provisions and to have an integrated approach towards sustainable management of municipal solid wastes in the city as well as in the country.

METHODOLOGY
This work has done basically based on secondary data from sources like Conservancy department of KCC, NGOs working in SWM System. The work process also involves observational study which guides the evaluation of current situation and identification of the causes responsible.

Existing Scenario
The major sources of solid wastes in Khulna are residences, whole and retail sale market places including shopping places, streets, hotels and restaurants, private clinics and hospitals, educational institutions, cinemas, railway, bus, and launch/steamer Ghats, slaughter houses, etc. In a study by Ahmed (1991) in Bangladesh, it has been found that during wet season the waste generation rate increases by 15% to 50%. Table 1 depicts that solid waste generation in Khulna city is growing with the growth of population.
The composition of solid waste varies according to location, level of income and standard of living of the households/people, energy sources and season. The quantity of waste generation increases during the rainy season, when many people eat vegetables and fruits such as mangoes and jackfruits.

Table 1: Solid waste generation in Khulna city

Year	Population (million)	Waste Generation Rate (kg/day/capita)	Total generation (tones/day)	Waste Collection (tones/day)	Collection Efficiency (%)
2008	1.5	0.35	525	275	52.38
2013	1.8	0.50	950	600	63.16

(Source: Conservancy section, KCC, 2013)

Table 2 indicates some major sources and characteristics of solid waste in Khulna city. It has been observed that 70 – 80 per cent of the generated waste are organic in nature and these are easily bio-degradable. And the rest 30 – 20 per cent of the total waste generated are inorganic and non-biodegradable.

Table 2: Sources and Characteristics of Solid Waste in Khulna city

Source/Type	Unit	Quantity Produced
Domestic	Kg/day/Household	1.0-0.5
Retail sale market	Kg/day	50-200
Slaughter house	Tones/day	2-3.5
Hotels and restaurants	Kg/day	50-150

(Source: Environmental Risk Management Action Plan for Khulna City, 2000)

Conservancy Department of KCC is responsible for the collection, transportation/removal and disposal of solid waste in Khulna city. Recently, in some parts of Khulna city NGOs have introduced door-to-door collection of solid waste. But neither communal bin system coverage nor house -to-house waste collection system is adequate yet. KCC is liable for the operation and maintenance of municipal services, including solid waste management.

Evaluation of Existing Situation

- Solid waste generation has increased steadily over as a result of higher consumption and greater packaging of goods. The rate is variable due to seasonal availability of fruit and vegetables and the occurrence of festivals.
- Currently, housewives or maid servants dispose of waste up to six times a day. It is frequently dumped indiscriminately due to a lack of roadside bins or bins being in a poor condition (low-income areas), bins used a variety of participatory methods being surrounded by waste or too far away and socially unsafe for maid servants to use (higher income areas). Hawkers (itinerant waste buyers) frequently call on householders to collect valuable emerged waste (e.g. paper, metal, plastics) for which they either make a small cash payment or pay in kind.
- A lot of waste is dumped in drains causing floods in the rainy season.
- There is no regular time for collection from the roadside waste bins by KCC trucks.

Existing Management System

Eight (8) functional departments and the conservancy department of Khulna City Corporation is liable for management, maintenance and monitoring of solid waste, street sweeping, public latrine and urinal, drain sludge, and street lighting. A total of 22 NGOs and CBOs are involved in MSW management in different wards of KCC in cooperation with the city authority and respective ward Commissioner (Riyad, 2014).

Problems with Existing SWM System

Existing system of solid waste management is problematic due to some certain causes which can be drawn from different stakeholder's perspective i.e. from community perspective and from the management authority's perspective.

Community identified the following problems with the present solid waste management system:

- Lack of awareness of waste disposal and environmental sanitation at household level. Also no awareness creation at community level;
- Insufficient roadside bins which are often broken. Scattering of waste from bins by dogs.

Khulna City Corporation (KCC) identified the following problems with the present solid waste management system:

- Lack of public awareness (e.g. dumping waste in drains etc.);
- Lack of community cooperation;
- Lack of funding (irregular payment of taxes by the citizens, insufficient government funds);
- Inadequate logistics;
- Lack of manpower and equipment which causing irregular disposal of wastes;
- Poor supervision of KCC staff and a feeling of job insecurity.

The NGOs and CBOs related with the solid waste management system has identified the following problems with the present system:

- Fixed time for waste collection not properly maintained;
- Involvement of children in collection of waste;
- Absence or irregular medical check-up facilities for people involved in waste collection and removal;
- Absence of legal status of involving authorities in solid waste management;
- Lack of co-operation among the organizations;
- Issue of sustainability of activities not seriously considered.

Behavioural Causes of the Problem

Some oblivious and hasty human activities are also responsible for the mismanagement and problems with the existing solid waste management system alongside the problems in the KCC or NGO level. These can be categorized as-

- Low or absence of motivation and irrational behavior;
- Lack of sense of responsibility to the society;
- Lack of social coherence and absence of community initiatives;
- Impassive to travel for dumping;
- Irregular payment of service charges;
- Absenteeism of the services of waste pickers/collectors;
- lack of incentive to encourage people to behave and take their waste to point of collection;
- Lack of community & public awareness;
- Absence of awareness about waste disposal and environmental sanitation in the Household level.

The conventional approach to SWM

Waste is generated in the home and usually stored until a small amount has been accumulated. It is the responsibility of the generating household to transport the waste to the nearest road side bin which is provided by the city corporation. The city corporation is responsible for the transfer of this waste from the roadside bins to the final disposal site.

Problems with the conventional approach

In many cases the city corporation fails to provide a sufficient number of roadside bins or does not position them in convenient occasions or fails to ensure that they are of an appropriate design. As a result, householders may dump the waste in open spaces, drains or simply around roadside bins. Poor motivation for proper waste disposal can be due to low awareness of the hazards of irresponsible solid waste management or social factors that make it unacceptable for certain members of the household to take waste to the roadside bins. Delays in waste collection and transportation to the final disposal site by the city corporation also occur due to institutional or financial problems.

Community Based Approach for SWM

The city wards are divided into small areas called primary collection blocks in any community based solid waste management approach. These blocks consist of approximately 500 households which are all served by one rickshaw van (WSP, 2000). Waste generated in the home is stored and collected everyday by a primary collector who transports the waste to nearby transfer points, normally in a rickshaw van. This is primary collection and is the responsibility of the community. Transfer points are places where waste is unloaded from primary collection vehicles to be taken away by secondary transport. Several primary collection blocks are served by a transfer point. The waste is then collected from the transfer points and taken to the final disposal point by a large truck. This is secondary collection and is the responsibility of the city corporation.

Implementation

Implementation of community based solid waste management can be done in several phases which will begin the collaboration of community with the city corporation and the collaborator usually the ward commissioner and NGO representative. That will have followed by building community organizations after defining primary collection blocks and lastly operation of primary collection system.

Phase 1: Building Community Organizations

- First, a community Organization for SWM have to be initiated;
- It will divide the whole community into several blocks for better management (Primary blocks);
- Each block will have a primary collection Point where waste will be dumped by the users (HH, Commercial/Other Users);
- Collection points will be decided by the organizations by negotiating with KCC;
- A primary collection system (collection rickshaw van) will be organized by the committee by the funding of the primary users of the block.

Table 3: Investment cost for primary collection system for one collection block

ITEMS	COST (BDT)
Rickshaw Van	10,500
Tools	1,500
Protective clothing	1,000
TOTAL	13,000

Source: modified and updated from (WSP, 2000)
*Cost may rise up to 2000 BDT

This items which will be used for primary collection system is not expensive and not different from communities daily uses. But what is important to notice here is that despite being dependent on the collection system of the city corporation, the community own will do the collection and disposal to the point from where the city corporation will do the secondary collection. Thus, the collaboration will help in decreasing impacts of solid waste mismanagement. Although the source shown is backdated, it was updated in 2014. That's why the data can be said of use.

Phase 2: Operation of Primary Collection System

- The Primary Collection System will collect the wastes twice a day (or once based on waste generation rate);
- Users will have to bear the operating cost of the system;
- Community Organization will fix the charge for the users of the collection system and will collect the charge as well;
- Charge may vary between different income groups;
- Charges may also be promotional (BDT 5-10), can rise with the change of time.

Table 4: Monthly operating cost of a primary collection system for each collection block

ITEMS	COST (BDT)
Van Drivers salary	2200
Assistants salary	800
supervision Cost of SWC	600
Repair & Maintenance	100
Depreciation Cost	300
Total	4000

Source: modified and updated from (WSP, 2000)

What's best about this community based approach is that it doesn't cost much after the initial investment to setup the collection system. The maintenance is cheap and per month overall cost is not very much considering the primary collection block do consist of 500 households. Moreover, the service provided will be well enough to serve the community, to collect the wastes twice a day and to transport them to the secondary collection point from which city corporation will collect the wastes and dispose it to the final disposal site.

Implementability & Replicability

Good thing about this "Community Based Solid Waste Management Approach" is that it's not only a rhetoric idea or concept but it can be easily implemented, replicated in other areas and also scaling up can be done of this approach. Low set up cost and operating cost makes it easy to implement in the community level. Also the maintenance is easy and the system is self-sustaining, so implementation and operation is not an issue to bother. Scaling up can be done if the city corporation adapt the practice in the wide scale in every ward and nationally as well, if other City corporations/ Pourashava use the model as an ideal one.

Management and Legal Support

To encourage community based solid waste management City Corporation may follow-

- Provide land for use as primary point of waste dumping;
- Collection of waste from primary collection point should strictly be maintained and monitored;
- Encourage involvement of NGOs and CBOs in SWM specially collection from the primary point;
- Shall make adequate arrangements for the removal of refuge from all public streets, public latrines, urinals, drains and all public buildings;
- Establishment of appropriate transfer points and secondary transportation that integrates well with the primary collection system;
- Legal framework to support NGO and CBO involvement should be prepared.

At the same time, City Corporation can also encourage NGO and CBO involvement in the management and disposal system. For the purpose the framework may be as it shown in Figure 1-

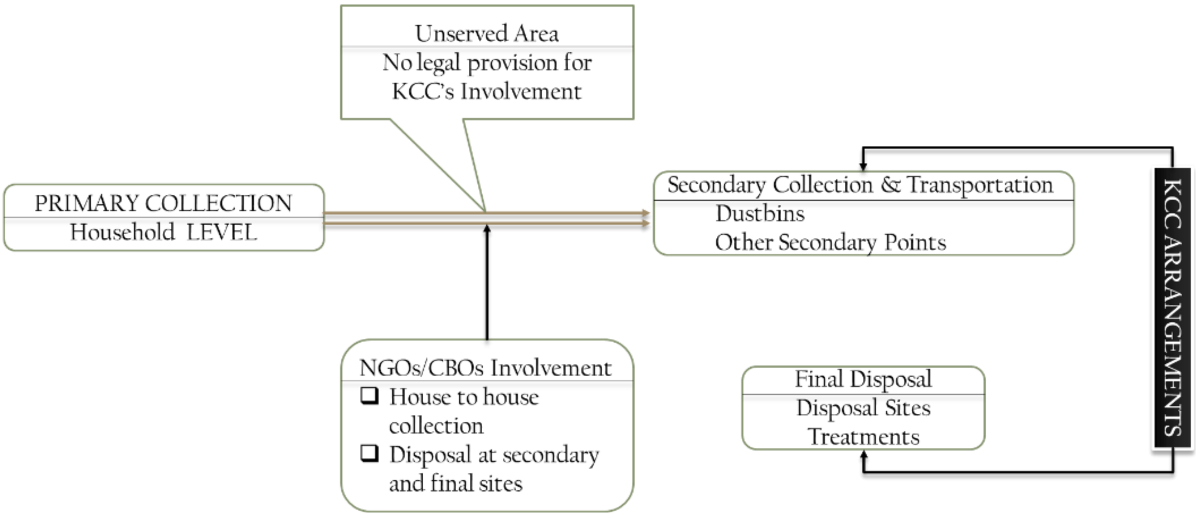

Fig. 1: Framework for NGO involvement (Murtaza, 2002)

CONCLUSION & REMARKS

It is evident from some from some previous studies that the city dwellers expressed their concerns about the solid waste management system in KCC and its associated problems that they are encountering. There are some hindrances in the KCC's solid waste Management system. These problems are arising from both the city corporation authority and the citizen of different levels. In most of the cases residents of a neighbourhood have a sense of responsibility for their home and immediate environment, but the public places such as streets and drains are considered the responsibility of the State. Willingness to pay is a rather central point because it is important for the success of a Participatory solid waste management project and it is related to many other aspects such as the motivation of operators and households and the reliability of the service (Rahman, et al., 2005).

Management of Participatory solid waste services is often a voluntary activity, mostly carried out by the more effluent residents, who are motivated by community benefits such as a cleaner environment, a better health of neighbourhood residents, status of the job, etc. While motivated management is one of the success factors of Participatory solid waste management project, exclusive dependence on one person who manages the operation of a solid waste service is considered undesirable, because accountability to the community and the continuity of the service may not be secured any more.

The salary of operators of waste collection services is often low, because waste collectors derive their income from waste collection fees and from the sale of recyclables. Both do not yield much revenue in low-income neighbourhoods. Fee collection is not high, because households in low-income neighbourhoods are not able to pay high fees. The waste that remains to be collected is often worthless due to its high organic content. Another reason for the low salary of operators of waste collection services is the size of coverage areas, which is often too small to earn an adequate income. The low status of waste collectors in the society may be caused by their low salary, the nature of their work and sometimes by their waste-picker background. The nature of their work is often considered unpleasant and filthy, not only collection but also activities such as sorting of garbage at a composting plant.

Solid waste management scenario in Khulna City Corporation area is being deteriorated day by day as the situation is very difficult to handle the colossal volume of waste in KCC due to the irrepressible migration of rural people to urban areas for better life. Public awareness, political determination and public participation are essential for the successful implementation of the legal provisions and to have an integrated approach towards sustainable management of municipal solid wastes in the country. All the practices and efforts should reflect the better future but practically all the activities are not in planned manner and not to target oriented. As an emerging area, Khulna city should develop in a proper way to make beautiful, liveable town in near future. Proper management and initiatives can lead organized and succeed outputs.

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TERTIARY TREATMENT OF TEXTILE EFFLUENT USING AN INTEGRATED FILTRATION SYSTEM IN BANGLADESH: A CASE STUDY

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ABSTRACT
Dye effluent from textile industries is one of the most difficult types of wastewater to treat. There has been exhaustive research on the removal of dyes from textile wastewater by adsorption and coagulation-flocculation processes. This study examines the removal efficiency of textile dyes at the tertiary level for the effluent of Masco Industries Ltd, deploying an integrated approach by an enhanced coagulation-flocculation method using a multispectral coagulant-flocculent then, filtering the supernatant through activated filter media (AFM). The results obtained by the batch tests show that AFM has a very poor adsorbent capacity compared to traditional adsorbents used by the textile industries. Moreover, this research investigated the removal efficiency of local sand against AFM filter medium, where the local sand shows better performance in order to filter out the remaining flocs from the supernatant. The removal of flocs was achieved around 38% by the local sand (size: 0.13-0.25 mm), while around 19% was achieved by AFM grade-1 (size: 0.46-1.0 mm).

Keywords: Adsorption; coagulation-flocculation; filtration; textile wastewater

INTRODUCTION
Pollution is a great concern for a sustainable future development. Water pollution is one of the key elements of this pollution (Gupta and Suhas, 2009). Severe pollution of this water is causing serious health consequences in the neighborhood, damaging fertility of the agricultural land, killing fishes and aquatic lives (Tareq and Khan, 2009). Being a riverine country, Bangladesh is largely dependent on this surface water. Therefore, preserving the clean surface water is crucial for the safety of the population and to some extent it is a matter of global concern. Many issues are responsible for surface water pollution in Bangladesh such as the chemical processing industries like tannery, paper, food, chemical, pharmaceutical and the textile processing industry. These industries are all discharging into our river network.

In order to maintain and improve the quality of the environment through preventing industrial pollution, a paradigm change in conventional effluent treatment system of different industries is necessary. There are many conventional and modified technologies are being applied to treat the effluents coming out of various industries in Bangladesh, however, very few of them have shown to be successful until now (Ranganathan, et al., 2007). Lack of knowledge, lack of the right technology and lack of proper study of the effluent quality are one of the few major reasons behind the failure of existing effluent treatment systems. Moreover, nowadays, the wide expansion of different industries like textile, pharmaceutical and tannery are seating as a tumour in a rural area. This unplanned expansion is deteriorating the rural ecosystem. Therefore, it is a great challenge to protect the rural ecosystem in the near future from these industrial pollutions.

METHODOLOGY
Preparing synthetic wastewater with different types of textile dyes to be used in the tests was not feasible. Therefore, the effluent from the existing ETP plant of Masco Textile Industries Ltd was preferred. Eighty litres (80 L) of wastewater was collected from the outlet of the secondary clarifier of the existing effluent treatment plant at Masco. It was kept at 4ºC in a cold room at the laboratory in

order to avoid biological degradation of the sample during the laboratory work. After that, the effluent sample was characterized to generate the baseline data for this study. Therefore, the following parameters were measured: Temperature, pH, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Total Dissolved Solids (TDS) and colour. The following flow diagram explains the entire research methodology at a glance (Fig. 1).

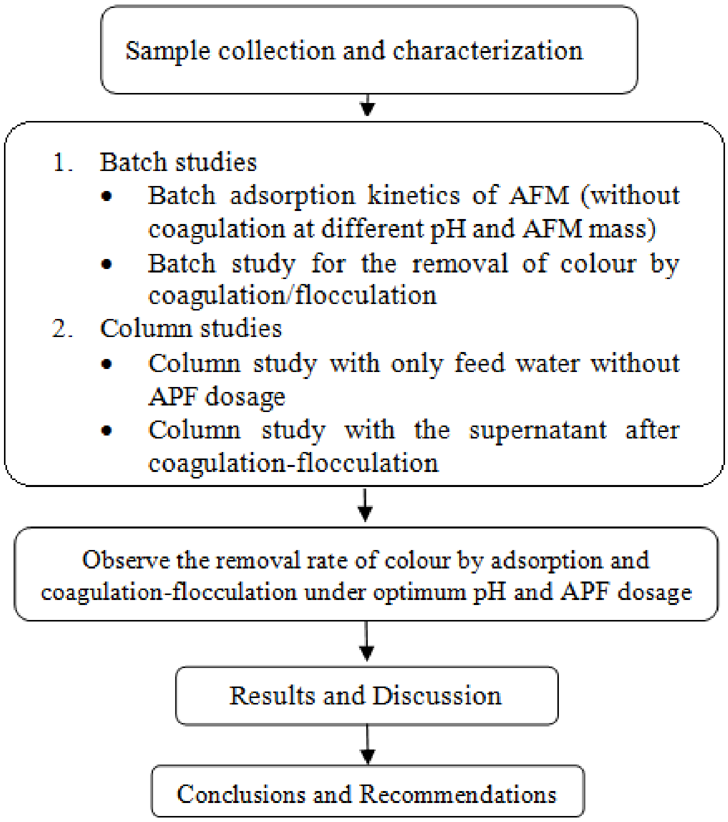

Fig. 1: Flow diagram of the research methodology

Batch Studies

Batch experiments were carried out using different masses of AFM grains and a fixed volume (100 ml) of feed water (the effluent sample collected from the outlet point of the secondary clarifier. In addition, the adsorption test was performed at a constant pH (7.81) as found in the sample (without adjusting) at a constant agitation rate (150 rpm) under ambient temperature (12 to 24.4ºC). Moreover, the pH and initial colour of feed water were measured every time just before running the batch. Then the batch adsorption was observed at 24, 48 and 72 hrs. The main intention of this batch experiment was to measure the adsorption of colour compounds at a fixed pH (without adjusting pH of the feed water). Furthermore, the effect of adsorbent dosage was observed on the removal by measuring different AFM mass and equilibrium dye concentration.

Column Studies

The adsorption capacity of AFM grains was studied via the batch experiments. However, it will not be sufficient to understand the actual behaviour of the AFM, because AFM used in a pressurized tank in the real treatment system, where the pollutants, such as organic particles, heavy metals and colour compounds are expected to be removed by two mechanisms: mechanical filtration (those are formed as bigger floc by coagulation-flocculation) and electro-static adsorption. In this case, the pressure is governed by the incoming flow rate and therefore, column tests were performed in order to understand the effect of different flow rates on the removal efficiency using AFM grains. Moreover, the sample feed water (without APF[1] dosage) and supernatant (after coagulation and flocculation with APF dosage) were used to pass through the column (Fig. 2) under two different operational conditions. Those conditions for column study are as follows:

- only feed water without applying pressure and APF dosing was used in order to observe the adsorption of colour compounds present in the feed water
- the supernatant after APF dosing and without applying pressure was used in order to observe the competitive adsorption of dyes (at the optimum coagulant dosage and pH previously found)

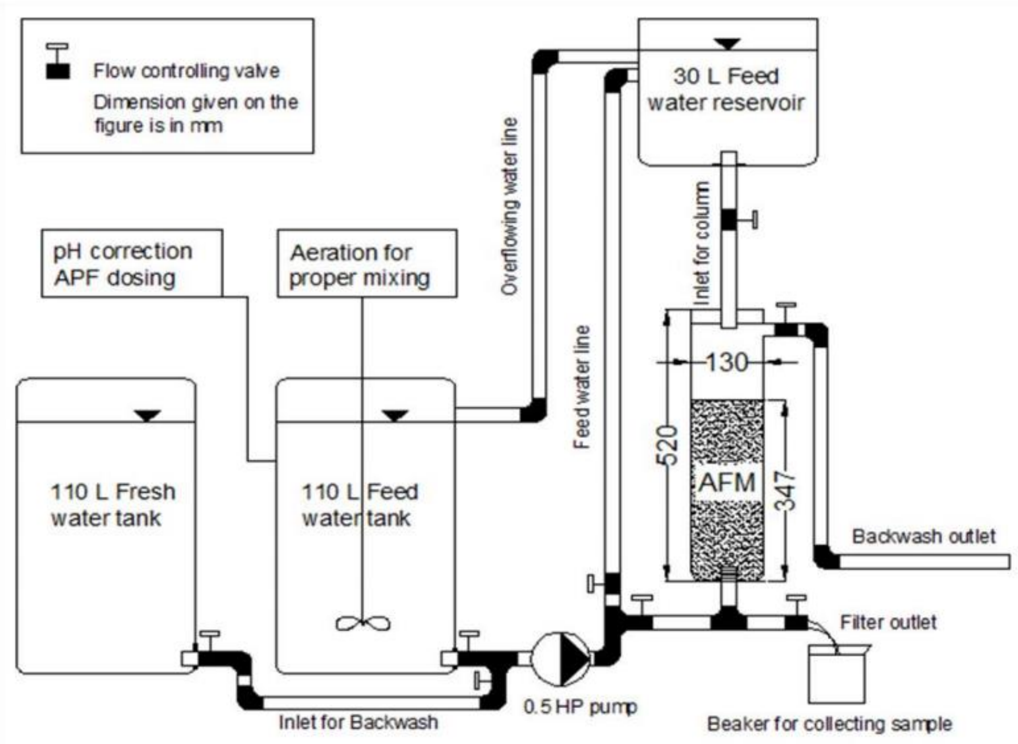

Fig. 2: Schematic of the column set-up at the laboratory

RESULTS AND DISCUSSIONS

Characteristics of the collected sample

In order to characterize the wastewater sample, the following tests had been carried out (Table 1) at the local laboratory of Biovista Bangladesh Ltd. and ICDDR,B[2]. The main intention of this characterization of the textile wastewater was to determine the quality of the feed wastewater. As the location of the sampling point was after the secondary clarifier, BOD and COD removal was expected because the effluent was coming to the secondary clarifier after receiving biological treatment (Activated Sludge). One of the problems was the low dissolved oxygen level in the effluent. In addition, the high TDS value often went beyond the standard because the dying process involved lots of salts (Joshi and Bansal, 2004). Moreover, colour is not an issue for the Department of Environment (DoE) in Bangladesh, but for the international buyers it is a requirement to keep the colour below 150 Pt. Co. So the existing treatment plant at Masco has to solve the problem of the coloured effluent as the amount of colour compounds present in the final effluent is much higher than the discharged standard, recommended by the international buyers (Table 1).

[1] APF—All Poly Floc, a mixer of polyelectrolyte used as a flocculent which is a product of Dryden Aqua Ltd.

[2] ICDDR,B— International Centre for Diarrhoeal Disease Research, Bangladesh

Table 1 Characteristics of sample wastewater (sampling point: after secondary clarifier)

Date of Sampling	Temp. (°C)	BOD_5 (ppm)	COD (ppm)	DO (ppm)	TDS (ppm)	TSS (ppm)	pH	Apparent Colour (Pt. Co.)
17/Dec/2014	31	28	96	4.1	1700	150	7.85	329
Bangladesh Standard	-	≤50	≤200	4.5-8.0	≤2100	-	6.0-9.0	-

Batch Adsorption Test for AFM

The batch adsorption test for AFM shows that the AFM filter media has no significant adsorption capacity (without APF dosing) to remove colour compounds from the textile wastewater. The removal of colour compounds was also not observed visually before and after the batch adsorption test. But the measured values differ slightly, which shows a little change before and after the batch test.

The initial colour concentration was 329 Pt.Co. in the feed water measured at site (Table 1). Before conducting the batch at the Biovista's laboratory (one day later), it was measured as 307 Pt.Co. and after the batch test (total 9 days, because the shaker machine had the maximum capacity to hold 6 bottles at a time), the colour concentration found at 282 Pt.Co. in the blank sample. Therefore, the natural degradation of dyes (including all other constituents present) in the feed water was observed at 8% as shown in the graph (Fig. 3). It clearly indicates that there is a natural degradation of colour compounds under the laboratory temperature (12-24.4 ^{0}C) though, there was no adsorbent dosed into the feed water sample.

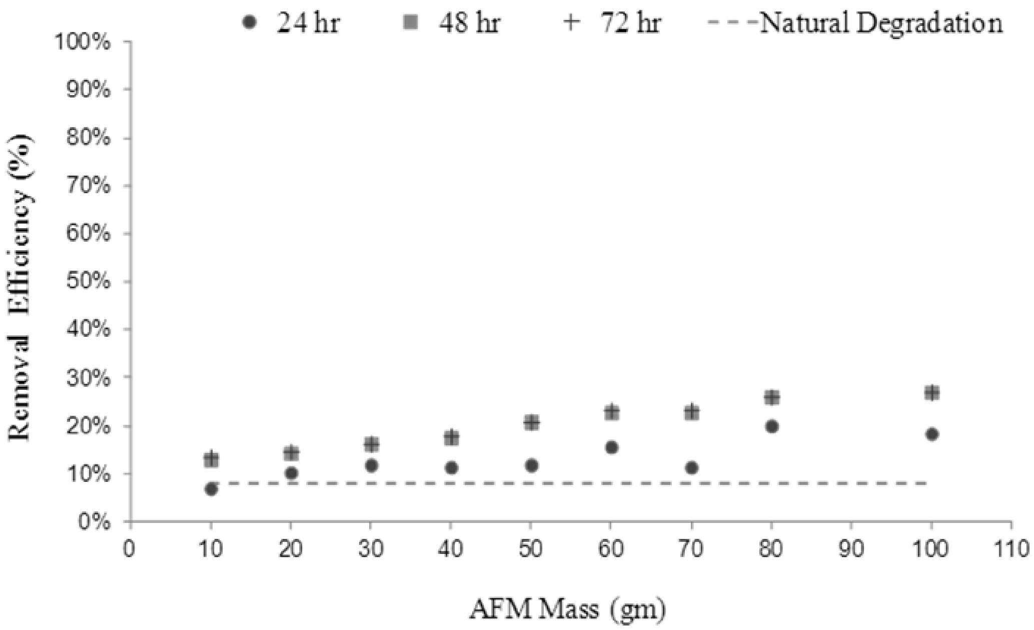

Fig. 3: Batch adsorption test for activated filter media

Column experiment with different flow rates (without coagulation-flocculation)

The column was run under three different flow rates: 120, 220 and 350 ml/min (Fig. 4). For the first two flow rates F1 and F2 were 120 and 220 ml/min, respectively. And, the removal rates for both cases were observed quite good (59%, where the initial colour was 184 Pt.Co. in the feed supernatant) but for 350ml/min, it was low (below 10%). Therefore, it is very clear that there is an effect of flow rate on the performance of the AFM filter media to remove colour. However, when comparing this above graph with Fig. 4, it can be seen that the removal of colour observed with supernatant is higher than that of with only feed water (without APF dosage). This is may be due to the very fine flocs that are remained suspended with supernatant and are retained in the filter. However, the removal efficiency was only for the first 10 minutes of the column operation (Fig. 4), and at lower flow rates.

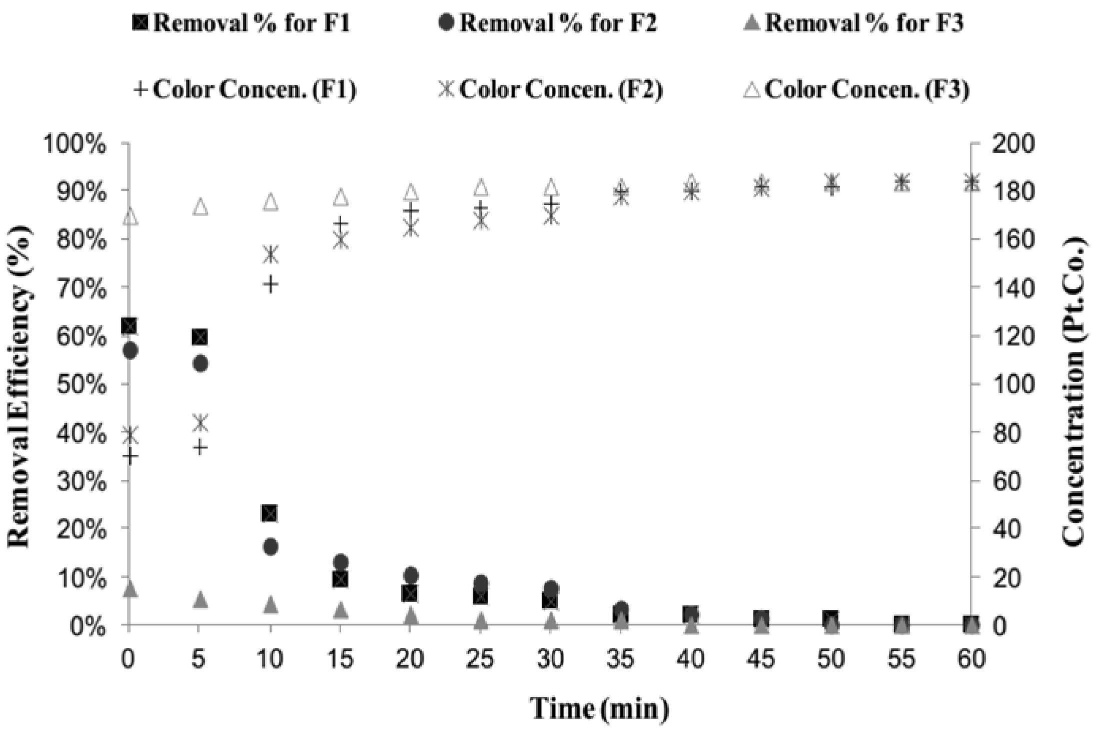

Fig. 4: Breakthrough curve for AFM with the supernatant (at different flow rates)

Column Experiment (supernatant after the coagulation-flocculation)

The initial colour was measured as 412 Pt. Co. in the feed water before coagulation (with different feed water collected at that particular day, but for the same ETP plant). After 20 hrs of retention time, the colour concentration in the supernatant was 184 Pt. Co. So, the removal rate was quite good (62%) by coagulation-flocculation process using APF as coagulant. The long retention time was needed as the floc took longer time to settle at the bottom, than for the batch test in the laboratory (4 hrs). It must be mentioned that the feed sample was different for different days; therefore, the initial colour concentration and removal efficiencies are different for each day. So, the column test was conducted at site with the feed sample that was produced daily at the existing effluent treatment plant.

Performance evaluation with alternative filter medium: AFM Vs local sand

Local sand was used for the filtration of the supernatant after coagulation-flocculation. In the Fig. 5, it can be seen that the removal of colour using sand was around 84% (from 119 to 19 Pt.Co.) at the very beginning, while it was for AFM around 86% (from 119 to 17 Pt.Co.). But, it declines very sharply within 10 minutes and reaches to 38% and 19% for sand and AFM, respectively. At the beginning, the peak was observed with more than 80%, due to the small amount of fresh water present in the filter bed. However, the fine sand (size: 0.125 to 0.25 mm) shows better removal than AFM grade-1 (size: 0.46 to 1 mm). Although, it was not possible to measure the actual pore size of the local sand at site but it seems quite smaller than 40 microns, that was known for the AFM grade-1 (AFM specifications). Only a single grade of AFM media (due to availability in the lab) was used, while two different grades of local sand were used in this column experiment. As a result, the fine sand retained finer flocs than AFM grade-1.

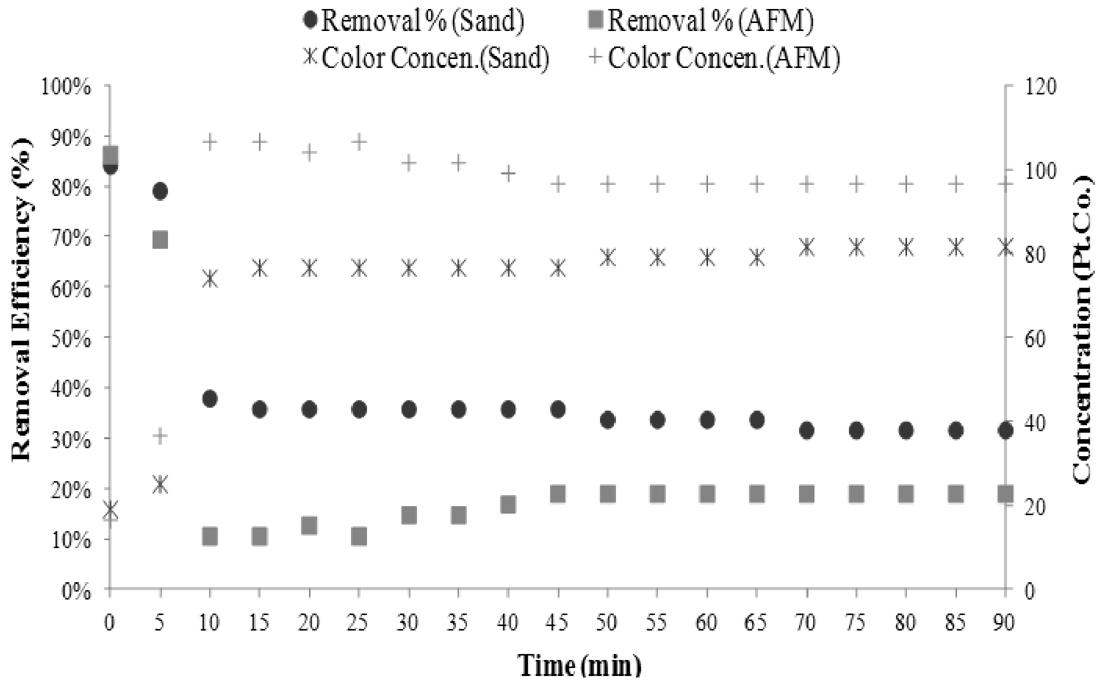

Fig. 5: Performance evaluations of the local sand and AFM as filter media

CONCLUSION

Based on the laboratory studies (both batch and column) at Masco Industries Ltd, it can be concluded that AFM system is not a suitable option as a tertiary treatment unit to remove colour from textile wastewater (after biological treatment). In addition, the AFM media has no significant adsorption capacity (with and without APF dosing). Moreover, significant result was achieved using local sand as filter media in order to remove fine flocs developed by APF flocculent at the tertiary level. But, in a long run sand might get affected due to bacteria present in the wastewater. That is why future study is essential to identify the appropriate filter media in order to polish textile wastewater at the tertiary level.

ACKNOWLEDGMENTS

I deeply express my gratitude to Dr. C.M. Hooijmans and Dr. H.A. Garcia Hernandez from UNESCO-IHE, Delft, The Netherlands, my honourable mentors, for their immense assistance, guidance and advice with encouragement.

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EFFECTIVENESS OF RAINWATER HARVESTING AS AN ALTERNATIVE SOURCE OF SAFE WATER: A CASE STUDY ON CHANDGAON RESIDENTIAL AREA

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ABSTRACT
The inability of public water facilities to function effectively in Chittagong City has made it impossible for most of the city dwellers to have access to safe water supply. In order to find out the effectiveness of rain water harvesting as an alternate source of water, we conduct a set of questionnaire survey on more than 100 numbers of building in Chandgaon Residential Area to identify the catchment options and to know dweller's perception. We take three different types of building as model sites and try to give a simple and easiest solution for installation of rainwater harvesting system. Additionally the study also looked at the quality aspect of the collected rainwater from those sites including pH, Electrical Conductivity, Total Dissolved Solids, Hardness, Chloride (NaCl), Alkalinity, Fecal coliform, and BOD_5. Initial test results indicated that the collected rainwater (collected immediately after the rain started) had presence of bacteria. But when we collect the rainwater after 15 minutes of rainfall the coliforms were removed completely. Depending upon the location, scarcity of existing safe water supply, people perceptions, technology, cost and quality of water, rainwater harvesting can be a better and cheaper alternative to extract water from surface water sources.

Keyword: Water Demand; rainwater quality; rainwater harvesting

INTRODUCTION

Chittagong is the second largest city of Bangladesh. Country's first export processing zone was established in this city. Development of industries has brought rapid increase of population. Chittagong has witnessed major growth in population over the last 3 decades; mainly due to migration from the country-side. This kind of growth represents tremendous challenges to the utility authorities in providing utility services.

Chittagong Water Supply & Sewerage Authority (CWASA) is the agency mandated for water supply and wastewater management in the city. The residents in the port city are facing acute water crisis as the CWASA is able to supply only 42 percent of the total daily demand. They get WASA supplied water for two to three days a week for two hours only leaving them to depend on private deep tube wells or shallow tube wells for water to continue their daily work for rest of the days. Again CWASA is dependent on groundwater for the 55% of their water supply. This is resulting the ground water to drop by 3 meter in every year. Due to shortage of supply of water, urban life in the port city has become miserable. So an alternative source of water or a method to stop using ground water to recharge is of utmost importance in Chittagong city for preserving environmental balance along with meeting human demand.

Considering the above condition Rainwater harvesting can be an alternative source of water. As it is an option, which has been adopted in many areas of the world where conventional water supply systems are not available or have failed to meet the needs and expectations of the people. From where people can use rainwater during the entire rainy season and about 2-4 months of the dry period. From existing different system and study we found that rainwater is free from arsenic contamination and the physical, chemical and bacteriological characteristics of harvested rainwater represent a suitable and acceptable means of potable water. Now our main focus of the study is to evaluate suitability of the RWH in a residential area of Chittagong city on existing catchment options to use rainwater in Sanitation purpose and also for Gardening and Car washing purposes which is the most part of our daily needs, without imposing any extra cost. Another target is to find out dweller acceptance and create awareness about rain water harvesting system.

METHODOLOGY

Chittagong is the second largest city and commercial capital of Bangladesh with a total area of 168 Sq. km. The study has been conducted in Chandgaon Residential Area located at Chandgaon Thana of Chittagong City. It is one of the major residential areas in here. It is situated near a place called "Bahaddarhat". The area is divided in two blocks, Block A and Block B. The total area covered by the society is 138.58 Acre. The geographical map of the study area is shown in Fig. 1:

Fig. 1: Geographical map of Changaon Residential Area

The purpose of this study is to evaluate the catchment options and to build economical rain water harvesting systems which is safe, affordable and socially acceptable. From Chandgaon Residential Area different qualitative & quantitative data were collected, which are required. The study was conducted during the period from May 2013 to October 2013. Methodology of the study consists with the following works:

- Data Collection from the social survey and field observation.
- Collection of rain water sample and completing the laboratory test.
- Data Analysis for appropriate system.
- Finding the appropriate solution on the existing building.
- Design the rain water harvesting system & determining the cost effect.

Data Collection

To find out the proper water solution beyond the traditional tube well water & supply of CWASA, a study has been conducted for water harvesting system at existing household. Social survey data has been collected to identify the people's opinion about the rain water harvesting system. A format of data collection through questionary survey and field observation is shown in Table 1.

Table 1: Format of Questionary survey & Field observation

Name of Building: ....………………………… Address: ……………………………….................			
Part-A			
Sl. No.	Particulars	Description	Remarks
1.	Building Type		
2.	No. of Story		
3.	No. of Flat		
4.	No. of People in Each Flat		
5.	Roof Area		
6.	Land Area		
7.	Storage Type		
8.	Storage Capacity		
9.	Daily Consumption		
10.	Present Source of Water		
Part-B			
What is your opinion regarding RWH?			
Answer:			
Are you satisfied in present water source to fulfill your water demand?			
Answer:			
Do you want to use Rain water in your daily consumption?			
Answer			
If you choose RWH system, what will be your purpose of using rain water?			
Answer: a) Drinking b) Sanitation c) Gardening & Car washing			
Do you interested to set a RWH system in your building?			
Answer:			

Rain Water Sample Collection & Conducting Laboratory Test

To conduct the environmental and health risk analysis, total 4 nos. rainwater samples from the study area were collected. First two samples were collected from two different catchment, one from a tin shed building roof and another from a 2 storied building roof (RCC) during starting of rain and next two samples were collected from same catchment after 15 minutes of rain in clean plastic containers by washing it with rain water three to four times. After collection, the rain water sample were stored and labelled with sample ID, date & location on the sticker tag. Sample were kept protected from direct sunlight and then taken to the laboratory for analysis. Necessary precautions have been taken during carrying of sample. After completion of laboratory test and analysis, results were compared with WHO guide line value and Bangladesh Standard for drinking water quality.

For laboratory analysis six physiochemical and two Microbiological water quality parameters were tested. These are:

- Physiochemical parameters: pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Hardness, Chloride, Alkalinity.
- Microbiological parameters: BOD_5, Fecal Coliform.

All Physiochemical parameters were tested at S. Alam Refined Sugar Industries Lab and Microbiological parameters were tested at A.K. Khan Water Health testing laboratories. The test procedure has been recommended by Lenore S. Clesceri et al for our laboratory evaluation.

Rainfall Data Collection

The study area is a small part of Chittagong city. As there is no reliable rainfall data available for the area, so for the convenience of work average rainfall date of Chittagong city is collected from Bangladesh Meteorological Department (BMD) [30 years average], which is used for the design of rainwater harvesting system in the study area.

Data Analysis

After collecting all data, data analysis has been done by step by step method**.** First one is Analysis of rain water test report. The test report of different quality parameters of collected sample (Rain water) will be compared with the standard quality parameters of water. After comparison the appropriate use of water will be defined. In order to improve rain water quality proper treatment and measures to prevent contamination will be taken for the study area and being documented. Second one is analysis of water harvesting options and possibilities. Different options for water harvesting e.g. motor jar, RCC ring tank, underground RWHS will be assessed properly. Finally communities view, preference, social culture has been taken into consideration carefully. Third one is analysis the data from CWASA, BMD & internet. Analysing all types of data, water demand, water shortage, water source and yearly rainfall data are prepared to solve the problem. Then identification the solution of rain water harvesting system on existing building is ascertained. Cost of the proposed system will be calculated.

RESULTS & DISCUSSION

Questionary survey & Field observation data

Questionary survey & Field observation data are shown in Table 2. For assessing the acceptability of rainwater harvesting in the study area through questionnaire survey we took more than 1000 people's perception of 106 numbers building. From which 80% peoples have positive response regarding rainwater harvesting, 18% people pose negative response and 2% said no comments. From 80% people who are interested to set up rain water harvesting system approximately more than 70% interested to use rainwater only for sanitation purposes, 21% interested to use for all purposes and 9% only interested to use for gardening, car washing and other cleaning purposes.

Table 2: Questionary survey & Field observation data

<table>
<tr><td>Particulars</td><td colspan="10">Description</td></tr>
<tr><td rowspan="3">Population</td><td colspan="4">Male</td><td colspan="4">Female</td><td colspan="2">Total</td></tr>
<tr><td colspan="2">Number</td><td colspan="2">3816</td><td colspan="2">Number</td><td colspan="2">3224</td><td>Number</td><td>7040</td></tr>
<tr><td colspan="2">Percentage</td><td colspan="2">54.2</td><td colspan="2">Percentage</td><td colspan="2">45.8</td><td>Percentage</td><td>100</td></tr>
<tr><td rowspan="3">Types of building & No. of Building</td><td colspan="2">1 story or Tin shed(TS)</td><td colspan="2">2-3 Storied</td><td colspan="2">4-6 Storied</td><td colspan="2">Above 6</td><td colspan="2">Total</td></tr>
<tr><td>Number</td><td>21</td><td>Number</td><td>239</td><td>Number</td><td>423</td><td>Number</td><td>21</td><td>Number</td><td>704</td></tr>
<tr><td>Percentage</td><td>3</td><td>Percentage</td><td>34</td><td>Percentage</td><td>60</td><td>Percentage</td><td>3</td><td>Percentage</td><td>100</td></tr>
<tr><td rowspan="2">Dependency on Water Supply</td><td colspan="4">CWASA</td><td colspan="4">Deep Tube well</td><td colspan="2">Both</td></tr>
<tr><td colspan="3">Percentage of Resident</td><td>79</td><td colspan="3">Percentage of Resident</td><td>3</td><td>Percentage of Resident</td><td>18</td></tr>
</table>

Rainwater Quality

The test result of the rainwater quality parameters of the collected samples are summarized in Table 3. From where we saw that all testing parameters are found within the standard value except fecal coliform . The fecal coliform test result is showing higher than acceptable limit, when samples are taken in initial stage of raining. But after 15 min of raining, the results are showing nil in both of RCC and tin shed catchment surface. The use of filters and first-flush devices will remove the fecal and total coliform which improve water quality.

Design & Cost Effectiveness Analysis of RWHS

The major component of a RWHS comprises of Catchment, Gutter, flushing system, storage tank and water collection points. For a RWHS all the components are must. Without any of the components it will not function.

Assessment and information required for designing a RWHS are:

1. Climatic and Environmental phenomena.
2. Social aspects like Social structure, family structure and family size, daily consumption rate.
3. Structural component of RWHS.
4. Economic aspects.

The most important considerations to design the RWHS are rainfall quantities and pattern. Rainfall in each area is not equal especially in Bangladesh. Average monthly precipitation in Chittagong is shown in Table 4.

Table 3: Comparison of test results of rainwater quality parameters with standard value of WHO & Bangladesh Standard for drinking water

Sl.No.	**Parameters**	**Results**				**Standard value**	
		Tin shed Initial	Tin shed after 15 min	RCC surface Initial	RCC surface after 15 min	WHO	BD
1.	p^H	6.2	6.25	5.65	5.61	7-8	6.5-8.5
2.	Conductivity (µS/cm)	31	29.50	18.75	18.5	500	1000
3.	Total Dissolved Solid (mg/l)	15	12.75	10.5	9.25	1000	1000
4.	Hardness(mg/l)	9	9	4	4	-	200-500
5.	Chloride(mg/l)	< 1	< 1	< 2	< 2	250	150-600
6.	Alkalinity(mg/l)	Nil	Nil	Nil	Nil	30-50	-
7.	BOD_5(mg/l)	0.05	0.052	0.05	0.045	-	0.2
8.	Fecal Coliform(CFU/100ml)	5	0	3	0	Nil	Nil

Table 4: Rainfall data for Chittagong (Source: BMD (30 yr period average))

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation(mm)	5.6	24.4	54.7	147.4	298.6	607.3	727.0	530.6	259.3	184.8	67.5	11.9	2919.1

Runoff coefficient plays an important role in assessing the runoff availability and it depends upon Catchment characteristics. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself. It is taken as 0.9 for most of the roof catchment. (Source : Pacey, Amold and Cullis, Adrian 1989, Rain water Harvesting: The collection of rain fall and runoff in rural areas). The standard consumption recommended for domestic use is 45 gpcd/170.32 lpcd. We can assume that sanitation uses in domestic uses is 81.75 lpcd for our design consideration. Average monthly rainfall (April to October) R = 393.57 mm/Month. Design of RWHS in three Model site shown in Table 5

Table 5: Design of RWH

Considering Item	Model Site 1	Model Site 2	Model Site 3
Existing Data	2 storied building, Plot no.-259, Block-B.Total land area-3600sft,Catchment surface 2300sft,Number of people 24	4 storied building, Plot no.-359, Block-B.Total land area-3600sft,Catchment surface 2508 sft, Number of people 24	Semi pucca shed, Plot no.-253, Block-B.Total land area-3600sft,CI sheet roof Catchment surface 2097sft,Number of people 12
Domestic water demand Annual Demand= Water Use × Household Members × 365 days	59 m^3/ month	59 m^3/ month	29.43 m^3/month
Rain water Supply (Rain water harvesting potential 50%) Supply = Rainfall × Area × Run-off coefficient	37.50 m^3 / month	40 m^3 / month	Runoff coefficient (for corrugated GI roof), C =0.8 30.68 m^3 /month
Size of the storage tank For 10 days storage	3.95m*2.25m*2.25m	3.95m*2.25m*2.25m	2.30m*2.20m*2.0 m
Conduit size to carry rainwater from catchment to RWHS	70mm (BNBC-1993)		
Use water Pumps (To lift water from sub surface tank to overhead tank). Use overflow pipe to allow excess rainwater to flow out of the tank when the tank is full. The primary purpose of a first-flush diverter is to take the first flow of rainwater from the roof and divert it away from our storage reservoir. As first-flush of water from the roof contain bacteria.			

Cost Effectiveness Analysis of three systems

Cost effectiveness analysis of three supply system for four storied building are done for the experiment. It includes (i) Estimating cost of the underground storage tank of RWHS (ii) Construction cost of RWHS in existing condition (iii) Cost comparison of RWHS with existing system. These analyses are shown in Table 6

Table 6: Cost Effectiveness Analysis of three systems

Rainwater Harvesting Technique	CWASA water supply	Tube well technology
Cost: Total construction cost Tk. 86,064. Maintenance cost Tk.200/year (including cleaning by chlorine and repairing if any leakage detected), Economic life = 20 years	*Cost (water scare areas):* Water use rate = Tk.0.91 to Tk. 1.15/liter per capita per day.	Improved Deep Tube well with direct lever system. Approximate cost for 400 ft deep tubewell is Tk 2,50,000. Maintenance & repairing cost Tk 500/year
Therefore, total cost = (86,064 + (200 x 20)) = Tk. 90,064	Total cost = (Tk.1.15 x6x4 person x 365 days x 20 years) = Tk. 2,01,480	Total cost =(2,50,000+(500x20)) = Tk 2,60,000
RWHS is 2.89 times cost effective than deep tube well & 2. 24 times cost effective than CWASA		

CONCLUSION & RECOMMENDATION

From above study we can conclude that it is easy to implement Rainwater Harvesting System in existing catchment option from all respect (Scarcity of existing supply of water, quality of rainwater, quantity of rainwater, people acceptance for RWHS) and in a economical way. Following activities recommended for proper management and success of RWHS.

- Mass awareness building and training program on the practice and storage procedures of RWHS are required.
- Community participation should be encouraged as it can lead a successful water supply scheme. This could be done in the form of contribution of money for the purchase and installation of additional storage facilities.
- Proper hygiene should be maintained.
- Monitoring Water quality.

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POLLUTION STATUS OF TURAG RIVER: SPATIAL AND TEMPORAL VARIATION OF WATER QUALITY

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ABSTRACT
This study was undertaken in order to identify the major sources of pollution along the Turag river and the spatial and temporal variation of water quality along the river stretch. Sources of pollution were identified and categorized through survey and water samples were collected from different locations along the river through a half-year duration to understand the seasonal impact. Industrial waste constituted the major point source while human waste, solid waste and run off constituted non-point sources of pollution. Among the various parameters, pH, dissolved oxygen, ammonia, nitrate, phosphate, conductivity, sulphate, dissolved solids did not comply with standards during dry season, but levels of these parameters were mostly acceptable during wet season. Coliforms and other disease causing bacteria were detected in the river water. Heavy metal contamination was not significant in selected locations. Such spatial characterization of Turag river at a broader scale would enable selecting multiple suitable intake points for water treatment and distribution purpose.

Keywords: Turag River; pollution; waste water

INTRODUCTION
Turag River, passing through the northwestern part of Dhaka city originates from the Bangshi River, an important tributary of the Dhaleshwari River, flows through Gazipur and joins the Buriganga at Mirpur in Dhaka District. Due to rapid urbanization, Bangladesh is one of those polluted countries, which currently holds 1176 industries that discharge about 0.4 million m^3 of untreated waste to the rivers in a day (Rabbani and Sharif, 2005). Around Turag river there are 152 polluter industries that include 56 dyeing and textile industries, 50 chemicals and pharmaceuticals, nine food processing and 37 other engineering industries. Huge quantities of industrial effluents, solid waste from river-side settlements, petroleum products from ships, launches, cargoes, boats, untreated sewage etc. regularly get dumped into the rivers which are already severely polluted (Khan *et al*., 2007). As the fluvial environment of Bangladesh is mainly controlled by seasonal fluctuations, it is important to characterize the seasonal change for evaluating the temporal variations of water pollution (Bhuyan *et al*., 2010). The Turag River has been declared as ecologically critical areas (ECA) by the Department of Environment on September, 2009. Thus monitoring of pollution status of this river is crucial to save the aquatic ecosystem of this river. The main objectives of this study are as follows:

1. Identification of the major sources of pollution of Turag river and their categorization.
2. Evaluation of the spatial and temporal variation of water quality along Turag river.

METHODOLOGY
The study was conducted between the area of Tongi Bridge and 2.6 km towards upstream such as Location 1 (Tongi Bridge), Location 2 (Tongi Railway Bridge), Location 3 (Azmeri Composite Knit), Location 4 (Tongi Nodi Bondor) and Location 5 (Hossain Dyeing).

Survey and analysis of water samples
Various point sources and non-point sources of pollution were identified along the river through survey. Monthly samples were collected from five locations (Fig. 1) along the river during wet (wet 1-September, wet 2-October) season and dry season (Pre Dry-November, Dry 1-December, Dry 2-January, Dry 3-February) for a 6 month's period. Collected samples were analyzed for important

water quality parameters (pH, Color, Turbidity, Iron, Arsenic, Electrical Conductivity, DO, Total Hardness, Chloride, BOD_5, Salinity, total dissolved solids (TDS), total suspended solids (TSS), NH_3-N, NO_2-N, SO_4, PO_4, faecal and total coliforms etc). Bacteriological analysis was conducted in the laboratory of Department of Pharmecy and certain heavy metals such as Pb, Cd, Cr, Cu, and Zn were analyzed for location 2 in the river in the laboratory of Department of Public Health Engineering (DPHE). Seasonal and spatial variation of water quality was evaluated further.

RESULTS AND DISCUSSIONS

Sources of pollution

The major point sources of pollution included waste from dying industries such as Azmeri Knit Composite, Hossain Dyeing, Mehmud Industries Limited etc. and waste from fish market. Domestic and human waste generated from slum and storm water runoff is the main non-point source of pollution into Turag river.

Water quality parameters

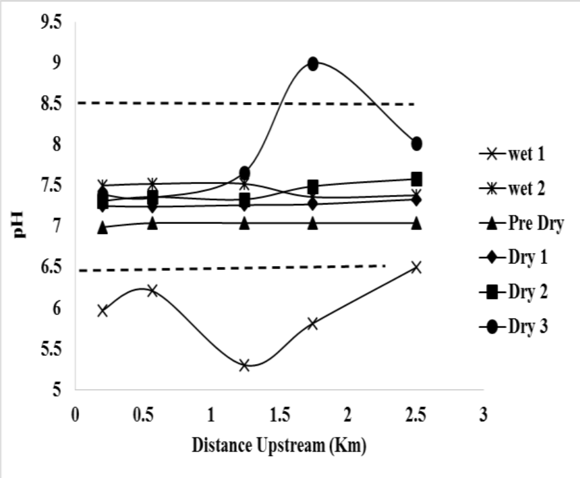
Summary of levels of water quality parameters measured for Turag river that did not comply with the standards to maintain aquatic ecosystem are provided in Table 1. The parameters were obtained towards the lower end of the ranges during wet season and those were mostly above the standard ranges during the dry season. Blackish color of water was seen in Turag River during dry season.

Fig. 1: Satellite image of sampling points along Turag River (inset shows the sampling stretch of the river on the map of Dhaka city)

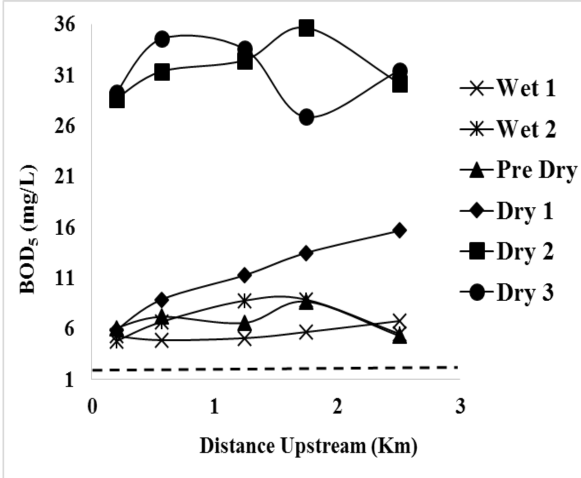
Fig. 2 shows the profiles of pH, 5-day biochemical oxygen demand, dissolved oxygen, ammonia and total dissolved solids along the river stretch.

Table 1: Ranges of concentrations of physical parameters along Turag river

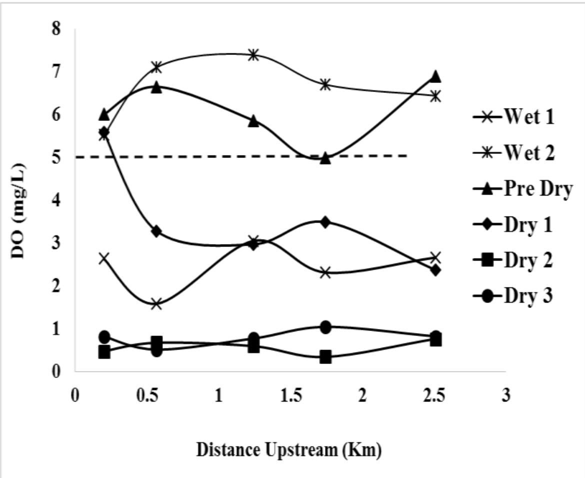
Parameters	Range of Concentration	DOE standards to maintain aquatic Ecosystem	Parameters	Range of Concentration	DOE standards to maintain aquatic Ecosystem
pH	5.3 - 9.0	6.5-8.5	NH_3 (mg/L)	0.11 – 8.16	0.5
BOD_5 (mg/L)	4.8 - 35.7	2	NO_3 (mg/L)	0.4 - 0.8	0.1
DO (mg/L)	0.34 -7.39	5	SO_4 (mg/L)	6.0 - 69	22
Conductivity (µS/cm)	88 - 1296	350	Cl_2 (mg/L)	77 - 166	13
PO_4 (mg/L)	2.0 - 16.2	6	TDS (mg/L)	41.7 - 641	165



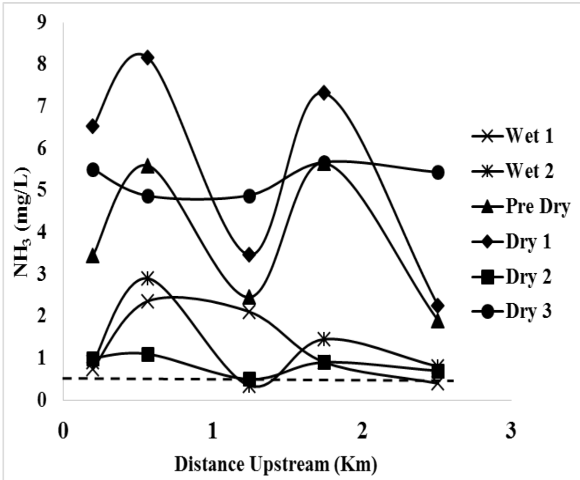
(a) pH



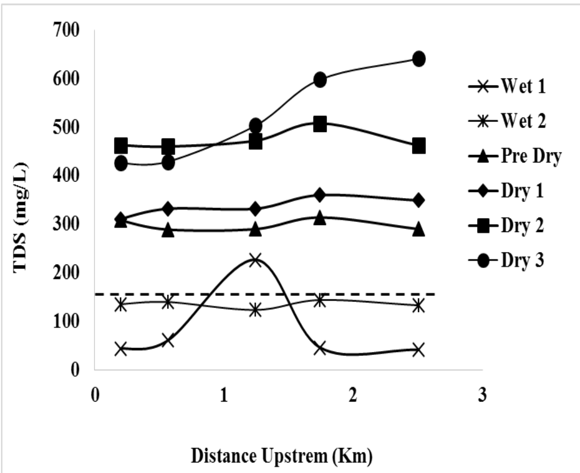
(b) Biochemical Oxygen Demand



(c) Dissolved Oxygen



(d) Ammonia



(e) Total Dissolded Solids

Fig. 2: Profiles of water quality parameters (a) pH; (b) Biochemical Oxygen Demand; (c) Dissolved Oxygen; (d) Ammonia and (e) TDS] along the river stretch at sampling periods starting from Sep 2015-Feb 2016 (Dotted line shows DoE standards for surface water quality)

As shown in Fig. 2, pH is within the standard range mostly except for early monsoon. BOD_5 reaches above 30 mg/L level during dry season. Accordingly, dissolved oxygen is adequate during wet season and below 2 mg/L during dry sampling periods. Oxygen demanding wastes get assimilated in the river easily during wet season whereas low flow conditions during dry season makes the recovery of the river zones from organic pollution difficult. Ammonia levels are measured above standard ranges at all instances, but reaches above 7 mg/L during dry seasons with considerable fluctuations along the stretch. Dissolved solids get diluted with the onset of monsoon and increases above 600 mg/L as the dry season proceeds.

Coliform test was done for one sampling in the month of December 2015 for Location 2 (Tongi Railway Bridge). Faecal and total coliforms were obtained at 1210 cfu/100 ml and 2180 cfu/100 ml respectively. Pathogenic contamination is significant in the river water possibly due to sewage pollution. This implies that Turag river water can be suitable for distribution only after conventional treatment (Ahmed and Rahman, 2000). Four species of bacteria were identified in the river water through bacteriological analysis such as *E. coli, S. typhimurium, Shigella spp. and Salmonella spp.*, which can impart health problems like diarrhoea, dysentery and skin disease etc.

Levels of five heavy metals (Pb, Cd, Cr, Cu, and Zn) were determined in the DPHE (Department of Public Health Engineering) laboratory from the location at Tongi Railway Bridge in Turag river. The heavy metal concentrations for the sampling site found in this study are shown in Table 2 along with the Bangladesh standards for the heavy metals.

Table 2: Heavy metal analysis results

Location	Bangladesh Standard	Unit	Concentration Present	Analysis Method	LOQ
Cadmium(Cd)	0.005	mg/L	0.001	AAS	0.00015
Copper(Cu)	1.0	mg/L	<LOQ	AAS	0.26
Chromium(Cr)	0.05	mg/L	0.007	AAS	0.001
Lead(Pb)	0.05	mg/L	0.009	AAS	0.002
Zinc(Zn)	5.0	mg/L	0.09	AAS	0.08

Note: LOQ = Limit of Quantitation, AAS = Atomic Absorption Spectrophotometer

The results of the study indicated that the heavy metal contents were within the range of standards. But the usages of these contents is increasing day by day, if the industries do not treat these contents seriously it would become a great concern soon. Future study is needed to identify heavy metal contents into the other locations of the river.

Comparison with previous studies

A number of studies have looked into the quality of the rivers around Dhaka city including Turag river. Some investigations that reported the status of Turag river water quality since last ten years have been summarized in table 3. Comparison of the previously analyzed water quality parameters with present study have led to the conclusion that the river water quality is deteriorating with respect to pH, EC, DO, BOD_5 and TDS. Multiple sampling points (both spatial and temporal) have been averaged and reported with standard deviation among the number of samplings in order to ascertain the variability in the levels of the concerned water quality parameters. The greatest variability along the river can be observed for the BOD_5 and TDS levels. This should of course be attributed to the locations of pollution sources along the riverside.

Table 3: Comparison of physical parameters with previous studies of Turag river with mean±standard deviation

Name of the Study	Year of study	pH	EC	TDS	DO	BOD_5	Alkalinity	Hardness
(Banu et al., 2013)	2006	7.1	98 (mg/L)	342 (mg/L)	6 (mg/L)	2.8 (mg/L)		
(Banu et al., 2013)	2010	7.5	1800 (mg/L)	812 (mg/L)	0 (mg/L)	22 (mg/L)		
(Meghla et al., 2013)	October 2011 to September 2012	5.69 ± 0.33	736.3 ± 41.52 (μs/cm)	398.9 ± 25.63 (ppm)	1.12 ± 0.50 (mg/L)	4.38 ± 3.57 (mg/L)	404.0 ± 30.19 (mg/L)	132.4 ± 13.53 (mg/L)
(Islam et al., 2012)	2012	7.40 ± 0.14	1273 ± 905.39 (μS/cm)	748.60 ± 549.78 (ppm)	2.36 ± 0.96 (ppm)	-0.98 ± 0.81 (ppm)		
(Mobin et al., 2014)	April 2013 to July 2013	6.76 ± 0.06	52.42 ± 10.47 (μS/cm)	319.92 ± 62.28 (ppm)	1.72 ± 0.53 (ppm)	1.15 ± 0.13 (ppm)	268.36 ± 28.31 (ppm)	127.09 ± 17.97 (ppm)
Present Study	September 2015 to February 2016	7.06 ± 0.56	577.47 ± 331.82 (μS/cm)	281.23 ± 163.18 (mg/L)	3.5 ± 2.52 (mg/L)	13.35 ± 12.13 (mg/L	53.03 ± 82.61 (mg/L)	130.67 ± 81.57 (mg/L)

Spatial Characterization of Turag River

This study involved sampling from different locations. Locations were chosen either near the industries or pollution sources or also at locations where no visible pollution sources existed in order to ascertain how much they contribute to pollute the water. Based on the water quality analyses, should Turag River be considered as a source of water for future treatment for drinking purpose, as the population is increasing and the scarcity of fresh water is getting higher, location 3 (Azmeri Composite Knit) could be a good option as the water quality was comparatively better from other locations as the results suggested. Most of the time the DO values were found higher in that point of sampling, which is also good for aquatic animals living in the water. Most of the water quality parameters for location 3 were closer to standard values than the other locations. Absence of non-point sources in the vicinity might be one of the causes for the parameters to be within the range. For subcritical flow conditions, sometimes the pollution cannot travel from upstream to downstream (downstream conditions are unaffected by upstream conditions). This along with other flow characteristics of the river might be the possible explanation for the location being less polluted than other locations. But further study is needed to identify better locations with more certainty.

CONCLUSIONS

- This study shows that the reasons behind the variations of water quality in different points of the river are mainly due to pollution as well as flow of water. At the points where the flow of water is less, the water there becomes more polluted than at the points where the flow of water is high.
- The major types of wastewater/ storm water outfalls contributing to the pollution of Turag river include: storm sewer pipes, open channels and small/big private outfalls.
- The major point sources of pollution are sewer lines and industries.
- The major non-point sources of pollution are human wastes, agricultural waste, indiscriminate dumping of untreated wastes, flood and runoff due to heavy rainfall.

- The investigated pH values were slightly high from DoE standards in dry season. Biochemical oxygen demand increased through the dry season, which was congruent with the decreasing levels of dissolved oxygen with the advancement of dry season. Electrical conductivity and total dissolved solids were above the DoE standard during dry season. Phosphate and ammonia levels were mostly higher from the DoE standard.
- All of the heavy metal Concentration values were within the range of Bangladesh Standard. So sampling locations were less polluted by heavy metals.
- Faecal coliforms and Total coliforms were analyzed for one location and the values were found to be 1210 CFU/100 ml and 2180 CFU/100 ml. Thus, water from Turag river can be considered for distribution purpose only after conventional treatment.
- Four species of bacteria were found through bacteriological analysis, which can impart diseases like diarrhea, dysentery and skin diseases.
- Spatial characterization of Turag River at a broader scale would enable selecting multiple suitable intake points for water treatment and distribution purpose.

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HEAVY METAL CONTAMINATION ASSESSMENT OF THE BURIGANGA RIVER BED SEDIMENT

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ABSTRACT

The Buriganga has become a dead river with thousand tons of polluted materials which are being deposited in the sediment from different sources containing heavy metals as well as non-biodegradable plastics. The sediment bed is the living place for different species which are dependent on it for their food and shelter. The accumulation of the contaminating elements in their body will be magnified through the ecosystem and will ultimately affect human health. By dredging, river bed sediment are transported for land filling purposes. The crops that are grown on the reclaimed land will accumulate the contaminants and ultimately affect the human health. For a developing country like Bangladesh, the solution for the problem is not sustainable if the cost is high or the technology requires much specialization. This study is to assess the present condition of the sediment of the Buriganga river bed. The sediments of the Buriganga have been found to be highly polluted with respect to Cu and Zn; unpolluted to moderately polluted with respect to Pb and moderately polluted to highly polluted with respect to Cr on the basis of USEPA sediment quality guideline.

Keywords: Riverbed sediment; heavy metal contamination; EPA guidelines; geo-accumulation index

INTRODUCTION

Rapid industrial development, coupled with the growing population has led to the generation of large quantities of industrial and municipal wastewaters, which are typically discharged into drainage canals/khals, that eventually take them to peripheral rivers and other water bodies. Buriganga river is the lifeline of many economic endeavors in Dhaka. In terms of quality, Buriganga is vulnerable to pollution from untreated industrial effluents and municipal wastewater, runoff from chemical fertilizers and pesticides, and oil spillage in and around the operation of river ports (Kamal et al., 1999; Ahmad et al., 2010; Saha and Hossain, 2011; Islam, 2015; Sikder, 2016). Wastewater pollution and its management is one of the biggest environmental concerns for Bangladesh. Pollution of the natural environment by heavy metals is a worldwide problem because these metals are permanent and most of them have toxic effects on living organisms when they exceed a threshold concentration. Discharge of greater quantity pollutants into aquatic environment may result in deterioration of ecological balance, changing the physical and chemical nature of the water and aquatic biota. River sediments are a major carrier of heavy metals in the aquatic environment. In addition, sediment-associated chemicals have the potential to adversely affect sediment-dwelling organisms (e.g., by causing direct toxicity or altering benthic invertebrate community structure). Therefore, sediment quality data (i.e., information on the concentrations of chemical substances) provide essential information for evaluating ambient environmental quality conditions in freshwater systems. This study assesses the present condition of the Buriganga river bed sediment and possible cost effective and eco-friendly measures to remediate the heavy metal contamination.

METHODOLOGY

The research work was conducted in the following way:
(1) Site Exploration: Before collection of the soil samples, the site of the bank of the Buriganga was visited several times for reconnaissance purpose for site selection and sample collection.
(2) Sample Collection: Disturbed soil samples were collected from surface and deep sediments of the river bed. For surface layer sediment, samples were collected by hand. For deep layer of deposition, dredging by excavator in the river bed was used as the soil sampling method. For the river bank soil,

hand sampling was used for sample collection. Fig. 1 shows the soil sampling from river bed and bank.

(3) Soil Classification: Soil samples were tested and classified as per the MIT Soil Classification

Table 1: Location of Sites for Sample Collection

Stations	Site Name	Longitude	Latitude
1	Shoari Ghat	E 90º 23′ 36.4″	N 23º 42′ 45.1″
2	Mitford Ghat	E 90º 23′ 54.4″	N 23º 42′ 43.6″
3	Babu Bazar Ghat	E 90º 24′ 9.78″	N 23º 42′ 33.57″
4	Sadarghat	E 90º 24′ 31.6″	N 23º 42′24.5″
5	Badamtoli Ghat	E 90º 24′ 13.47″	N 23º 42′ 31.8″

(b)

(a) **(c)**

Fig. 1: Photographs showing: (a) hand sampling of soil samples; (b) collection of soil samples from riverbed using excavator and (c) collecting riverbed sediments using excavator

System. Clay and silt are commonly referred to as fine grained soils, while sand and clay are referred to as coarse grained soils. ASTM D422 was performed to determine the soil grain size distribution.

(4) Tests on Soil Samples**:** Tests were done to determine the grain size distribution, specific gravity, organic content and heavy metal content of the soil of the Buriganga river.

RESULTS AND DISCUSSIONS

The contamination from the perspective of heavy metals present in the sediment is compared using different international guidelines and index values. The results are compared using different bar charts, graphs and tables.

Physical Properties

Physical properties include specific gravity and grain size distribution of the soil samples. The specific gravity of soils varies within the range of 2.65 to 2.75.Grain size has a great influence over the adsorption capacity of heavy metals. The soil samples contained 16% silt (size from 0.002 mm to 0.06 mm) and sand 84% (size ranging from 0.06 mm to 2 mm) . According to MIT soil classification system, the soil samples are silty sand. Average organic content of the samples was 1.65%.

Chemical Properties

Chemical properties include organic content and heavy metal content in the Buriganga river bank soil. Five samples were collected from the five locations of the Buriganga river bank for heavy metal content. The results are presented in Table 2.

The chemical contamination in the Buruganga river bank soil can be evaluated by comparison with the sediment quality guideline proposed by USEPA. These criteria are shown in Table 3.

Present study shows that for Pb, Site 1 and 3 are heavily polluted while Site 2 and 3 are moderately polluted and Site 4 is not polluted. For Cr and Zn, sites 1, 2, 3and 4 are heavily polluted and site 5is moderately polluted. For Cu, all the five sites are heavily polluted. For Ni, there is no guideline value.

In the present study, maximum contamination factor was found at Site 5 where the degree of contamination is 14.56. Contamination factors, $C_f > 6$ (very high contamination) have been found in Site 1, 4 and 5 for Cu. All the sites have a contamination factor (C_f) > 1 for all tested heavy metals except site 2 and 4 for Cr, site 2 and 5 for Ni (Table 4 and Table 5).

In the present study, according to the Muller's scale, the calculated results I_{geo} values indicate that the Buriganga river sediments for Pb is unpolluted to moderately polluted for station 2, 4 and 5. At stations 1 and 3, the sediments are moderately polluted for Pb. For Cr, all the stations are unpolluted indicating negative values. For Cu, at stations 1, 4 and 5 the sediments are moderately to strongly polluted. At station 2, the sediments are moderately polluted. At station 3, the sediments are unpolluted to moderately polluted. For Zn, all the stations are unpolluted to moderately polluted except station 4 with indications of being unpolluted. For Ni, all the stations are unpolluted except station 4 which shows unpolluted to moderately polluted indication.

Table 2: Concentration of heavy metals in the Buriganga riverbank soil

Sample No.	Concentration of heavy metal (mg/kg)				
	Pb	Cr	Cu	Zn	Ni
1	71.11	100.51	203.86	251.85	26.10
2	42.43	79.52	151.96	267.09	11.11
3	65.46	108.16	77.30	333.22	31.11
4	35.51	45.18	192.03	152.04	55.11
5	45.42	132.19	234.02	355.03	19.12
Maximum	71.11	132.19	234.02	355.03	55.11
Minimum	35.51	45.18	77.30	152.04	11.11
Background value	20.00	97.00	32.00	129.00	22.00

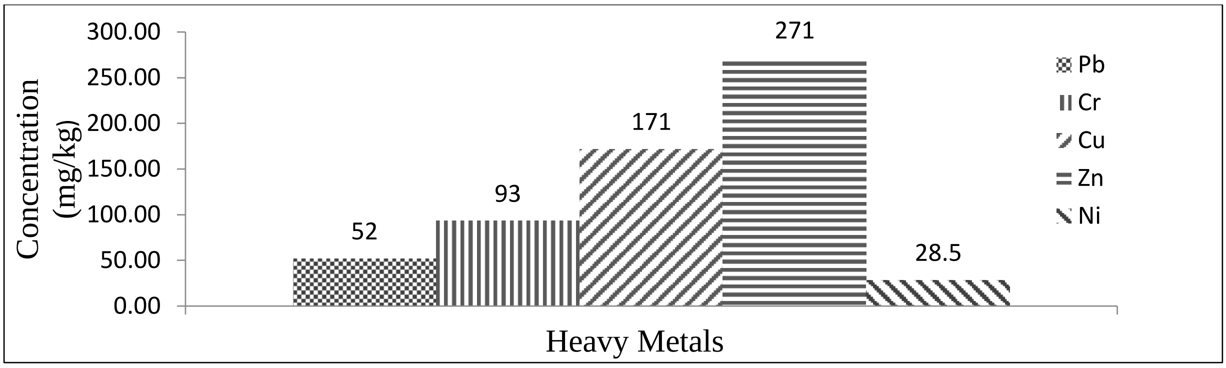

Fig. 2: Comparison among concentrations of heavy metals using the mean value from five locations

Table 3: EPA guidelines for sediment contamination for heavy metals

Metal	Not Polluted	Moderately Polluted	Heavily Polluted	Present value
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Pb	<40	40-60	>60	35.5– 71.1
Cr	<25	25-75	>75	45.2 – 132.2
Cu	<25	25-50	>50	77.3 – 234.0
Zn	<90	90-200	>200	152.0 – 355.0
Ni	–	–	–	11.1– 55.1

Table 4: Contamination factor and level of contamination

Contamination Factor (C_f)	Level of Contamination
$C_f < 1$	Low contamination
$1 \leq C_f < 3$	Moderate contamination
$3 \leq C_f < 6$	Considerable contamination
$C_f > 6$	Very high contamination

Table 5: Contamination factor values for sediment samples of the Buriganga river

Stations	Contamination Factor (C_f)					Degree of Contamination
	Pb	Cr	Cu	Zn	Ni	
1	3.56	1.04	6.37	1.95	1.19	14.11
2	2.12	0.82	4.75	2.07	0.50	10.26
3	3.27	1.12	2.41	2.58	1.41	10.79
4	1.78	0.47	6.00	1.18	2.50	11.93
5	2.27	1.36	7.31	2.75	0.87	14.56

Saha and Hossain (2011) also reported similar results. For the safe use of Buriganga water and river bed sediment, remediation of heavy metal is necessary. In a recent study, Choudhury et al. (2015) presented that Indian Mustard and Marigold plants can be used for treating heavy metal from the Burigonga river bed sediment.

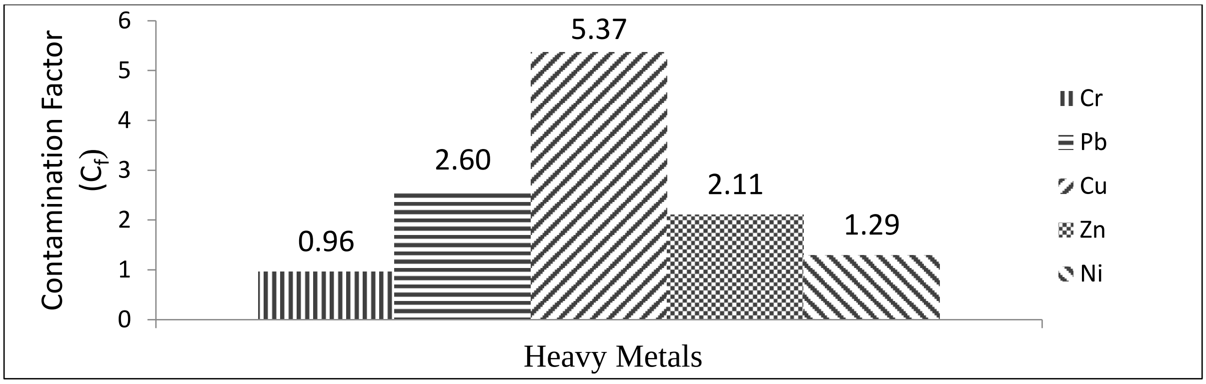

Fig. 3: Comparison among contamination factors for different heavy metals from five locations

Table 6: Muller's Classification for the Geo-accumulation Index

I_{geo} Value	Class	Sediment Quality
<0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly to extremely polluted
>6	6	Extremely polluted

Table 7: Geo-accumulation index values (Igeo) for the sediment samples of the Buriganga river

Station	I_{geo}				
	Pb	Cr	Cu	Zn	Ni
1	1.25	-0.53	2.09	0.38	-0.34
2	0.50	-0.87	1.66	0.47	-1.57
3	1.13	-0.43	0.69	0.78	-0.08
4	0.24	-1.69	2.00	-0.35	0.74
5	0.60	-0.14	2.29	0.86	-0.79

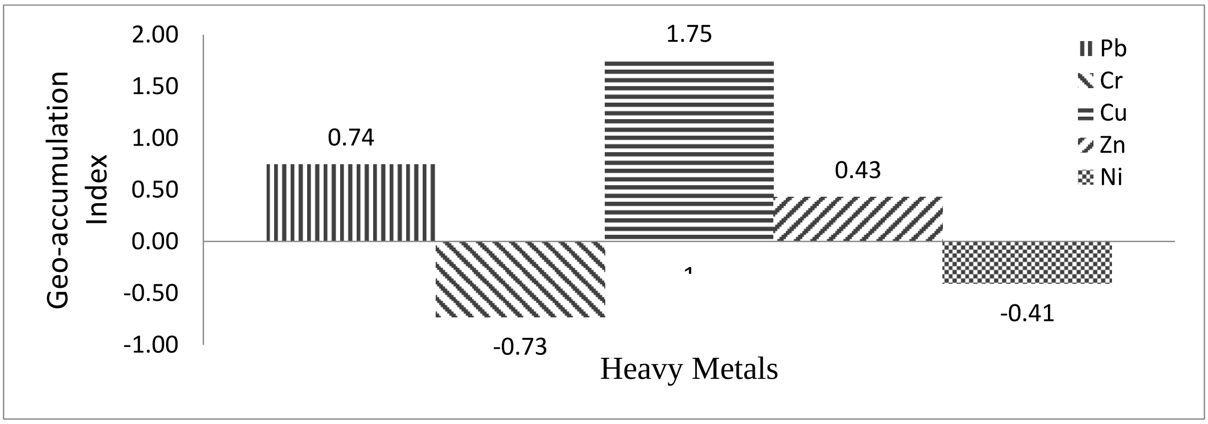

Fig. 4: Geo-accumulation index values for different heavy metals at five locations

CONCLUSIONS

Soil samples were collected from Burigonga river bed and bank. Heavy metal content of the samples was assessed in the study.

(1) The sediments of Burigonga river assessed in this study have been found to be highly polluted with respect to Cu and Zn; unpolluted to moderately polluted with respect to Pb and moderately polluted to highly polluted with respect to Cr on the basis of USEPA sediment quality guideline.

(2) According to contamination factor, level of contamination is moderate to considerable for Pb, moderate to low for Cr, very high to considerable for Cu, moderate for Zn and moderate to low for Ni.

(3) In accordance with geo-accumulation index, sediment quality is unpolluted to moderately polluted for Pb, unpolluted for Cr, moderate to strongly polluted for Cu, unpolluted to moderately polluted for Zn, unpolluted for Ni. The degree of contamination is greater than 10 for each station. At station 1 and 5, the condition is worst.

(4) Bioremediation for the existing extreme condition of contamination is suggested for low cost and eco-friendly solution for Bangladesh.

Other heavy metals (Cd, Fe, Al, As, Hg) and other parameters such as total organic carbon, sediment oxygen demand and moisture content may be considered for further analysis and in-depth research. Assessment of heavy metal contamination in water samples can be carried out and correlation of heavy metal contamination between sediment and water samples of the Buriganga river can be prepared. Other rivers of Bangladesh may be considered for further research. GIS and Remote Sensing based maps on sediment contamination can be prepared. It is suggested that pH, salinity, temperature etc. should be investigated further to comprehend details about metals in this environment of the Buriganga river.

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DETERMINATION OF OPTIMUM RAINWATER HARVESTING TANK FOR SALINITY AFFECTED COASTAL AREAS OF BANGLADESH

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ABSTRACT

Increasing salinity intrusion, pollution of surface water bodies, and groundwater contamination by arsenic are very critical problems in coastal areas of Bangladesh. As a result, rain water harvesting (RWH) has become a potential source of water supply in coastal areas of Bangladesh. A user-friendly software has been developed by using a simulation model and employed to estimate the optimum rainwater storage tank size, which is the most costly component of a RWH system. The procedure developed constitutes an effective tool for estimation of the most satisfactory storage capacity for any combination of catchment area and material, and water demand. The software also estimates reliability of the corresponding water supply system. The runoff coefficient for various types of materials and the rooftop area for the concerned household are considered as variables. The rainfall data for a 24-year period for different coastal areas of Bangladesh were collected from Bangladesh Meteorological Department (BMD) and used in the model. The software developed in this study would be very useful in determining optimum tank size of RWHS and estimating operational period of such systems for coastal areas (Cox's Bazar, Sandwip, etc.) as well as other areas of Bangladesh.

Keywords: Rain water harvesting (RWH); storage capacity; time reliability; volumetric reliability

INTRODUCTION

Despite of being one of the basic minimum requirement of healthy living, public water supply in Bangladesh evidently provides a shortfall in demand. Nationally about 13 percent population still use "unimproved" water sources (Unicef and WHO, 2015). Furthermore, salinity intrusion is an increasing problem in the coastal areas around the world. SAARC Meteorological Research Council (SMRC) found that the trend of sea level rise in Cox's Bazar is 7.8 mm/year respectively based on 22 years' historical data (Rahman and Alam, 2003). Salinity intrusion affects fresh water availability into the river systems and therefore, deteriorates usability of drinking and irrigation water. Hence rainwater harvesting has thus become a viable alternative. Although rainwater harvesting (RWH) is being practiced in many regions of Bangladesh, its design has received limited attention from professionals. Estimating correct size of the rainwater storage tank and determining its operational period are the most important aspects of a RWH system since storage tank is the most expensive and critical component. This paper presents a model and its application for estimation of RWH tank size for coastal area and for any combination of roof area, material and user number. The model also determines the volumetric and time reliability of rainwater harvesting system, including the time period during which the system will remain operational.

METHODOLOGY (SECTIONS)

Computer Based Simulation method was used for determining the optimum tank size of RWHS system. Here Yield after spillage was adopted (Fewkes and Butler, 2000). For this approach the following equations can be used to determine the yield from the tank and the volume of water in the tank (Fewkes A. and Butler D,2000)

$$Y_t = \min(D_t, V_{t-1}) \quad (1)$$

$$V_t = \min(V_{t-1} + Q_t - Y_t, S - Y_t) \quad (2)$$

Where, Y_t is the yield from the tank during the time interval t; V_t is the volume of rainwater in the tank at the end of time interval t; Q_t is the volume of rainwater that enters the tank during time interval t; D_t is the demand (volume of water that is removed from the tank) during time interval t; and S is the maximum storage capacity.

The reliability of a rainwater storage system can be expressed using either time or volumetric basis. Volumetric reliability is the ratio of the total volume of water supplied and the total water demand. (Islam M. M et al., 2010)

$$R_v = \{(V_{t-1}) + \sum_{t=1}^{T} Q_t\}/\{\sum_{t=1}^{T} D_t\} \quad (3)$$

Time reliability is the fraction of time in which demand is fully met. (Justin Mechell,2005) It can be expressed as:

$$R_t = 1 - d_f/n \quad (4)$$

Where, R_t is the time reliability, d_f is the number of failure days, n is the total number of days

To simulate the performance of a RWHS, a water-balance simulation model on daily time step was built using JAVA. This model accounted for various factors for a RWHS, such as tank size, daily rainfall, daily water demand, coefficient of the catchment, and catchment area. A behavioral model (yield-after-spillage type) was adopted in this study to simulate the long-term water balance of a RWHS. The YAS approach has been recommended for design purpose (Fewkes A. and Butler D,2004) as it gives a conservative estimate of system performance.

The program was also arranged in a process to give a graphical representation of the volumetric reliability versus optimum tank volume and time reliability versus optimum tank volume. As such the user will have a choice on what level of service they demand depending on their ability and their preference on time or cost.

Two coastal areas Cox's Bazar and Sandwip have been chosen for estimation of optimum tank size for different operational condition.

The variation of tank reliability was assessed by varying the catchment area and keeping the demand constant. As the RWHS tank is basically designed to supply water to a family only for drinking and cooking purpose, a demand of 5 liter per capita per day was assumed, considering local conditions. Considering a family/ user size of 10 persons, a daily water demand was set at 0.05 m^3/day.

Different types of materials are used as roofing materials in Bangladesh, including thatched roof, and corrugated sheets. Considering a runoff coefficient of 0.50 for thatched roof, and 0.9 for corrugated sheet (Dharmabalan.P, 1989), a runoff coefficient of 0.7 was used for reliability assessment.

RESULTS AND DISCUSSIONS

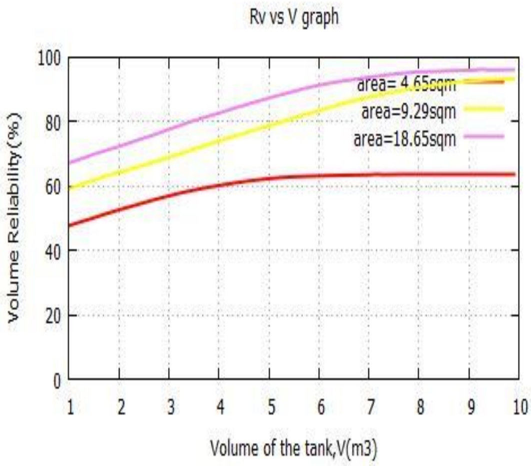
The efficiency of a rainwater harvesting tank can be determined by assessing its reliability.

[1] Effect of regional variation: Table 1 shows the optimum tank size for the two locations for different reliability figures (varying from 50 to 90 percent) for two different sizes of catchment. For a particular reliability and catchment area, a higher volume tank is required in Cox's Bazar, compared to Swandip.

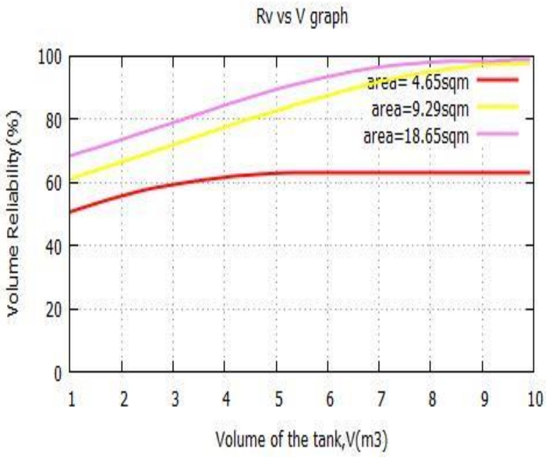
[2] Effect of Catchment Area: With the increase in catchment area, the inflow increases and as a result the tank becomes more reliable in terms of volume. Figure 1 shows volume reliability and time reliability for three different catchment areas and different tank sizes in Cox's Bazar and Swandip. For a particular tank size, the reliability increases as catchment area increases.

Table 1: Tank size for different reliability and catchment for a 10 member family

Catchment Area	Reliability (%)		Tank Size (cubic meter) Cox's Bazar	Tank Size (cubic meter) Swandip
9.29 sqm (100 sft)	Rv	50	1.00	1.00
		80	5.30	4.50
		90	7.80	6.60
	Rt	50	1.00	1.00
		80	5.80	5.00
		90	8.30	7.10
18.58 sqm (200 sft)	Rv	50	1.00	1.00
		80	3.50	4.90
		90	5.70	7.20
	Rt	50	1.00	1.00
		80	4.10	3.90
		90	6.30	5.90

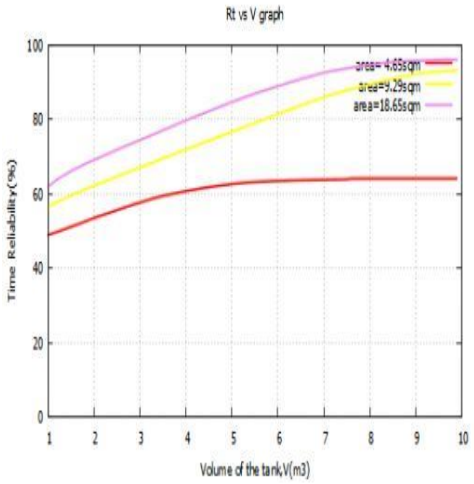


(a)

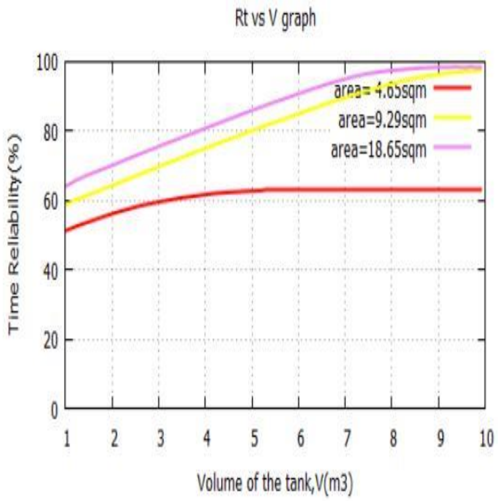


(b)

Fig 1: Volumetric reliability of Cox's Bazar (a) and Swandip (b) (10 members)



(a)



(b)

Fig 2: Time reliability of Cox's Bazar (a) and Swandip (b) (10 members)

CONCLUSIONS

Rainwater harvesting is an important water supply option in salinity affected coastal areas, as well in areas suffering from ground and surface water contamination in Bangladesh. The storage tank is the most expensive and critical component of a RWHS; it also dictates the volume and time reliability of a RWHS. Since catchment (i.e., roof) area and rainfall intensity vary widely, it is difficult to estimate the optimum tank size for a RWHS in a particular area and estimate its reliability. A software/tool has been developed for estimation of optimum tank size and assess its reliability for any area, based on rainfall pattern of 24 years of the area, catchment size and characteristics and water demand. In coastal region, a rainwater harvesting system with optimum tank size would be able to provide water for to a 10 member family having a catchment area of 9.29 sqm (100 sft) for eight months of a year, during monsoon (June to August) and during post monsoon (September-November).

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QUALITY ASSESSMENT OF INDUSTRIAL EFFLUENT IN CHITTAGONG INDUSTRIAL AREA, BANGLADESH

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ABSTRACT

Chittagong is the largest city of Bangladesh based on commerce and industries.Fish processing, detergent, dying & washing, Textile & pharmaceuticals, etc is now the most important and rapidly developing industrial sectors in Bangladesh. It has a high importance in terms of its environmental impact, since it produces large amounts of effluent. A major environmental problem of these industries is the discharge of untreated effluent to the environment, causing pollution of nearby soil and water. The aim of the present study is to determine the Physiochemical & Biological properties of waste water of some industries of Chittagong & to investigate their effects on natural environment. 5 (Five) waste water samples were collected from different types of industries (Fish Processing, detergent, dying , washing & pharmaceuticals) at two location Sagorika & Fozdarhat industrial area under Chittagong and 13 water quality parameters were analyzed: Temperature(°C), Color, Turbidity, TDS , EC , pH, Iron (Fe) ,Total Hardness, Chloride (Cl-) , Alkalinity ,BOD, COD & DO. Among the 5 types of industries low pH (5.80) was found in the sample of Glaxco pharmacuticals and low DO (0.0ppm) value was found in the waste water sample of SAR & Co fish processing , Glaxco pharmaceuticals, Unilever detergent & Reliance dying & washing .Although SAR & Co fish processing, Glaxco pharmaceuticals, Unilever detergent are using the ETP but it may not be 100% effective to treat the discharging wastewater. maximum value of Color (275 TCU), pH (5.7), EC (3464 μS/cm), TDS (3260ppm), Turbidity (33.46 NTU), DO (0.0ppm), & BOD (144 ppm) were found in Reliance dying & washing industry which do not satisfy the Bangladesh national water quality standard. It has found that water quality parameters of those industries which are discharging effluent by using ETP are almost in acceptable range as per BECR 1997. So it is recommended that to sustain the safe ecological environment, industrial effluent should be treated before discharging on open land & water body.

Keywords: Industrial effluent; industrial area; discharge; water quality; effluent treatment plant

INTRODUCTION

Chittagong is the largest Bay of Bengal port city of Bangladesh based on commerce and industries.According to population census 2001, Chittagong City Corporation has 1.99 million populations. This growth rates represent on average 40,000 people a year being added by natural increase over the twenty year period 1991 to 2011(MAPS [2011]).Being the country's major seaport much of Bangladesh's export and import passes through the port of Chittagong. The main industrial locations of Chittagong are concentrated in kalurghat, nasirabad, sholashahar, patenga, kaptai, bhatiary, barabkunda and fouzdarhat. The major types of industry include jute, pulp and paper, textiles, fertilizers, rubber and plastic, leather, food and beverages, sugar, cement, pharmaceuticals, tobacco, iron and steels, distilleries etc. Of these, the main polluting industries are tanneries, pulp and paper, fertilizer, distilleries, iron and steel, sugar and chemicals (Hashemi, Reza et al. [2011, 2010]).

The environment of Chittagong is being polluted because of growth of industries has been unplanned and most industrial units have no adequate facilities for treatment of wastes produced. So the industries discharge their liquid, semi-solid and solid, toxic gaseous, degradable and non-degradable substances in water,air and land. The highly toxic effluents discharged in nature or contaminated water, air and land and affect organisms and ultimately human health. It reduces economic productivity and amenities. A majority of the industries are located near the banks of water bodies discharged by the industries (URL,Reza et al. [2011]).

METHODOLOGY

Site selection & sample collection

During the study period (January to July, 2015) a total of 5 samples were randomly collected from 5 different industries of Chittagong Metropolitan City as shown in location Fig. Sample numbers and sampling locations were selected based on the density of industry. Sampling points & number of collected samples is summarized in table.Sample is collected in a plastic bottle. The plastic bottle was first washed thoroughly using detergent and dried. Before taking wastewater sample the bottle were ringed with water. After taking the sample, the bottle labeled by mentioning the name and location of the sample site.The sample was transferred to the laboratory for analysis with minimal and acceptable changes & standard method.

RESULTS AND DISCUSSIONS

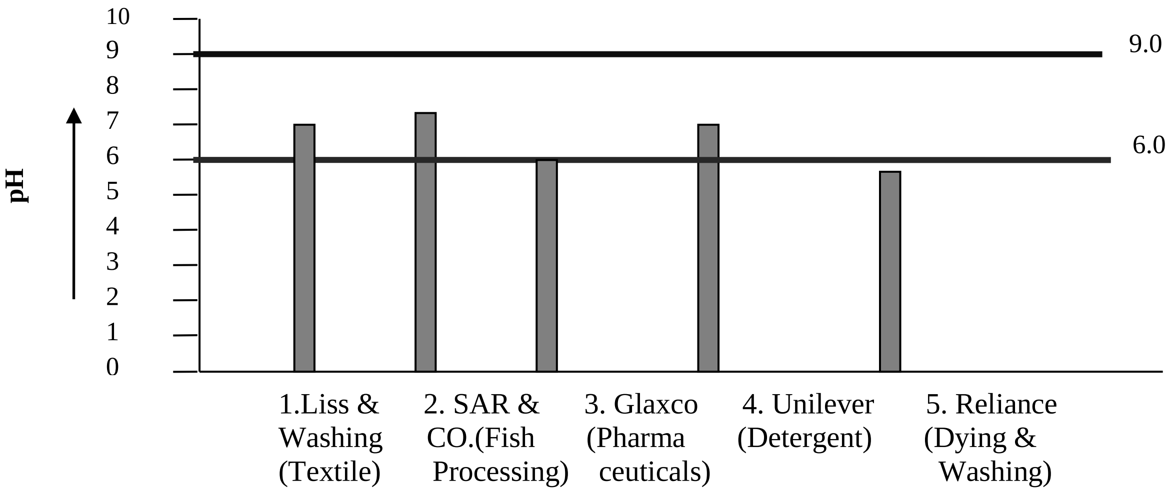

Fig.1: Variation in pH range of "industrial waste water" in Chittagong

pH is a measure of whether a liquid is acid or alkaline. Lower pH water is likely to be corrosive. pH values of the water samples were determined directly by a digital pH meter. pH varied from acidic to alkaline where the maximum value 7.30 at SAR & Co Fish processing industries and minimum value 5.70 at Reliance dying Industries. Two industry pH are lower than the DoE standard which indicates the effluent is acidic & harmful

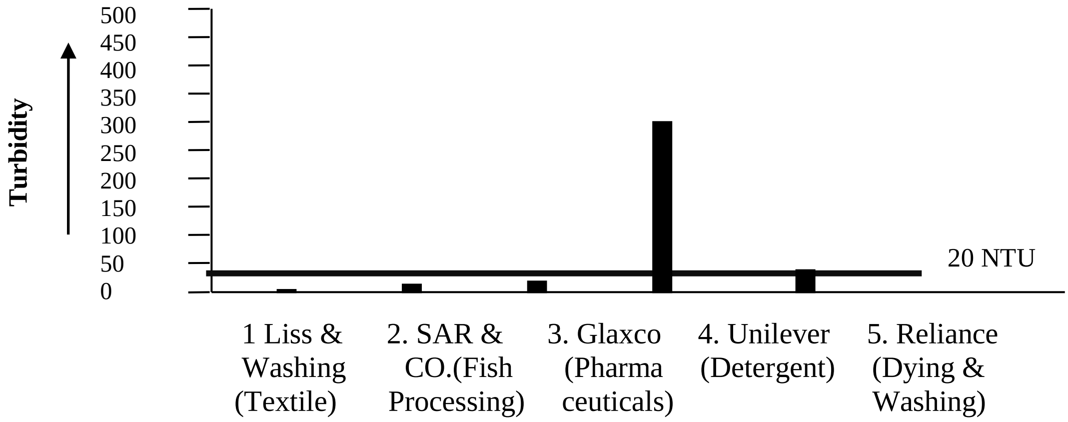

Fig. 2: Variation in Turbidity range of "Industrial Waste Water" in Chittagong

Turbidity or cloudiness in water is due to very small solid particles which tend to float because of their low weight .Turbidity of collected water sample measured by Electric Turbidity Meter. The maximum turbidity 33.46 NTU was found in a water sample collected from Reliance dying Industries & minimum 0.85 NTU found at Liss washing. Out of 5 Industries, 2 Industries effluent range exceed the national standard quality range 20 NTU.

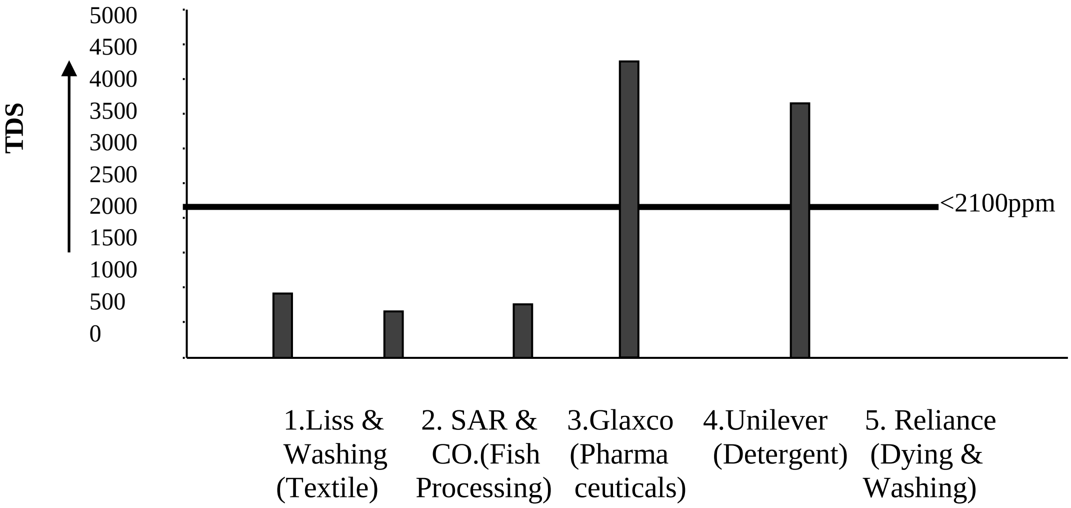

Fig. 3: Variation in TDS range of "Industrial Waste Water" in Chittagong

Total dissolved solids were measured with in 5-10 minutes after collection of sample at the sampling site by TDS meter/combo meter**.** The maximum concentration of TDS was 4200 ppm at Unilever and minimum 680 ppm at SAR & Co. From 5 industries only 2 industries effluent exceed the national standards 2100 ppm as shown in fig. TDS effluent mainly consists of ammonia, nitrite, phosphate, calcium, some acids, metallic ions etc.

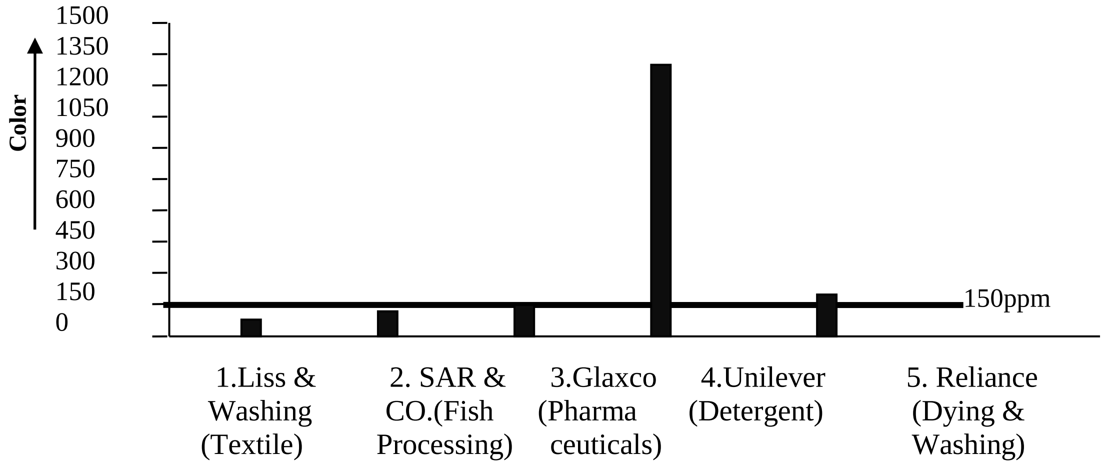

Fig. 4: Variation in Color range of "Industrial Waste Water" in Chittagong

Color concentration of water samples were determined by Platinum Cobalt method. Color concentration values in collected water samples were 47 TCU, 53 TCU, 146 TCU, 229 TCU and 275 TCU found in 5 Industries respectively. Unilever & Reliance dying industries effluent concentration value exceed the national standard value 150 TCU.

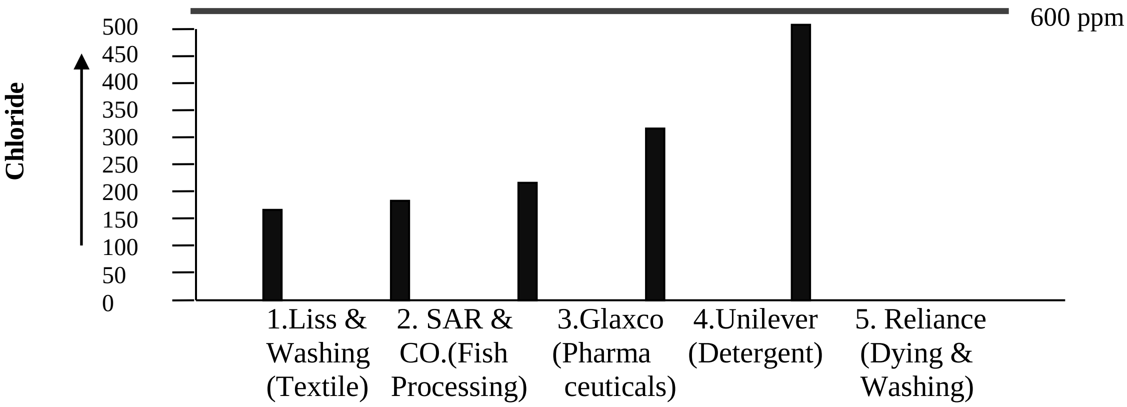

Fig. 5: Variation in Chloride range of "Industrial Waste Water" in Chittagong

Chloride concentration of water samples were determined by titration method. Chloride concentration values in collected water samples were 155 ppm, 180 ppm, 240 ppm, 332 ppm and 560 ppm found in 5 industries respectively.The effluent quality range with in national standard value is 600 ppm.

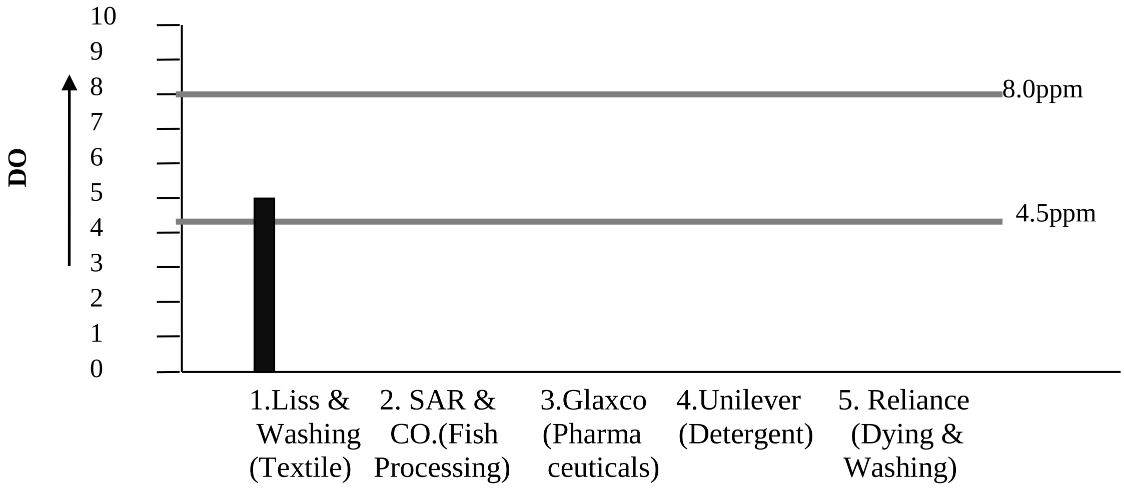

Fig. 6: Variation in DO range of "Industrial Waste Water" in Chittagong

DO is denoted as dissolved oxygen & measured by DO meter at the laboratory after four hours of collection of water sample from the sampling site. DO indicates the health of water. The maximum DO is 5.0 ppm found Liss washing effluent and minimum is 0.0 ppm found Other 4 Industry . So this 4 industries effluent concentration range are not satisfy the National standard (4.5 ppm - 8ppm) value of DoE . The lower value of DO may be due to the use of various organic chemicals in industry which is dangerous for aquatic life.

The chemical oxygen demand test (COD) is commonly used to indirect measure of the amount of organic compounds in water. It is useful to assess strength of waste which contains biologically resistance organic substances. The maximum values is found 436 ppm at Reliance Industries & minimum value is found 190 ppm at SAR & CO. The COD value of 5 industries water sample satisfy the Bangladesh national water quality standard.

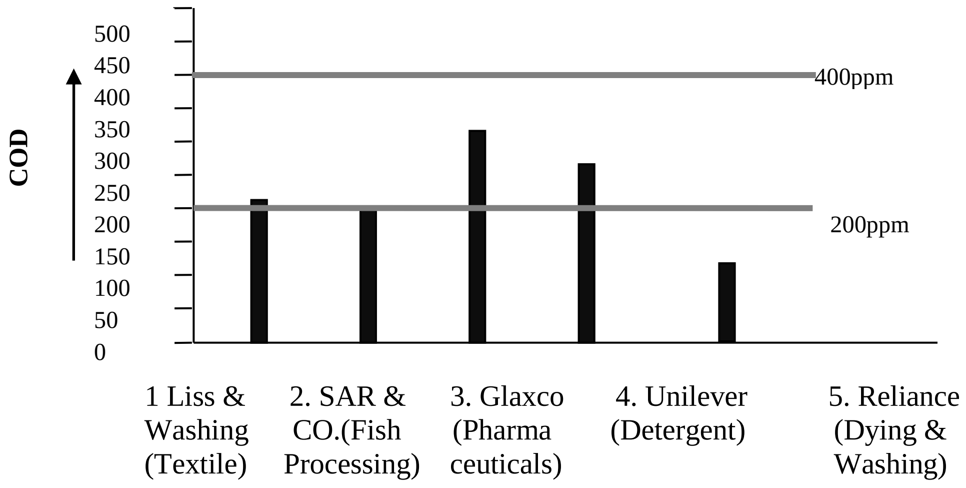

Fig. 7: Variation in COD range of "Industrial Waste Water" in Chittagong

Table 2: Summary of Test Result

Sl no	Parameter	Textile	Fish processing	Pharmaceuticals	Detergent	Dying & Washing
		1.Liss Washing	2. SAR & CO	3. Glaxco	4. Unilever	5.Reliance
01	Temperature °C	26	27	28.5	29.0	27.0
02	pH	7.10	7.30	5.80	6.80	5.7
03	EC (μS/cm)	1270	910	700	910	3464
04	TDS (mg/l)	930	680	690	4200	3260
05	Alkalinity (mg/l)	188	130	350	1375	178
06	Hardness (mg/l)	228	146	120	312.5	240
07	Turbidity (NTU)	0.85	5.11	12.85	238.8	33.46
08	Color (TCU)	47	53	146	1224	275
09	DO (mg/l)	5.0	0.0	0.0	0.0	0.0
10	BOD (mg/l)	90.0	58.0	132	228	144
11	Chloride (mg/l)	155	180	240	332	560
12	COD(mg/l)	228	190	320	256	436
13	Iron (mg/l)	0.01	0.05	0.01	0.21	0.01

CONCLUSIONS

This study was conducted by collecting waste water of different industries of Chittagong to assess the different physical, chemical & biological characteristics. For these purposes, samples were collected from 5 different types of industries (textile, food processing,pharmaceuticals, detergent, Dying & Washing) at two different locations (Sagorika & Hathazari I/A).

1.Among the 5 types of industries, low pH (5.80) was found in the sample of Glaxco pharmacuticals and low DO (0.0ppm) value was found in the waste water sample of SAR & Co fish processing , Glaxco pharmaceuticals, Unilever detergent & Reliance dying & washing .

2.Although SAR & Co fish processing, Glaxco pharmaceuticals, Unilever detergent are using the ETP but it may not be 100% effective to treat the discharging waste water.
3.On the other hand Reliance dying & washing industry have no ETP & maximum value of Color (275 TCU), pH (5.7), EC (3464 μS/cm), TDS (3260ppm), Turbidity (33.46 NTU), DO (0.0ppm) & COD (436ppm) were found which does not satisfy the Bangladesh national water quality standard.
4.Out of 13 parameters, maximum parameters except EC & DO of Liss & washing textile, SAR & Co fish processing, Glaxco pharmaceuticals, Unilever detergent industries are within satisfactory level.

So it is evident from the study that waste water quality of the industries which have ETP is comparatively better than other industries.

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ASSESSMENT ON SOLID WASTE MANAGEMENT IN CHITTAGONG CITY, BANGLADESH: A CASE STUDY OF SANONDA R/A

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ABSTRACT

Generation of solid waste (SW) is a major problem in urban areas and its management is obligatory functions for both urban local authority and the urban people. This study was conducted at Sanonda Residential Area of Bagmonirum Ward 15 under Chittagong City Corporation (CCC). The study involved a questionnaire and encompassed 50 households from three different socioeconomic groups (SGs): middle (MSG), upper middle (UMSG) and high (HSG). It was found that the residential waste generation rate was 0.35 Kg/person/day and an average household generation of 2.02 kg of waste per day. The household solid waste (HSW) comprised of nine categories of wastes with vegetable/ food waste being the largest component (64%). Vegetable/ food waste generation increased from 52% (observed for HSG) to 76% (for MSG). By weight, 65.9% of the waste was compostable in nature. Finally, the research suggests some appropriate recommendations on how a participatory-sustainable residential solid waste management system could be developed in the area of CCC to achieve its goals.

Keywords: Solid waste; generation; composition; recovery potential; house hold stage

INTRODUCTION

Solid waste generation has increased proportionately with the growth of urban. Chittagong city is facing great difficulties because of high rates of urbanization due to rural exodus/migration. Municipal solid waste (MSW) management systems are becoming more complex in many countries with movement from landfill-base systems to resource-recovery-based solutions (Abu-Qdais, H. A. (2007). The average generation of solid waste in the urban areas of Chittagong is 1550 tons per day. Berkun et. al(2005). The quantity of household solid waste (HSW) generated is much higher than the amount of waste generated by industries and health sectors (Culot et.al(1999). The domestic wastes (mostly inorganic) comprise about 80% of total generated wastes in major cities (Pongrácz, 2009).Solid waste disposal is a greater problem because it leads to land pollution if openly dumped, water pollution if dumped in low lands, and air pollution if burnt. Inadequate management of solid waste in Chittagong leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses(Josiah et. al(2004). The objectives of the survey study are:

- To explore the present scenario of solid waste management system of Chittagong city by analzing a housing society (Sanonda Residential Area).
- To determine house hold solid waste (HSW) generation and its composition.
- To recommend some remedial measures in order to improve the present waste management system

METHODOLOGY

Firstly, a study involving the assessment of documents and records relating to municipal solid waste in Chittagong City has been conducted. Reconnaissance survey was conducted in July’2014 to February’2015 identify the socioeconomic status and solid waste generation scenario of the study area, especially the sources and sub-sources of household solid waste generated, physical composition and information regarding quantity and quality of solid waste (SW). Ward number 15 was selected purposely for the present study and has a population of about 150000 residents. The study area comprises of Sanonda R/A, Baghmonir about10.36 sqm. at ward 15 and has inhabitants about 1100-1200 under Chittagong City Corporation (CCC) of Bangladesh.

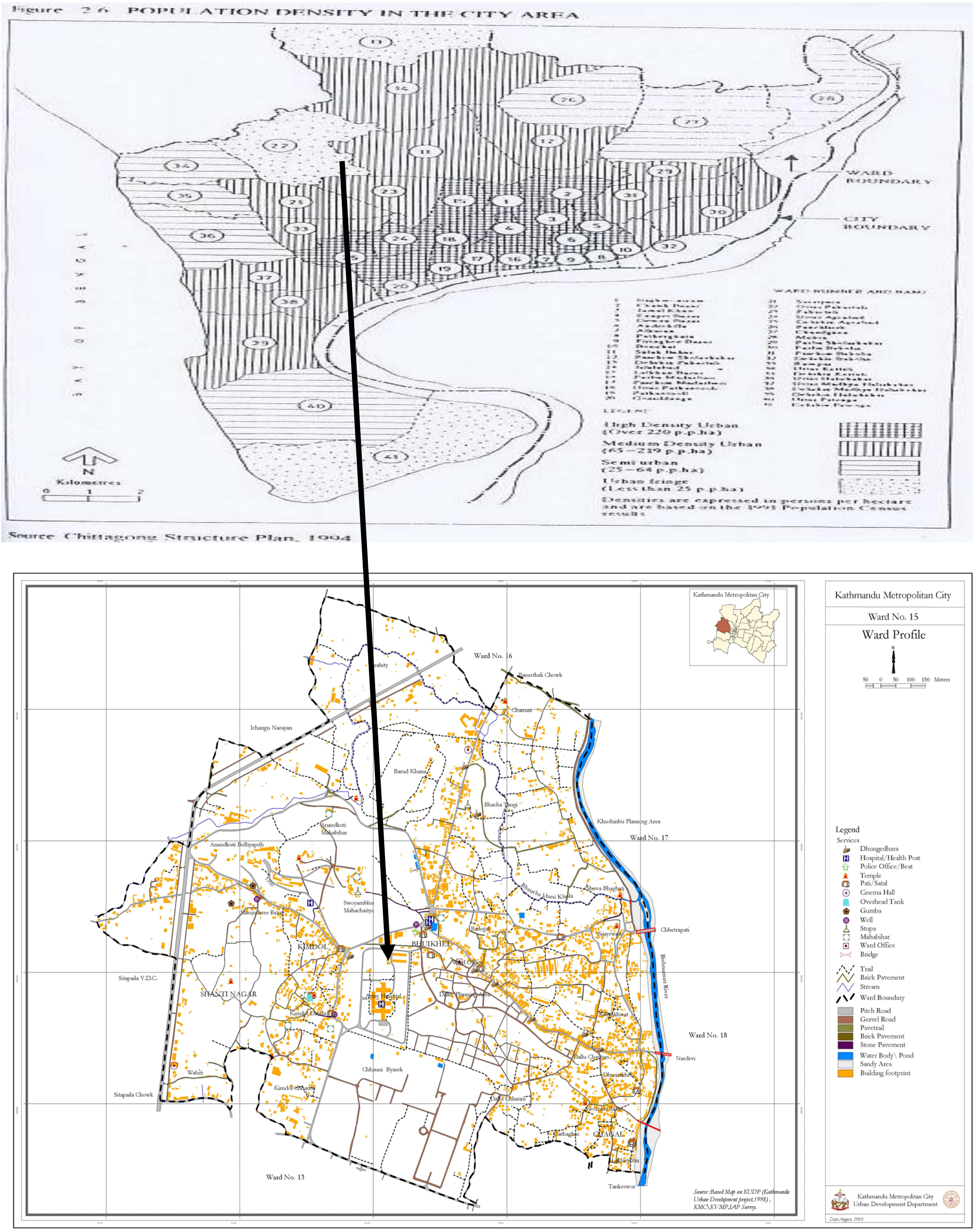


Fig. 2: CCC Wad no. 15

SECONDARY DATA OF SANONDA R/A UNDER WARD NO –15, BAGHMONIRAM:

Table 1: Waste management facilities in ward no. – 15

Sl no	Particulars	Quantity
1	Total Dust-bin	43 nos.
2	Total Generated Solid Waste	About 57 tone/day
3	Total Waste Transport Vehicle	2 nos.
4	Schedule of waste disposal time	6 am – 8am
5	Solid waste carrying vehicle type	Truck & Van
6	Number of waste crew	46 nos.
7	Total population	About 100000 nos.
8	Total House in Sanonda R/A	180 nos.
9	Total inhabitants in Sanonda R/A	About 1100 ~1200 nos.
10	Container	6 no
11	Waste Generation Rate	0.57 kg/Cap/Day

Source: Survey, June'2012, Study on MSWM, CCC

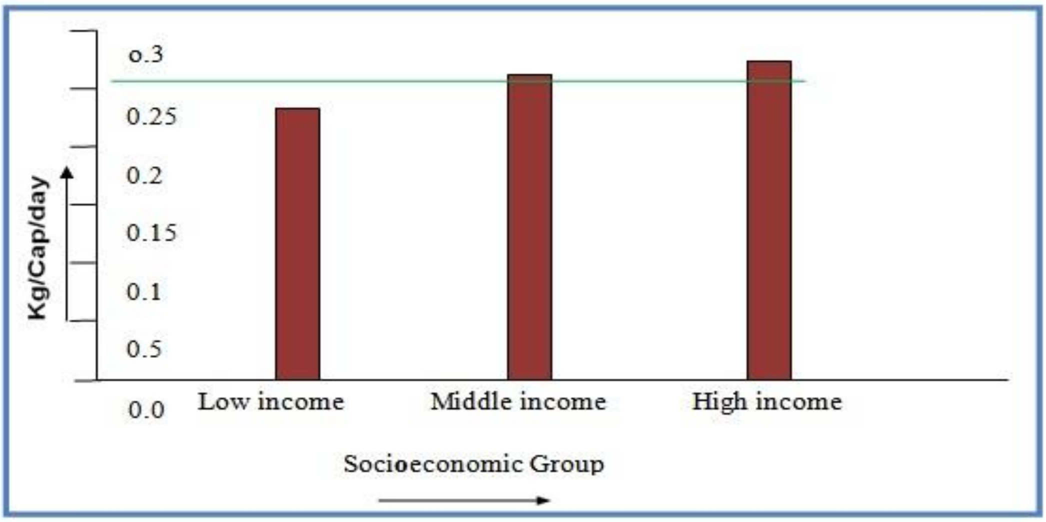
Table 2: Socioeconomic groups on the basis of the household's monthly income

SL. No.	Socioeconomic group	Monthly income level	Number of studied house	Number of person studied
1	HSG (High Socioeconomic Group	above Tk. 50,000	14	70
2	UMSG (Upper Middle Socioeconomic Group)	between Tk. 20,000 and Tk. 50,000	20	125
3	MSG (Middle Socioeconomic Group)	between Tk. 10,000 and Tk. 20,000	16	112

Table: 3 Residential Waste Generation Rate

Socio-economic group	Number of hh studied	RWGR Kg/hh/day	Number of persons studied	RWGR Kg/person/day
HSG	14	3.13	70	0.62
UMSG	20	1.79	125	0.28
MSG	16	1.14	112	0.16
Total	50	2.02	307	0.35

hh = Household; RWGR=Residential Waste Generation Rate.



Waste generation rate (Kg/cap/day)
Average domestic waste generation rate

Fig. 3: Variation of "RWGR" wastes Generation Rate of CCC at Sanonda R/A

RESULTS AND DISCUSSIONS

Table 4: Physical Composition of RSW Generated By Different Socioeconomic Groups

Socio-economic group	Waste Category (%)								
	Non-Compostable							Compostable	
	Paper	Pack	Can	Plastic	Glass	Bones	Textile	Vegetable	Wood
HSG	9	12.6	10	3.35	2.55	3.5	4	52.7	2
UMSG	6.3	9.5	5	3.6	2.20	2.5	5.3	63.2	1.7
MSG	5.4	2.45	3.38	3.82	1.85	1.42	3.6	76	2
GW per day by all SEGs.	6.9	8.18	6.12	3.57	2.18	2.49	4.3	64	1.9

G W =Generation Waste; SEGs =Socioeconomic Group

PHYSICAL COMPOSITION OF COMPOSTABLE AND NON COMPOSTABLE SOLID WASTE

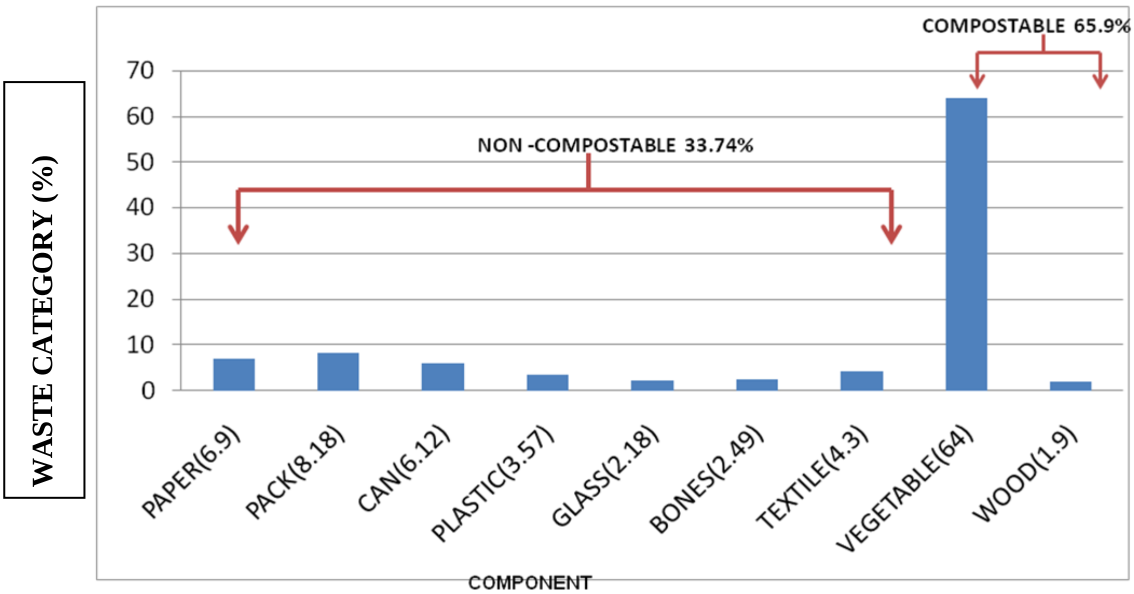


Table 5: Comparison of Solid Waste's Physical Composition data between SANONDA R/A and CCC Study

Component	CCC MSWM Household (%)	Sanonda R/A Assessed Household (%)	CCC MSWGR Kg/Cap/Day	CCC Ward No. 15 Generation Rate g/Cap/Day	Sanonda R/A Assessed Generation Rate Kg/Cap/Day
Paper	4.68	6.9	0.420	0.57	0.35
Pack	ND	8.18			
Can	2.65	6.12			
Plastic	8.70	3.57			
Glass	0.00	2.18			
Bones	0.63	2.49			
Textile	2.40	4.3			
Vegetable	70.50	64			
Wood	1.20	1.9			
Compostable	71.70	65.9			
Non Compostable	28.30	33.74			

DATA INTERPRETATION

- CCC RWGR of HSG 0.281 Kg/cap/day which is different from Assessed waste generation rate of Sanonda R/A, HSG RWGR 0.57 Kg/cap/day but average data of UMSG and MSG RWGR 0.27 Kg/cap/day almost same as CCC RWGR.
- From above analysis it is seen that CCC MSWGR is 0.42 kg/cap/day which has studied on entire Chittagong city which includes not only domestic waste but also commercial and market wastes of composition.
- Ward no. 15 is Baghmoniram ward where Kajir Dewri Kaccha Bajar, lots of academic institution and press are situated. So waste generation is higher in this ward (0.36 kg/cap/day) compared to the average city data.
- It is mentioned that assessment of our study is based on three socioeconomic level (HSG, UMSG & MSG) where as CCC also included lower income group. It is also notice that CCC MSWM composition is not similar with Sanonda R/A.

CONCLUSIONS

Solid waste generation has increased proportionately with the high density of population but support for waste management is inadequate. The purpose of this study is to analyze the existing solid waste management system in Chittagong City Corporation. Moreover, it also evaluates priorities for sector reforms as well as identification of investment projects in the aforementioned urban local bodies. HSWM refers to all activities pertaining to the control, collection, transportation, processing and disposal of waste in accordance with the best principles regarding public health, economics, engineering, conservation, aesthetics and other environmental considerations. The generation of 9 category house hold wastes are paper, packaging materials, cans, plastic, textiles, glass, vegetable, bones/dirt and wood which has 65.9% wastes is compost able & 33.74% waste is no compostable& total waste produce from this society about 400 kg/day. On the other hand the study also exposed that CCC is not fully capable to properly & regularly handling the wastes from the city without environmental interfere, so MWMS has to be integrate to disposal the solid waste with best practice.

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The authors would like to acknowledge the help of the authority of University for providing various facilities.

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ASSESSMENT OF CONTRIBUTION OF POLLUTANTS BY SEVEN SELECTED KHALS INTO THE RIVER KARNAFULLY

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ABSTRACT
The Karnafully is the biggest and important tidal river in the south eastern part of Bangladesh. During its course to the Bay of Bengal, the river receives a lot of canals, tributaries and small river, which has been played a dominant role on the hydrobiology of the Karnafully River, contributing large amount of contaminated water, solid wastes, sewage etc. At present the river is under severe pollution threat. To investigate water quality of Karnafully River, water samples were collected from 200m upstream & 200m downstream of Syed Khal to Siriar Khal in flood tide and ebb tide. Water samples were analysed for ten different water quality parameters, i.e, pH, Color, Turbidity, Hardness, TDS, DO, BOD, Salinity, Alkalinity & Iron. The highest value of Color (47 Pt-Co Unit) and BOD (3.83 mg/l) was found in GID Khal whereas the highest value of Turbidity (8.6 JTU) was found in Kada Khali Khal. The highest value of TDS (53.5 mg/l) was found in Syed Khal. The Hardness, Salinity & Iron values were in acceptable limit for drinking in all sampling locations.All parameter values are compared with Bangladesh standard for wastewater discharge to inland surface water as per ECR 1997.

Keywords: Karnafully River; pollutants; selected khals; contaminated water

INTRODUCTION
Bangladesh is a land of rivers. Around 230 rivers flow through the country including 53 international rivers. Urbanization is the main reason of pollution for these rivers and other water bodies (DoE, 2001).Several studies (DoE, 1993); (Hossain, 2001) showed that surface water quality of the rivers of the country is highly polluting day by day. Industrial wastes are known to adversely affect natural life by direct toxic action or indirectly through qualitative alterations in the character of the water as well as that of the stream bed (Ahmed, 2000). Incongruously, growing urban population is producing greater loads of urban waste, and the industries that need so much clean water are throwing out their effluents directly or indirectly into Karnafully (Majid, *et. al.*, 1999). Rahman et al. studied of the water quality of the Chittagong region, it can be concluded that the condition of the Karnafully River is critical and Halda River may be affected by the polluted Karnafully River water. Karnafully is the largest and an important river in Chittagong. Thousands of industries and factories are situated on the bank of the Karnafully River or very close to the river system and they do not have any waste treatment facilities. They discharge the untreated waste into the nearest water bodies, which finally reach into the Karnafully River through different canal systems.So the study is done to assess the pollution level of 7 different khals of karnafully river and to determine whether the water of those khals are suitable for drinking, domestic purpose, irrigation or not.

METHODOLOGY
A survey work was conducted for identifying sampling spots and the current quality conditions for a large part of the rivers, lakes and groundwater sources of the this region. For the Karnafully River, seven sampling spots at different distances from the river mouth, such as the river Kalurghat bridge (0 km), Syed khal (3.6 km), GID khal (4 km), Walong khal (5.5 km), Hodh khal (6.8 km),Vhandal jhuri khal (9.2 km),Kada khali khal (9.7 km) and Siriar khal (15.6 km) at different distances from the river mouth of the Karnafully River were selected. The Karnafully water samples were collected from 200m up stream & 200m down stream of selected khals at high and low tide according to the tide table collected from the Department of Hydrography, Chittagong Port Authority. Statistical methods of sampling were used for collecting samples. Multiple samples were collected from the same spot at

different tide conditions. The surface water samples were collected in the boat if possible in the middle of the flow. The water samples were collected within 3-9 inches from the surface of the water.

Table1: Syed khal Test report (physical/chemical analysis of surface water sample)

SL. No.	Water Quality Parameters	Unit	Concentration Present (flood tide-200 m down stream)	Concentration Present (flood tide-200 m up stream)	Concentration Present (ebb tide-200 m down stream)	Concentration Present (ebb tide-200 m up stream)
01	PH	-------	6.3	6.35	6.39	6.45
02	Color	Pt-Co	46	34	39	37
03	Turbidity	JTU	3.4	3.5	7.99	7.76
04	Iron (Ee)	mg/I	0.10	0.12	0.05	0.07
05	DO	mg/I	7.6	7.67	6.1	6.1
06	Total Hardness (as CaCo3)	mg/I	50	48	53	54
07	BOD	mg/I	3.6	3.62	3.4	3.55
08	Salinity	./..	0.04	0.04	0.03	0.02
09	TDS	mg/I	45.8	44.7	53.5	53.6
10	Temperature	˚C	25	25	25	25
11	Alkalinity	Mg/L	31.2	32	31.4	32.2

RESULTS AND DISCUSSIONS

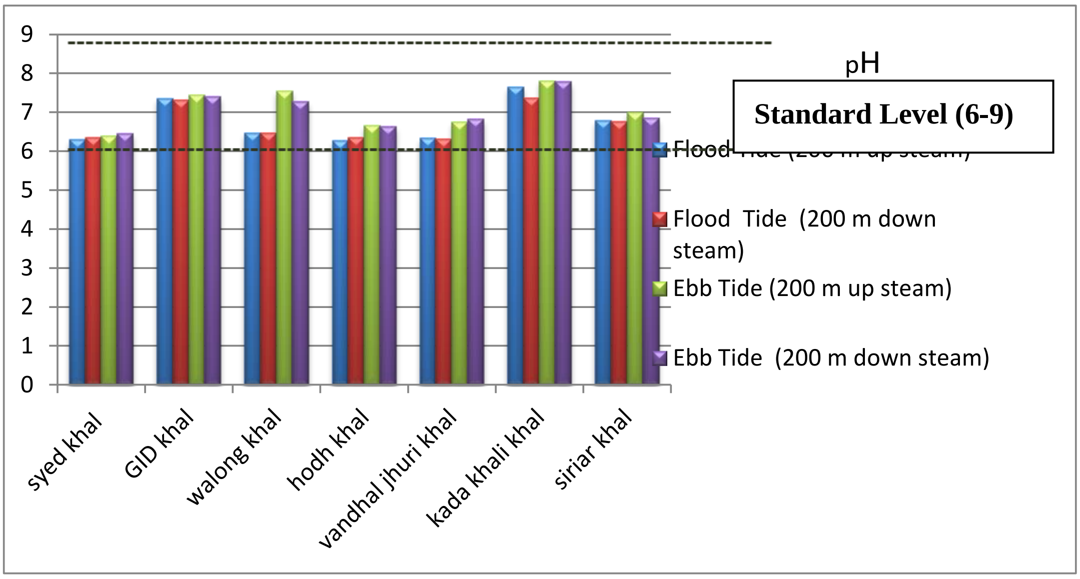

Fig. 1: pH of the Karnafully River Water

pH

According to EPA, pH for fresh water is 6.5-8.5. Most of the samples were found in the alkaline pH range i.e. within the allowable limit. The highest value (7.8) of pH was found in Kada Khali Khal

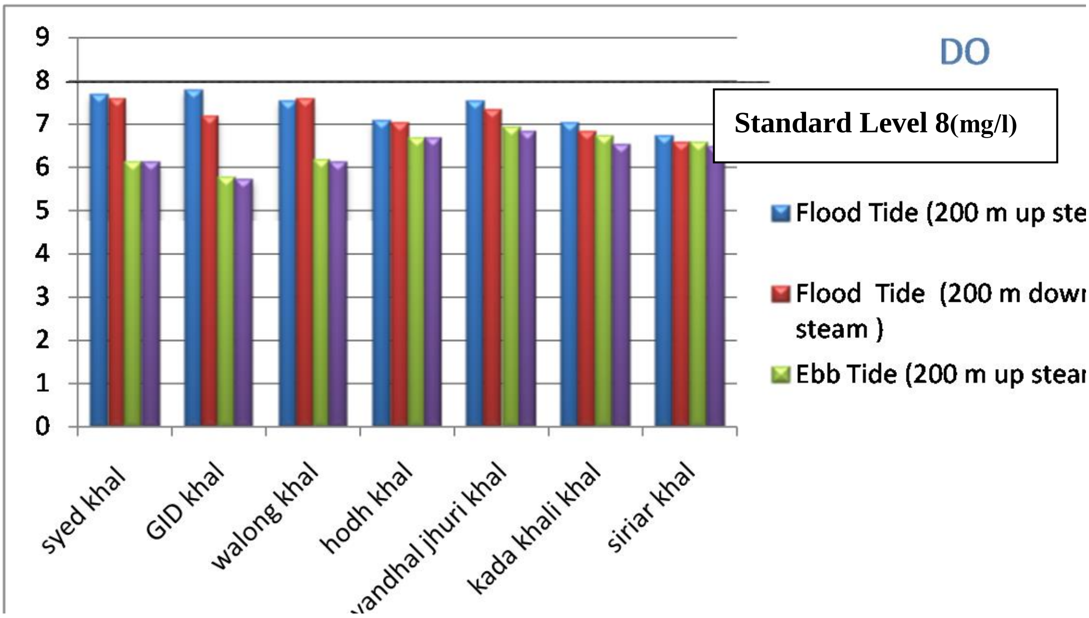

Fig. 2: Dissolved Oxygen of the Karnafuli River Water

DO

In case of dissolve oxygen, standard for sustaining aquatic life is 4 mg/l, whereas for drinking purpose it is 6 mg/l. The dissolved oxygen was higher in all khals during flood tide than ebb tide. The maximum DO (7.8 mg/l) was found in GID khal in flood tide whereas the minimum value was found in that khal in ebb tide.

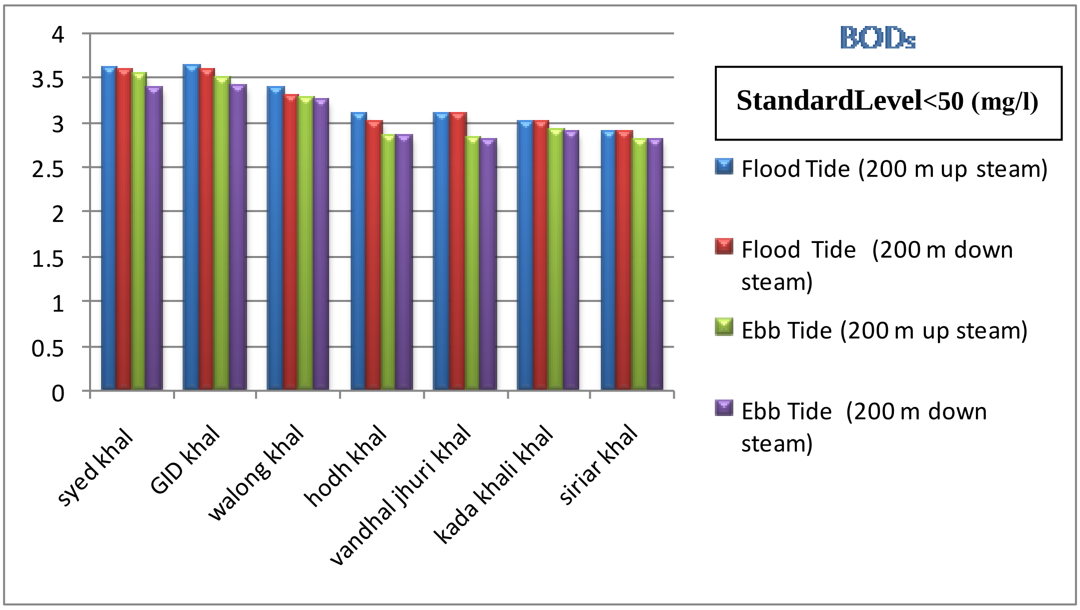

Fig. 3: BOD of the Karnafuli River water

BOD

BOD standard for inland surface water is 2 mg/l but all of samples had BOD value up to 3.63 mg/l which exceed water quality standard. The highest value was found in ebb tide at GID khal where the lowest value was found in ebb tide at Siriar Khal.

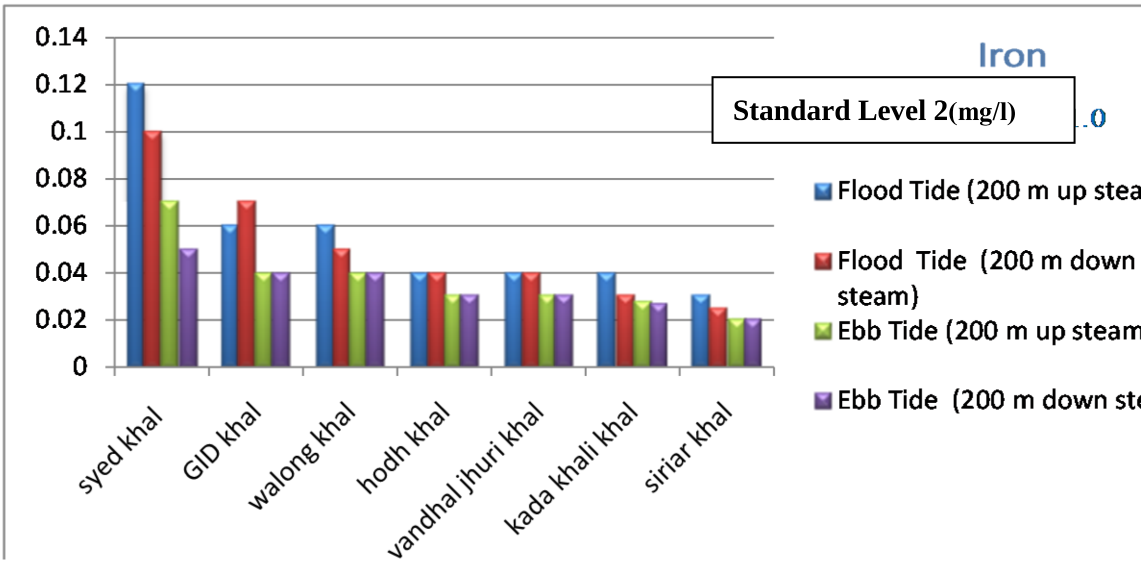

Fig. 4: Iron of the Karnafuli River water

IRON
The concentration of Iron at all sampling location was below the acceptable limit (0.3-1.0) for drinking purpose.

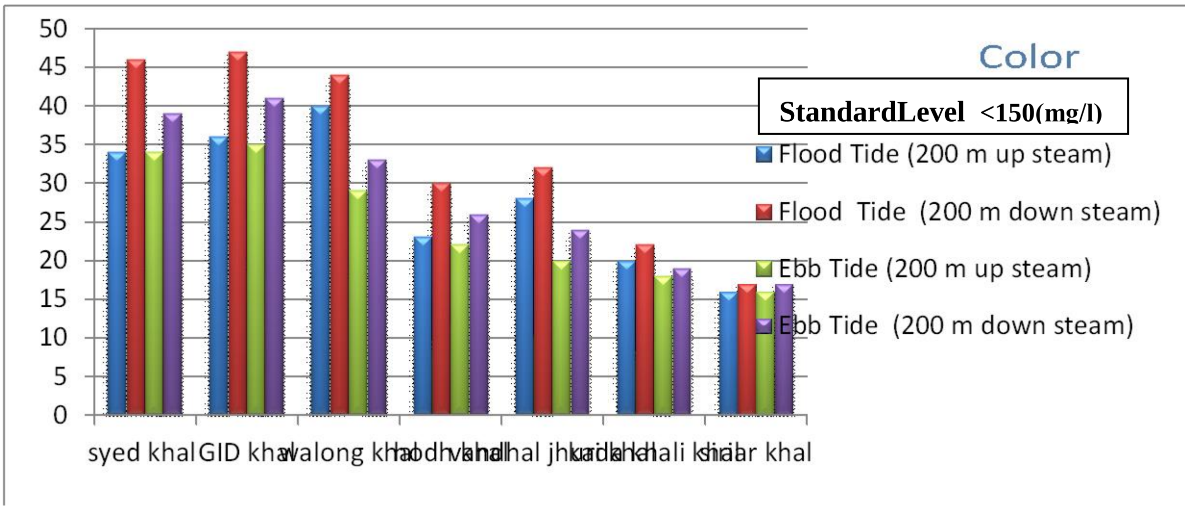

Fig. 5: Color of the Karnafully River water

COLOR
The standard value of Color is 15 Pt-co unit. Highest value (47Pt-co) was found at flood tide at Syed khal & GID khal point and lowest value (16 Pt-co) was found at flood tide also at Siriar khal point.

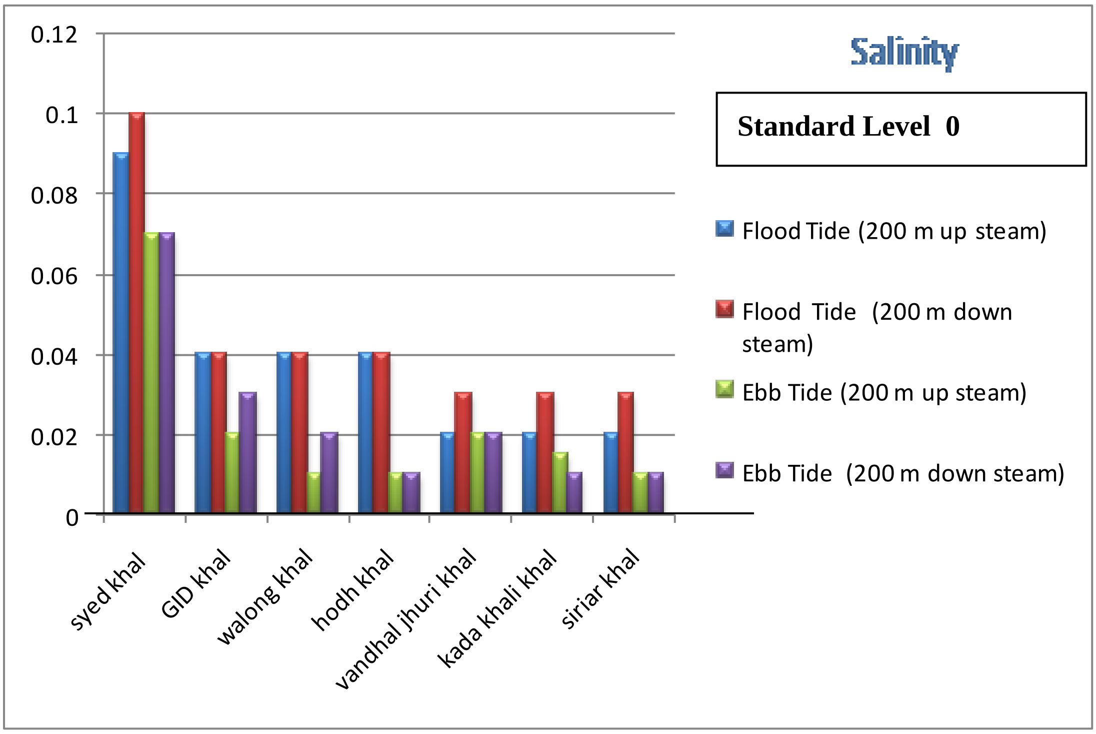

Fig. 6: Salinity of the Karnafuli River water

SALINITY

The samples have Highest value of Salinity (0.1) was found at flood tide at Syed khal karnafuli point. The lowest value (0.01) was found at Ebb tide at Siriar khal points.

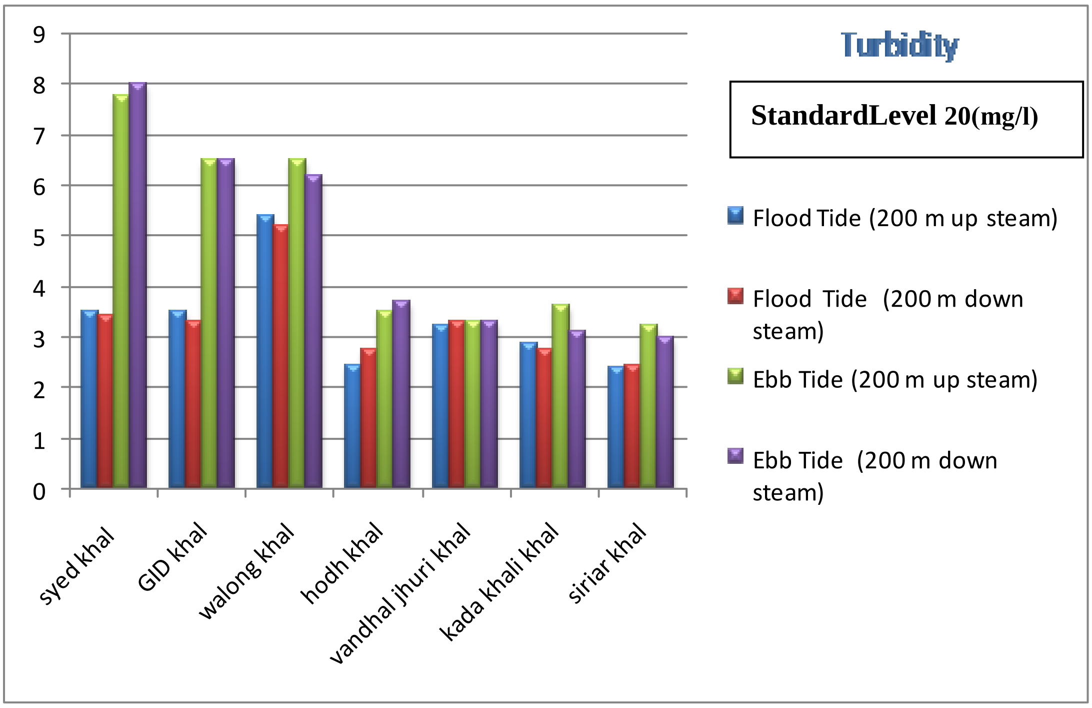

Fig. 7: Turbidity of the Karnafully River water

TURBIDITY

Highest Turbidity value (7.99 JTU) was found at ebb tide at Syed khal karnafully points. The lowest value (1.48 JTU) was found at flood tide at Siriar khal karnafully points.

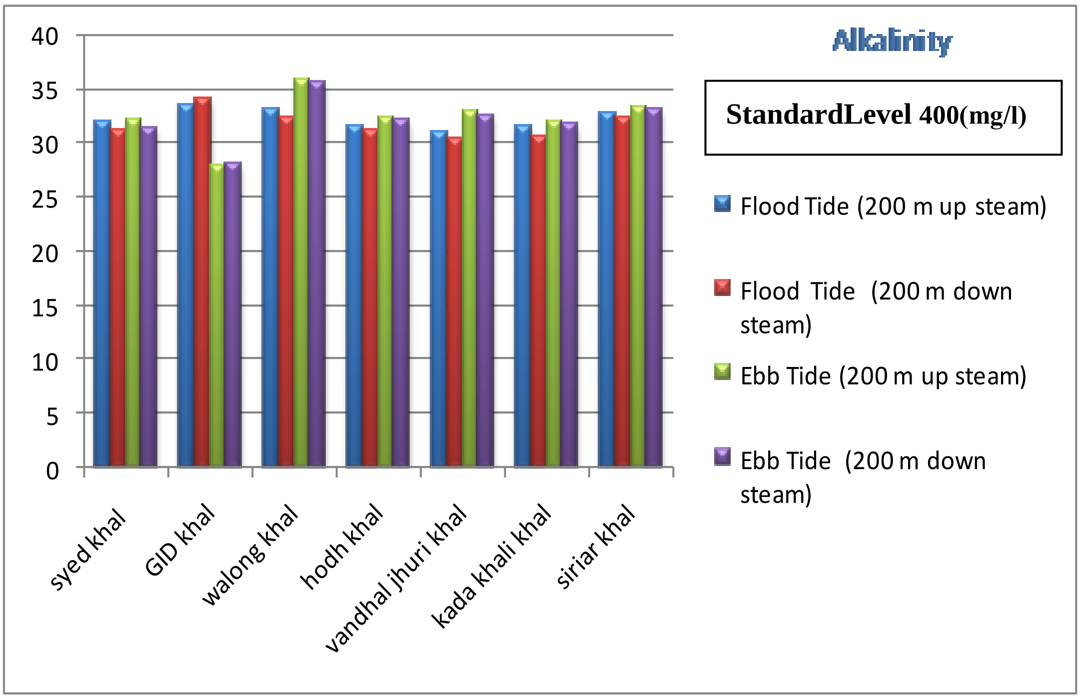

Fig. 8: Total Alkalinity of the Karnafully River water

Alkalinity

Highest Alkalinity value (35.85 Mg/L) was found at ebb tide at Walong khal points. The lowest value (28 Mg/L) was found at ebb tide at GID khal points.

CONCLUSIONS

The present study represent the water quality of seven canals such as syed khal to siriar khal which are situated after kaloorghat bridge and there are no industries at or near those canals. For this reason water quality of selected locations may be not so critical such as dissolved oxygen of all selected locations were above 6 mg/l and BOD value also lies between 3 to 4 mg/l. The color of all stations were above standard limit but the salinity & iron of water samples were negligible. So it can be concluded that the water is certainly unfit for drinking purposes without any form of treatment, but for various other surface water usage purposes like fisheries or irrigation purposes, it still could be considered quite acceptable.

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TREATMENT OF CONTAMINATED WATER WITH FILTRATION AND UV DISINFECTION

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ABSTRACT
Disinfection is a challenge in small water supply systems (e.g., rainwater harvesting, pond water), as often a family or small communities do not have necessary facilities to disinfect water properly. Also many commercially available household-level treatment systems are not very effective in removing pathogens. Thus the main objective of the present study was to evaluate the effectiveness of different filtration system (consisting of sand, gravel and activated carbon) and UV disinfection in removing fecal coliform (FC) from contaminated surface water. Effectiveness of filtration columns (147.32cm length) consisting of sand and activated carbon in removing FC was evaluated. A range of laboratory experiments have been carried out in a large tank (152 cm ×48 cm x48 cm) for UV disinfection. The effects of important operational and water quality parameters were assessed for filtration and UV disinfection. UV disinfection could significantly reduce microbial (FC) contamination from highly polluted surface water. The effectiveness of UV disinfection has been found to depend on a number of operational factors including intensity of lamp, exposure time, and distance from the lamp.

Keywords: Filtration; fecal coliform; UV disinfection

INTRODUCTION
In Bangladesh surface water (e.g., pond/river water) and rainwater are important sources of potable water, particularly in areas suffering from arsenic contamination of groundwater and high salinity. However, surface water suffers from high microbial contamination and needs disinfection for potable use. Water from surface water sources (e.g. ponds, lakes, rivers etc.) is often used for drinking purpose through use of pond sand filtration (PSF); however, such systems have not been very successful due to problems related to operation and maintenance **(**BGS and DPHE, 2001; BBS and Unicef, 2015; Hug et al., 2011). The main problem related to use of ponds and rivers for potable water supply is widespread fecal/microbial contamination of these water sources (ITN-BUET, 2015). Recent research works also suggest that many commercially available household-level treatment systems are not very effective in removing coliform bacteria (FC). Thus an effective and low-cost disinfection system that could be implemented in rural areas could significantly improve access to safe potable water in many areas of Bangladesh. The overall objective of the research was to assess the effectiveness of filtration by varying different parameters such as: (i) filter media; (ii) flow rate, and (iii) initial level of contamination (FC) on disinfection efficiency. The performance of UV disinfection has been assessed under different operational (e.g., UV lamp intensity, exposure time) conditions.

METHODOLOGY
Filtration System
Filtration experiments have been conducted in a cylindrical filtration column, 147.32cm in length and 7.62cm in diameter. Two different filter media were used: (1) 30.48cm gravel layer followed by 30.48cm coarse sand layer, and finally 30.48cm of fine sand layer; (2) the above layers with additional 15.24cm layer of activated carbon at the bottom.

UV Disinfection

The experiments for UV disinfection have been carried out in a large acrylic glass tank, 152cm in length, 48 cm width and 48 cm in height. The capacity of the tank is about 355 liters. The tank was fitted with a port for UV lamp at one end, and four sampling ports 30.5 cm away from each other. UV lamps of 6W to 16W intensities were employed in this study. Water from a pond that receive domestic sewage discharge, and amended water (e.g., groundwater amended with polluted water containing microorganisms) were used as raw water in the disinfection experiments. For each set of experiment, the raw water was analyzed for a range of parameters including fecal coliform (FC). Initial FC was varied (by dilution with groundwater) in the disinfection experiments in order to assess its impact on disinfection.

Fig. 1: Filtration system

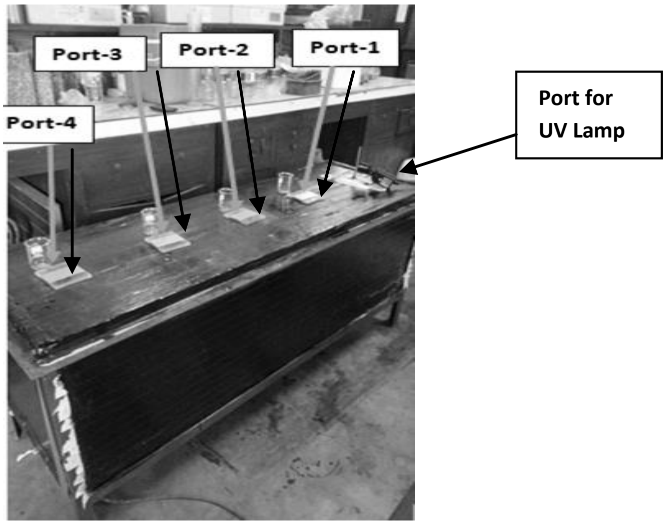

Fig. 2: Experimental set up for UV disinfection

RESULTS AND DISCUSSIONS

Removal of FC by Filtration

The important factors affecting the effectiveness of filtration include: (1) Filter media gradation, (2) Properties of filter media, (3) Inflow Rate, (4) Infiltration Rate, (5) Initial FC concentration, etc. Several experiments were conducted with this filtration system with different initial FC and flow rate. Table 1 shows some of the results of the filtration experiments. It shows that the filter media, with or without activated carbon, have not been very efficient in removing FC from contaminated water.

TABLE 1: REMOVAL OF FC FROM CONTAMINATED WATER IN FILTER COLUMNS

Filter Media	Flow Rate (ml/min)	FC (cfu/100ml)		Efficiency (%)
		Initial	After filtration	
Gravel, Coarse Sand, Find Sand	73	77	25	67.5
Gravel, Coarse Sand, Find Sand	61	85	64	24.7
Gravel, Coarse Sand, Find Sand, Activated Carbon	65	1120	312	72.1

UV Disinfection

Effects of Initial FC Concentration

Table 2 shows the effect of initial FC concentration on disinfection efficiency with a 16W lamp. From an initial concentration of 8000 cfu/100 ml, FC concentration was reduced to 50 cfu/100 ml in Port 1 in 10 minutes; whereas for an initial FC concentration of 9000 cfu/100 ml, the corresponding value is 230 cfu/100 ml. Thus, higher initial FC concentration would reduce disinfection efficiency significantly.

TABLE 2: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY AS A FUNCTION OF EXPOSURE TIME FOR SAMPLES COLLECTED FROM PORT 1 IN DISINFECTION EXPERIMENTS CARRIED OUT WITH 16W LAMP, FOR WATER SAMPLES WITH TWO DIFFERENT INITIAL FC CONCENTRATION (8000 AND 9000 CFU/100ML)

Time of Exposure	Residual FC (cfu/100mL)		Efficiency (%)	
Raw/0 Min	8,000	9,000	0	0
10 Min	50	230	99.4	97.4
20 Min	30	150	99.6	98.3
30 Min	22	56	99.7	99.4
40 Min	12	16	99.9	99.8

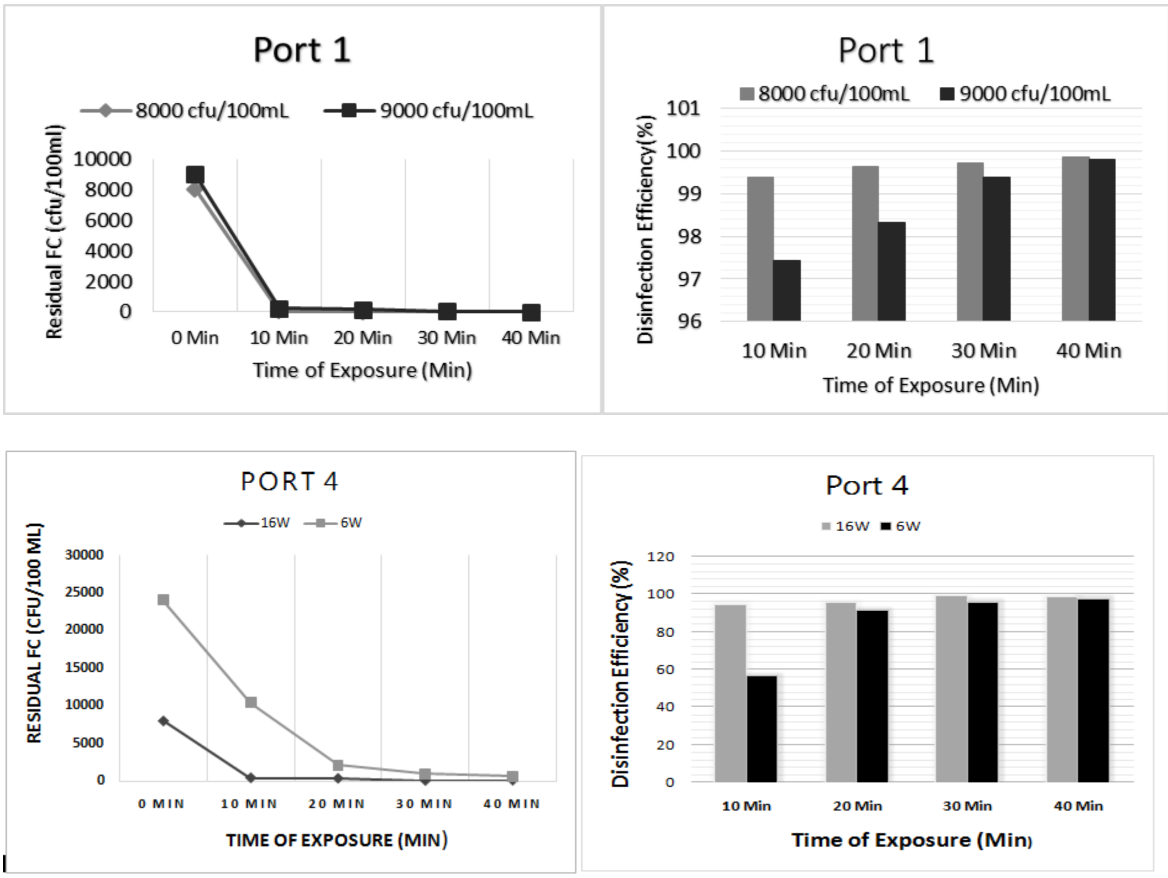

Fig. 3: Effect of Initial FC Concentration at Port 1 and Port 4 for different time exposure with 16W UV lamp

Effects of UV Lamp Intensity on Disinfection

In order to evaluate the effects of UV lamp intensity on disinfection efficiency, a number of experiments were carried out with 6W and 16W UV lamps. Table 3 and Table 4 show the residual FC concentration and disinfection efficiency for water samples collected from Port 1 and Port 4, respectively at different exposure times. Fig. 4 and Fig. 5 graphically show the residual FC concentrations for Port 1 and Port 4, respectively. It should be noted that among the sampling ports identified, Port 1 receives the highest UV intensity, while Port 4 receives the least; thus these two ports are of highest interest. The figures and tables show that disinfection efficiency depends on UV lamp intensity, and higher intensity UV lamp could achieve higher removal efficiency.

TABLE 3: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY FOR WATER SAMPLES COLLECTED AT DIFFERENT EXPOSURE TIMES FROM PORT 1 OF WATER TANK FITTED WITH 6W AND 16W UV LAMP

Exposure Time	FC (cfu/100 mL)		Disinfection Efficiency (%)	
	6W	16W	6W	16W
Raw/0 Min	24000	8000	--	--
10 Min	600	50	97.5	99.4
20 Min	500	30	97.9	99.6
30 Min	320	22	98.7	99.7
40 Min	120	12	99.5	99.9

TABLE 4: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY FOR WATER SAMPLES COLLECTED AT DIFFERENT EXPOSURE TIMES FROM PORT 4 OF WATER TANK FITTED WITH 6W AND 16W UV LAMP

Exposure Time	FC (cfu/100 mL)		Disinfection Efficiency (%)	
	6W	16W	6W	16W
Raw/0 Min	24000	8000	--	--
10 Min	1760	300	92.7	96.3
20 Min	1280	270	94.7	96.6
30 Min	450	185	98.1	97.7
40 Min	350	84	98.5	99.0

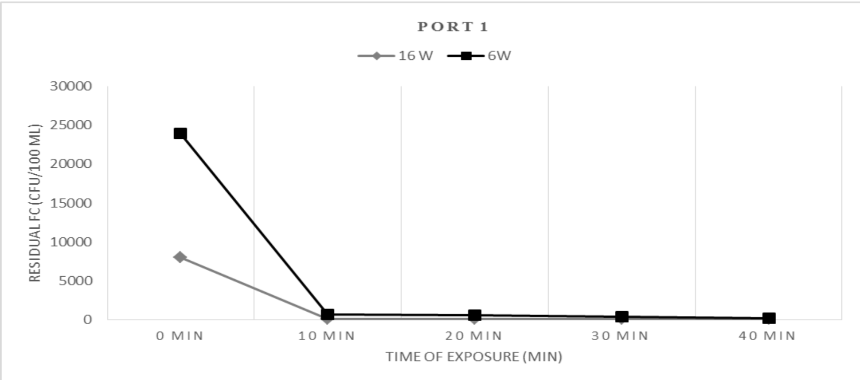

Fig. 4: Residual FC concentration in water samples collected from Port 1 at different exposure times, with 6W and 16W UV lamps

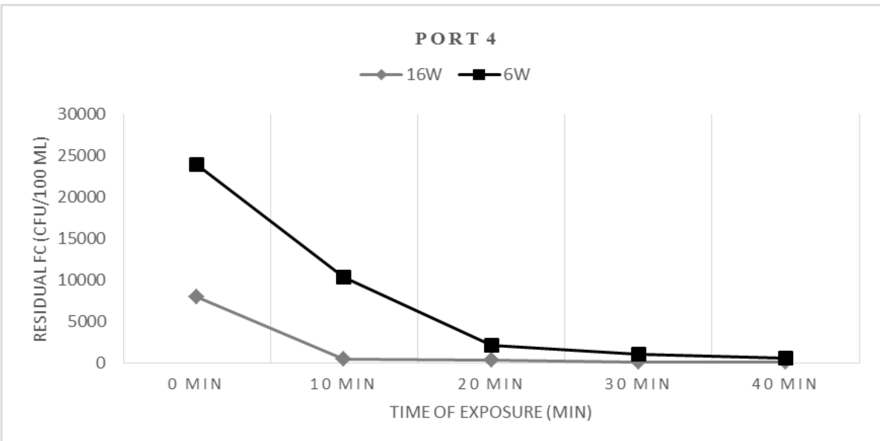

Fig. 5: Residual FC concentration in water samples collected from Port 4 at different exposure times, with 6W and 16W UV lamps

Effect of Exposure Time

Higher exposure to UV radiation would yield higher disinfection efficiency. However, higher exposure means higher power consumption and lower lamp-life, and therefore it is important to estimate the optimum exposure time for a particular condition of UV irradiation and water quality (Das, 2001; Zimmer and Slawson, 2002). Table 5 and Table 6 show that exposure time has a clear effect on disinfection efficiency; higher the exposure time, the better is the disinfection efficiency (Fig. 6 and Fig. 7). However, as discussed earlier, the effect of exposure time is also a strong function of the position of the sampling port with respect to the lamp; Port 1 would require less exposure time of UV radiation compared to Port 4 for achieving the disinfection efficiency.

TABLE 5: RESIDUAL FC CONCENTRATION OF WATER SAMPLES (INITIAL FC: 8000 CFU/100ML) COLLECTED AT DIFFERENT EXPOSURE TIME FROM THE WATER TANK FITTED WITH 16W UV LAMP

Time of Exposure	Residual FC (cfu/100 mL)			
	Port 1	Port 2	Port 3	Port 4
Raw/0 Min	8000	8000	8000	8000
10 Min	50	250	300	420
20 Min	30	160	270	350
30 Min	22	120	155	200
40 Min	12	20	84	96

TABLE 6: RESIDUAL FC CONCENTRATION OF WATER SAMPLES (INITIAL FC: 9000 CFU/100ML) COLLECTED AT DIFFERENT EXPOSURE TIME FROM THE WATER TANK FITTED WITH 16W UV LAMP

Time of Exposure	Residual FC (cfu/100 mL)			
	Port 1	Port 2	Port 3	Port 4
Raw/0 Min	9000	9000	9000	9000
10 Min	230	400	460	840
20 Min	150	280	350	450
30 Min	56	150	180	230
40 Min	16	60	85	120

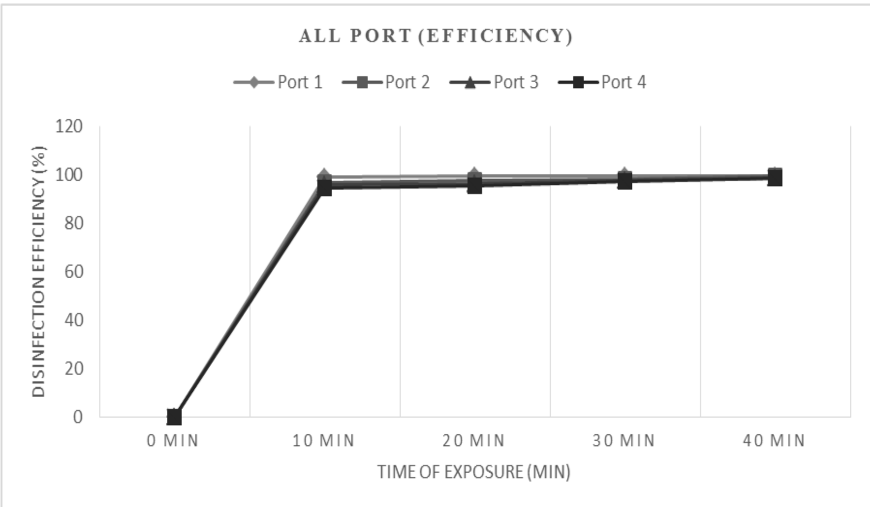

Fig. 6: Effect of exposure time on UV disinfection efficiency of water samples (Initial FC: 8000cfu/100mL) for experiment carried out with 16W UV lamp

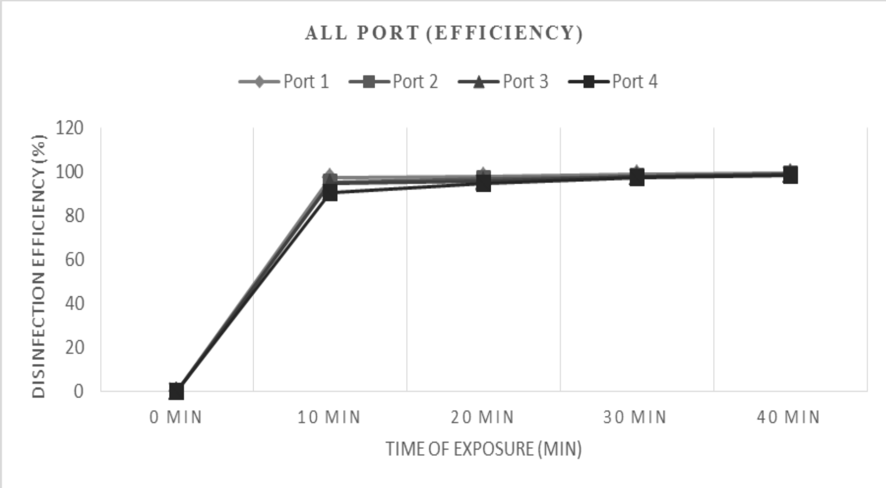

Fig. 7: Effect of exposure time on UV disinfection efficiency of water samples (Initial FC: 9000cfu/100mL) for experiment carried out with 16W UV lamp

CONCLUSIONS

Although FC concentration could not be reduced to zero (which is the national drinking water standard) with UV lamp under the experimental condition used in this study, the results suggest that this could be achieved with appropriate combination of lamp intensity, exposure time and tank dimension for UV disinfection system. Filtration with commonly available filter media (sand, gravel, activated carbon) does not appear to be suitable for removal of FC from water. UV disinfection could potentially be used for treatment of surface (pond/river) water in water scarce areas (e.g., arsenic-affected or salinity-prone areas).

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POTENTIALITY OF POND WATER AS ALTERNATIVE SOURCE

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ABSTRACT
This study has taken an attempt to analyse the quality of ponds water in Rajshahi City. Fourteen water quality parameters were analysed for water samples collected from thirty different ponds from thirty wards. The quality of water has extremely failed to satisfy the drinking standard for suspended solids, turbidity, pH, conductivity, dissolved oxygen, organic matter, BOD_5, COD, total cloiform and also faecal coliform. It is evident from the study that the pond water of Rajshahi City is found to be severely polluted. So pond water cannot be used as a source of drinking purposes without treatment. The pond must be protected from contamination to use as alternative source for domestic use.

Keywords: Pond water; alternative source; domestic use; polluted; treatment

INTRODUCTION

Water is one of the important natural resources useful for developmental purposes in both urban and rural areas. Despite this, most of the rural communities in the developing countries, especially Bangladesh, lack access to portable water supply. They rely commonly on rivers, streams, wells, and ponds for daily water needs (Nevondo and Cloete, 1991). However, World Health Organization (WHO, 2011) mentioned that water from most of these sources is contaminated, yet they are used directly by the inhabitants.

Agricultural wastes such as pesticides, fungicides and fertilizers, human and animal feces, seepage from pit latrines and septic tanks, refuse dump, industrial, domestic and municipal wastes released into water bodies are often responsible for surface water contamination. Contaminated water is associated with health risks. The diseases associated with most surface water supplies include Campbacteriosis, Shigellosis, Salmollosis, Cholera, Dysentery, Typhoid, Diarrhea and a varieties of other bacteria as well as fungi, viral, and parasitic infection (Grabow, 1996).

It is ancient practice of Rajshahi city duelers to use pond water for their, bathing, washing of cloths, utensils and cattle and even cooking. However, pond is being polluted day by day through various ways. Toxic element and harmful germs may present in the surface water body of the city. All most all minor surface drains are linked with pond in any way and septic tanks are connected with these minor surface drains. Beside these, there are 149 industries in the BSIC industrial area of Rajshahi City (Alexandra, et al. 2006) from which, waste discharges into the surface water. As a result, all the sources of surface water are being polluted by the released wastes. In addition to that insecticides, chemical fertilizers, cow dung etc. are being used for fish cultivation that also increases the pollution level of surface water of the study area. However, water supply coverage is not satisfactory in Rajshahi city (Bari, et. Al, 2005). As a consequence, searching for alternative source is becoming a prime necessity.

Clean, safe and adequate freshwater is vital to the survival of all the living organisms and the smooth functioning of ecosystems, communities and economics. It might not be possible to make the water pollution free by overnight but it is possible to define different sources for different uses with proper treatment if necessary. The water of the study area might not equally polluted by the all contaminants. Pollution level might vary from place to place, time to time and season to season. Some are suitable for drinking, water from some sources are suitable for household works and some are so polluted that even cannot touch. The easiest solution to make the inhabitants free from diseases by making them known which water should be used for what purposes. Therefore, the aim of this study is to determine the scope of using the existing pond water through the determination of their water qualities as an alternative source of groundwater to reduce the pressure on it.

METHODOLOGY

The study is conducted following sequential standard procedure of selection of ponds, collection of water sample from sources and experimental analysis of water quality parameters. The surrounding physical conditions such as connection with surface drain, domestic wastes disposal, fish culture, etc. of the ponds were also observed.

Selection of Ponds

Total 30 ponds were selected taking one from each ward of Rajshahi City Corporation area. The pond which is larger and frequently used for bathing, washing and other purposes by the people was selected. The selected pond from 30 wards are Horogram Munshiparara pukur, Horogram Notunparar pukur, Bohorompur Pukur, Bulonpur pukur, Mohishbathan pukur, Baganpara pukur, Vatapara pukur, Kajihata pukur, Shahmakhdum dargah pukur, Medical Campus pukur, Methorparar pukur, Fudkipara pukur, Gorhanga pukur, Terokhadia College pukur, Boro pukur, Koyerdara pukur, Postal Academy pukur, Asham Colony pukur, Nol pukur, Sultanabad pukur, Shagorpara pukur (1); Shagorpara pukur (2); Ramchandrapur State Waqof pukur, Ramchandrapur pukur, Raninagar pukur, Meherchhondi Gojari pukur, Shiroil Moth pukur, Dharampur pukur, Dashmari pukur, Iblish Chottor pukur, respectively.

Sample Collection and Storage

The water samples were collected following standard procedure in well washed PET bottles with screw cap to make sure that it is completely free from any undesirable materials. Three samples are collected from each pond. The collected samples are stored in refrigerator for carrying out the analysis at suitable time in the laboratory.

Experimental Procedure

The water quality parameters such as TDS, TSS, TS, pH, DO, Conductivity, Turbidity, Colour, Chloride, Alkalinity, BOD_5, COD, and Organic matter were analyzed. Total Solids (TS), Total Dissolved Solids (TDS) and Suspended Solids (SS) are determined according to APHA 2540B (2005), APHA 2540C (2005) and APHA 2540D (2005), respectively. Conductivity, Dissolve Oxygen (DO) concentration and pH were measured with HACH instrument (APHA 2510, 2005). Turbidity was measured with Turbidity Meter and Colour was measured with Colour disk and Hatch colour kit. The amount of chloride present in water was determined by titrating the given water sample with silver nitrate solution (APHA 4500-Cl^-B, 2005). The alkalinity of water was determined by titrating the water sample with Sulphuric acid of known values of pH, volume and concentrations according to APHA 2320 (2005). The Biochemical Oxygen Demand (BOD_5) and the Chemical Oxygen Demand (COD) were determined as described in APHA 5210B (2005) and APHA 5220C (2005), respectively. The content of organic matter was determined by heat and loss method.

RESULTS AND DISCUSSIONS

Ninety water samples from 30 selected ponds were tested for 14 water quality parameters in the laboratory. The average results of all parameters of selected 30 ponds waster are presented in Fig. 1 to 4.

Total Dissolved Solids

Total dissolved solids (TDS) are the measure of presence of mineral impurities which may indicate the salinity behaviour of water. Water containing more than 1000 mg/l of TDS is not considered desirable for drinking as per Bangladesh and WHO standard. It is found from the experiment that the total dissolved solids are varying from 221.3 mg/l to 782.7 mg/l which is within the acceptable limit. However, total dissolved solids for 19 ponds are above the 500 mg/l out of 30 ponds and in eight ponds it is within 70% to 80% of allowable limit which is alarming for the users. This higher level of TDS is due to washing of cloths by detergent, putting chemical fertilizer for fish culture and minerals coming from the household through drainage connection.

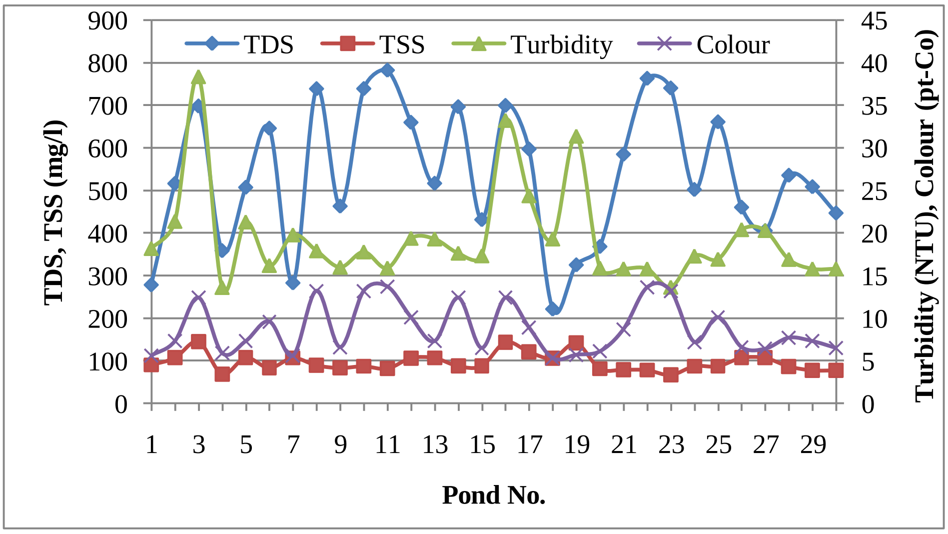

Fig. 1: Concentration of TDS, TSS, Turbidity and Colour of water of 30 ponds in Rajshahi city

Suspended solids

Suspended solids can cause the turbidity of water which indicates the presence of impurities and contaminants. The higher level of suspended solid can cause the aesthetic problem of the users. Therefore, suspended solid should be below the 10 mg/l according to Bangladesh standard for drinking purpose. The results show that the suspended solid in pond water varies from 66.3 mg/l to 144.6 mg/l which is extremely very high. The causes of high suspended solid in all ponds water is due to the throwing of household wastes, drainage connection, fish culture and so one.

Turbidity

Turbidity is a measure of light transmission and indicates the presence of suspended material such as clay, silt, finely divided organic material, plankton and other inorganic material. Higher turbidity indicates the presence of possible bacterial contamination. According to WHO guideline, turbidity in excess of 5 NTU (Bangladesh standard is 10 NTU) is usually objectionable for aesthetic reasons. In case of freshwater lakes and ponds, due to contamination and algal growth the turbidity of these water increases to very high levels. The experimental results show that the turbidity is varying from 13.6 to 38.4 NTU among the 30 pond water. It means that water quality in all ponds in Rajshahi city excessively exceeds the WHO as well as Bangladesh standard and not safe for drinking purpose.

Colour

Coloured water is not always harmful to man, but in most cases even if the water is not harmful people for aesthetic reasons do not prefer it. So it is important to limit the colour of water for domestic supplies. According to Bangladesh Environment Conservation Rules (1997) and WHO guideline the drinking water standard for colour is 15 pt-Co units. The experiment shows that the colour for the pond water in the study area is varying from 5.3 to 13.7 pt-Co units. Though the colour is within the allowable limit but in some ponds' water the colour is closer to the limiting value. The cause of colour is usually due to presence of dissolved and suspended impurities in water. Therefore, care should be taken to reduce the dissolved and suspended solids.

pH

The pH values of 30 ponds water were measured to be of 8.01 to 8.89 which means the water are of alkaline in nature. However, the allowable limit is varying from 6.5 to 8.5 as per WHO and Bangladesh standard. The pH values of pond water from ward no. 8, 12 and 13 have exceeded the allowable limit and 7 and 26 are at the limiting value of 8.5.

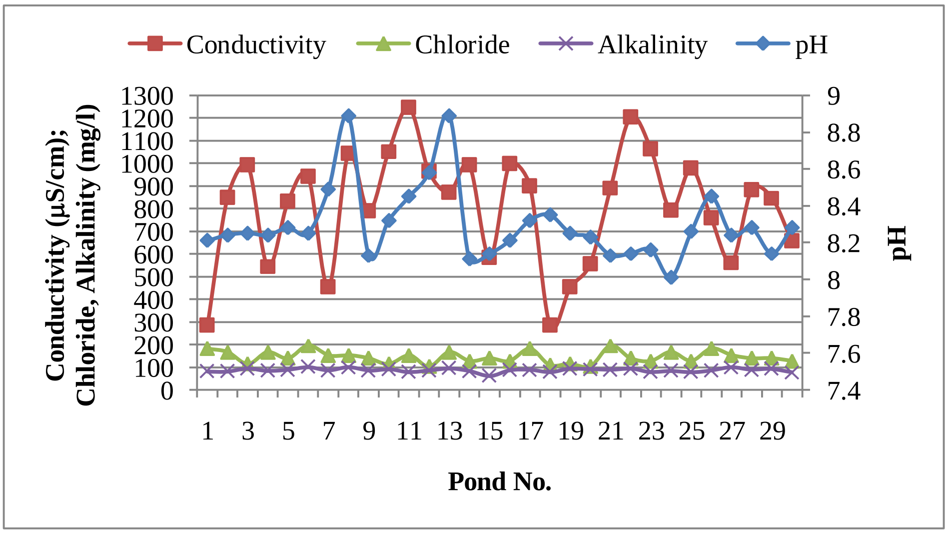

Fig. 2: Concentration of conductivity, chloride, alkalinity and pH of water of 30 ponds in Rajshahi city

Electric conductivity

The electric conductivity value gives a rapid and inexpensive way of determining the ionic strength of a solution. This is an easy measurement to make and relates closely to the total dissolved solids content of water. The total dissolved solids are about seventy percent of the conductivity. In the ground water, the ionisable salts are lesser and thereby the conductivity is also lesser in nature. Water having more number of ionisable salts for example sea water, is having high conductivity. The fresh water bodies only have a minimum amount of salts and have moderate conductivity. The conductivity of distilled water should be of 0.5 µS/cm and the water having conductivity within the ranges of 500 to 800 µS/cm can be used for drinking and domestic purposes. The experimental results show that the conductivity of pond water varies from 285 to 1246 µS/cm. Furthermore, it is found that more 50% pond water exceeds the maximum limit of conductivity. However, water can be used as potable water up to the conductivity limit of 1055 µS/cm (WHO, 2011).

Chloride content

The high concentrations of chloride ions may aide the corrosion of plumbing system. Very high chloride content of water may also produce laxative effect. An upper limit of 250 mg/l has been set by WHO for the chloride ions but Bangladesh has set a wide ranges varying from 150 to 600 mg/l. An increase in the normal chloride content of water may indicate possible pollution from human sewage, animal manure or industrial wastes. From the graph it is shown that the chloride of all the samples is less than 250 mg/l. So it is within the WHO and Bangladesh standard. This water can be used for any purpose if other parameters satisfy the standard.

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. The predominant chemical system present in natural waters is one where carbonates, bicarbonates and hydroxides are present. Water may have a low alkalinity rating but a relatively high pH or vice versa, so alkalinity alone is not of major importance as a measure of water quality. Alkalinity is not considered detrimental to humans but is generally associated with high pH values, hardness and excess dissolved solids. High alkalinity waters may also have a distinctly flat, unpleasant taste. For the pleasant taste of water, alkalinity should not exceed 200 mg/l for potable water. For the fresh water alkalinity ranges between 20 to 100 mg/l. For drinking purpose the standard desirable limit of alkalinity in potable water is 120 mg/l (WHO, 2011). It is found that the value of Alkanity of pond water of Rajshahi lies within the acceptable limit in drinking water and varying is from 60 mg/l to 100 mg/l.

Dissolved oxygen

Higher value of dissolved oxygen indicates the presence of less organic matter. On the other hand, lower value of dissolved oxygen means the presence of high content of organic substances and continual degradation of it by the microbial action. Lower DO concentration also indicates the presence of high number of microorganisms. For drinking purpose the standard DO value must be 6 mg/l or above as per both Bangladesh and WHO standards. However, the DO value must be 5 mg/l or above for other purposes like irrigation, fisheries, recreational activities. From the experiment it is found that the DO concentration is very low of the ponds in Rajshahi city compared to the standard value. It is varying from 2.5 to 4.9 mg/l. This lower dissolved oxygen might be due to the degradation of household wastes which thrown in the ponds.

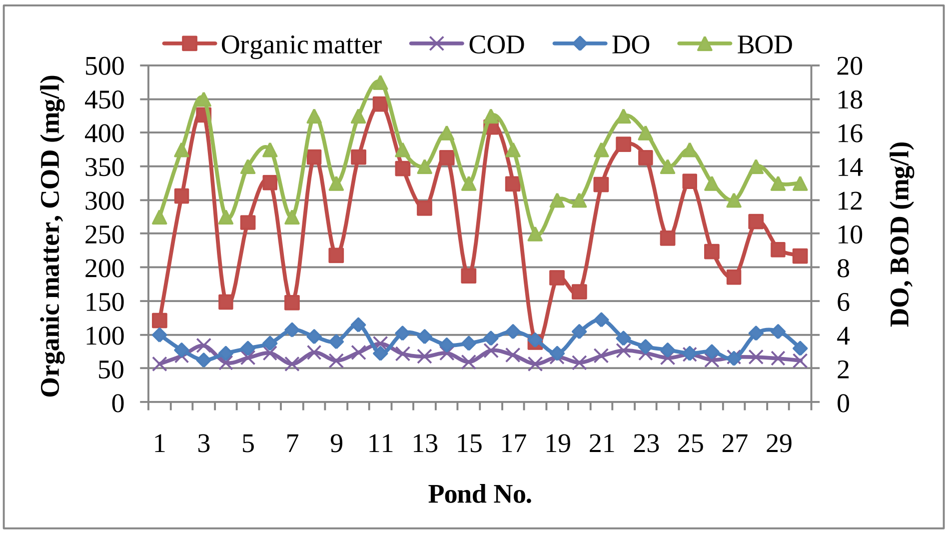

Fig. 3: Concentration organic matter, OD, BOD and COD of water of 30 ponds in Rajshahi city

Organic matters

Organic matters pollute the water. The presence of organic matter in the concentration of more than 500 mg/l, the water is considered as polluted water. If the concentration of organic matter is within 50 mg/l to 500 mg/l then it can be used for other purpose like aquaculture, recreational and irrigational purposes. The allowable level of organic matter for drinking water is less than 50 mg/l. The ponds water of Rajshahi city contain organic matter varying from 89 mg/l to 443 mg/l. Therefore, the water cannot be considered as polluted but cannot be used for drinking purpose without necessary treatment.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) detects only the destructible proportion of organic substances and as a general principle is therefore lower than the COD value, which also includes inorganic materials and those materials which cannot be biologically, oxidized. Ordinary domestic sewage may have a BOD of 200 mg/l. Any effluent to be discharged into natural bodies of water should have BOD less than 30 mg/l. This is important parameter to assess the pollution of surface waters and ground waters where contamination occurred due to disposal of domestic and industrial effluents. Drinking water usually has a BOD of less than 1 mg/l. But, when BOD value reaches 5 mg/l, the water is doubtful in purity (WHO, 2011). The BOD of pond water of the study area is ranges from 10 mg/l to 19 mg/l which is very high compared to the acceptable limit for drinking purpose by WHO. The results indicate that the water of the ponds are containing impurities and cannot be used for drinking without treatment. However, this water can be used for irrigational.

Chemical Oxygen Demand (COD)

For domestic and some industrial wastewater COD is about 2.5 times BOD. The ratio of BOD to COD is useful to assess the amenability of waste for biological treatment. Ratio of BOD to COD greater than or equal to 0.8 indicates that water highly polluted and amenable to the biological treatment. The standard value of COD by WHO (WHO, 2011) and Bangladesh standard is 4 mg/L (GoB, 1997). The COD of pond water in the Rajshahi city is also higher than the acceptable limit as BOD which is ranging from 57 mg/L to 87 mg/L. This high content of BOD and COD is due to the addition of household organic and inorganic wastes, drainage effluent, fish feed, detergent, etc.

Coliform

Single number of faecal coliform or total coliform is not allowed for drinking water. Total coliform and faecal coliform in pond water are found from 131 CFU/100 ml to 362 CFU/100 ml and 77 CFU/100 ml to 244 CFU/100 ml, respectively. The results depicted that the water of these selected ponds are highly polluted with disease producing bacteria.

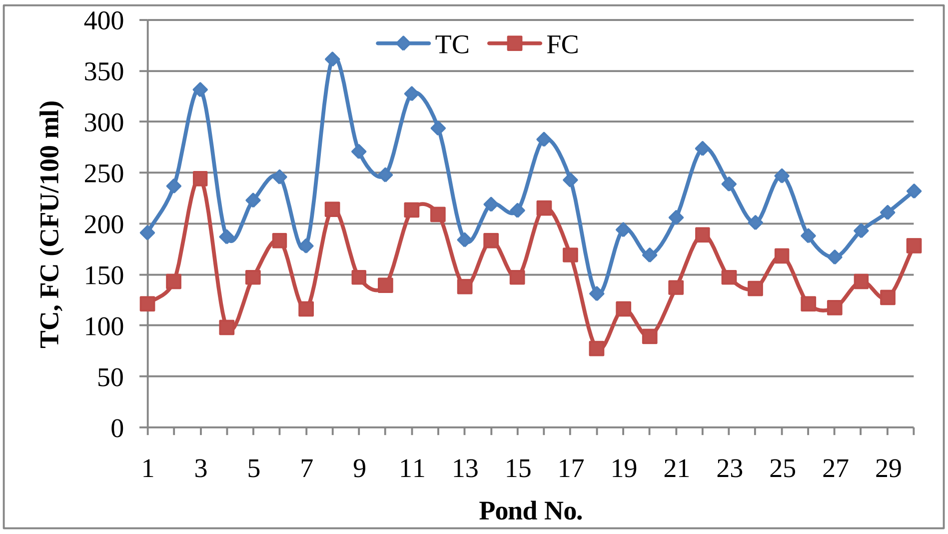

Fig. 4: Bacteriological quality of water of 30 ponds in Rajshahi city

CONCLUSIONS

It can be concluded from the study based on the experimental results that the water of all the ponds are highly polluted and not safe for using in drinking purpose and even for domestic use. The worst quality of water is found in Methorparar pukur under ward no. 11 and on the other hand, relatively less polluted water quality is found in Asham Colony pukur under ward no. 18. The ponds must be protected from wastewater discharge through the drainage connection, household wastes throwing, cattle washing and addition of fertilizer to use the pond water as an alternative source of domestic water supply. At the present situation, the pond water is not safe for even bathing, washing of utensils, washing of cloths, etc.

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EVALUATING THE EFFECTS OF DISSOLVED ORGANIC CARBON (DOC) AND pH ON POSSIBLE TRIHALOMETHANE (THM) FORMATION IN TEXTILE LIQIUD EFFLUENTS AFTER TREATING WITH CHLORINE

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ABSTRACT
The chlorination leads to the formation of disinfection by products. Any process that uses chlorine gas directly or chlorine liberating chemicals or where chlorine is produced in the process, formation of chloro-organo compounds is a real possibility if alkanes, alkenes etc. are available. The trihalomethanes (THMs) and haloacetic acids (HAAs) are the two most prevalent classes of disinfection byproducts. Chlorine reacts with natural organic matter (NOM) to form a number of carcinogenic byproducts. Treated effluents from ten chlorine based textile effluent treatment plants (ETPs) were assessed for trihalomethanes (THM). The presence of THMs in the outlet stream was confirmed in this study. The concentration of THMs was found below the WHO concentration where the effluents contain a lower value of dissolved organic carbon (DOC). Trihalomethanes (THMs) formation increases significantly with the increase concentration of DOC and increasing pH. But THM concentration is independent of pH at concentration above 150ppb. The pH value is 8.5 at 150 ppb concentration of THM. Curves have been generated in Matlab software to find out the concentration of THM for different chlorine dose, pH and DOC values. The concentrations of THM in the outlet stream of different ETPs can be found out using these curves. The results are very close to the practical measured values.

Keywords: THM; DOC; ETP; DBP

INTRODUCTION
The rise in the number of textile industries in Bangladesh has seriously increased water pollution in the country (Sultana et al., 2013). Effluent from the textile industry is often a major source of environmental pollution, especially water pollution. Among the various stages of textile production, the operations in the dyeing plant, which include pre-treatments, dyeing and finishing, unused or partially used organic compounds and have a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). They are often of strong color and may also be of high temperature. When disposed into water bodies or onto land these effluents can result in the deterioration of ecology and damage to the aquatic life. (Khan F., 2014)
In Bangladesh chlorine is cheap or available as an otherwise unusable product from chlor–alkali plants (Quader, 2010). Chlorination of textile wastewater achieves all the objectives of textile liquid waste treatment (Quader, 2010) but chlorination leads to the formation of carcinogenic disinfection by products (WHO, 2005). Chlorine reacts with natural organic matter (NOM) to form a number of carcinogenic byproducts. These include but are not limited to trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles, haloketones, haloaldehydes, chloropicrin, cyanogens chloride, and chlorophenols. The THMs and HAAs occur most frequently and generally represent the highest concentrations of the organic contaminants. Chloramines react with NOM to form byproducts similar to those formed by chlorination but at lower concentrations (U.S. EPA, 1995).

Trihalomethanes (THMs) are the major category of disinfection by-products in chlorinated water and dissolved organic carbon is the major precursor of THM formation (Mac Crehan et al., 2005). The maximum contaminant level (MCL) set by USEPA for the concentration of total THMs in drinking water is 80 µg L-1. The concentration of total THMs regulated by the European Union in drinking water is 100 µg L-1 (EPA, 1998). WHO guideline values for $CHCl_3$, $CHCl_2Br$, $CHClBr_2$ and $CHBr_3$ are 200, 60, 100 and 100 µg L^{-1} respectively. The formation of disinfection byproducts (DBPs) is a function of many factors. The formation of DBPs during the chlorination process is very important and needs to be monitored. The prediction model for DBPs has proved to be a very useful approach in controlling and monitoring the formation of DBPs (Chowdhury et al., 2009.)

The use of chlorine in the treatment of textile wastewater can be a desirable option if the THM level is kept below WHO standard. This study is aimed to investigate the presence of THMs in chlorinated treated water and evaluate the effect of dissolved organic carbon (DOC) and pH on the concentration of THMs.

METHODOLOGY

Textile liquid waste samples were collected from the equalization tank of ten chlorine based effluent treatment plants. All possible efforts were made to minimize the time lag between collection and analysis so that no significant change may occur in the quality of the samples. The collected samples were transported to the laboratory quickly and then samples were preserved in the refrigerator in accordance with the standard Methods. To determine the THM in the treated effluent THM Plus method (Method 10132) was used with Hach DR/2010 Spectrophotometer. The effect of free residual chlorine, pH, and temperature on THM was assessed using the correlation developed by Rodrigue (2000).

The model developed by Rodriguez et al. (2000) has been used to find out the concentration of DOC in the outlet stream. The model is, $\mathbf{TTHM = 0.044(DOC)^{1.030}(t)^{0.262}\,pH^{1.149}(D)^{0.277}(T)^{0.968}}$ **(1)**
Parameters TTHM= Total Trihalomethane (ppb), DOC= dissolved organic carbon (mg/l), t= contact time (min), D= Chlorine dose (mg/l), T= outlet stream Temperature (^oC). The temperature, pH and chlorine dosing data were collected from the ETPs and contact time was taken as 48 hours.

Curves have been generated using MATLAB software. Here two parameters contact time (t), and temperature (T) have been kept constant. Contact time was taken as 48 hour and temperature was fixed at 50^0 C as the average textile outlet stream temperature is 50^0C (Babu et al, 2007) and no significant increases in THMs beyond 48 hours of chlorination (Chowdhury et al.2009)

RESULTS AND DISCUSSIONS

The presence of THMs in all treated samples was confirmed in this study. However, the concentration of THMs in treated samples was found below the WHO guide line (180ppb) values. Increase in DOC generally led to increase in THMs formation (Muller, 1998). Figure 1 illustrates the correlation between DOC and THMs of different treated sample of different ETPs. Figure shows that strong correlation between DOC and THMs (r^2 =0.86). It may be observed that textile liquid wastes content a lower value of DOC ranged 0.6 to 2 mg/l approximately.

The study identified pH, chlorine dose as significant for THMs formation. The effect of pH on THMs formation of treated textile waste water samples is presented in figure 2. The pH has been found to be correlated with THMs formation. 30% to 50% increase in THMs formation was noted when the pH was increased from 6 to 11(Chowdhury et al., 2009). It is observed in figure 2 that trihalomethanes formation increase significantly with increasing pH which corresponds to results noted in previous studies (Khan. F., 2014).

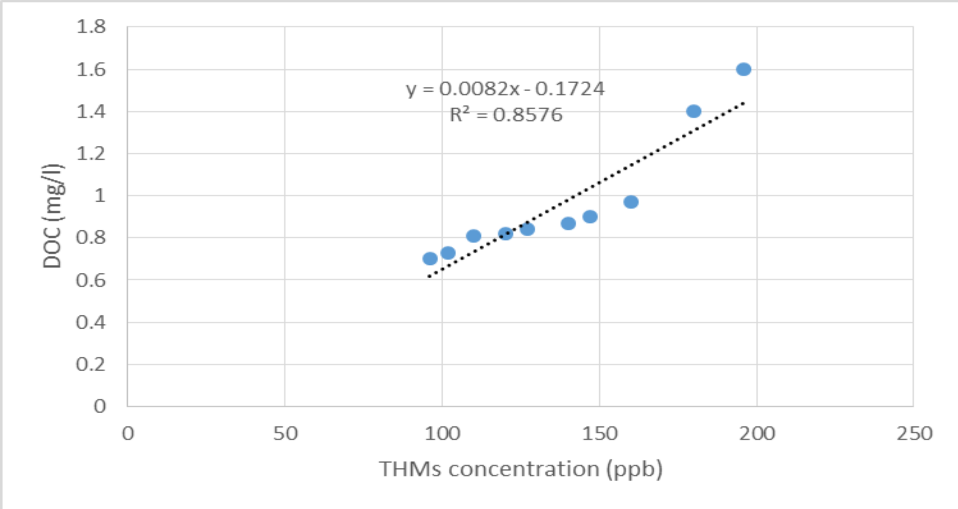

Fig.1: Effect of DOC on THMs formation

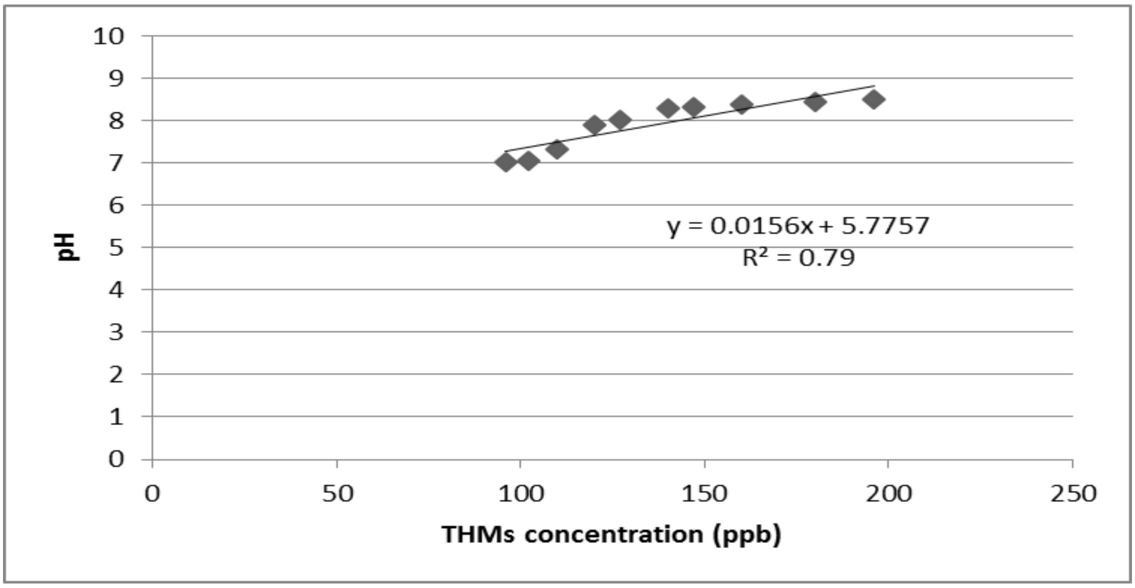

Fig.2: Effect of pH on THMs formation

The effects of reaction time on THMs formation is illustrated in the figures exposed to different pH and chlorine doses. Chlorine dose is affected by the amount and type of organic matter (Chowdhury et al., 2009.). The amount of chlorine used for disinfection is referred to as the chlorine dose. [Fig] 3 to 6 shows the effect of chlorine dose on THMs formation. For these Figures, seven chlorine doses were administered It can be seen that, at the lowest chlorine dosages, the THMs concentrations were less than those found at intermediate chlorine dosages. However, THMs formation was not found to increase significantly when the chlorine doses were increased further. This may be due to the fact that the chlorines beyond breakpoints had insignificant amount of organics to react.

CONCLUSIONS

THM Plus method (Method 10132) was used with Hach DR/2010 Spectrophotometer to investigate the formation of disinfection byproduct, trihalomethane (THM) in the treated effluent since these disinfection byproducts are suspected to cause cancer, liver and kidney damage, related fetus growth. The concentration of THM was found ranged between 62-130 ppb shows that no significant amount of THM was formed in the chlorinated.However, the concentration of THMs in treated samples was found

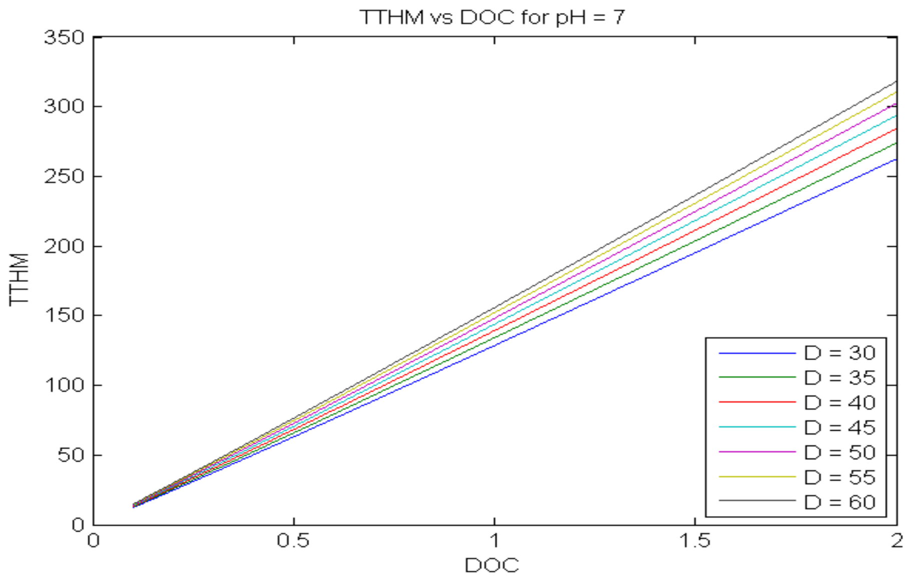

Fig.3: Effect of DOC and Chlorine dose on THMs formation at pH=7

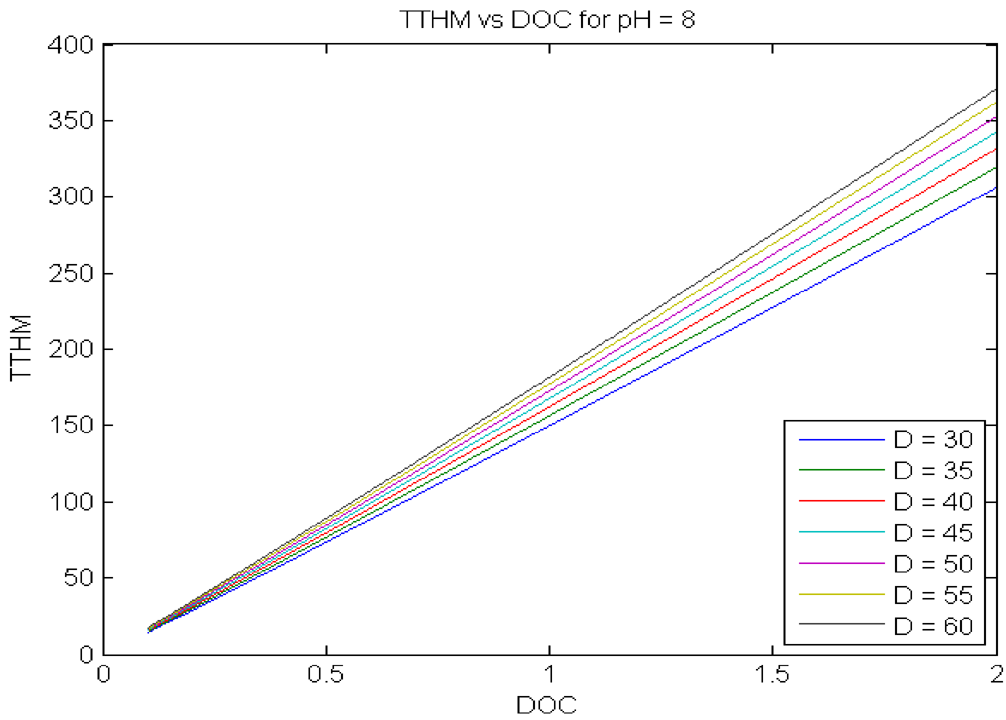

Fig. 4: Effect of DOC and Chlorine dose on THMs formation at pH=8

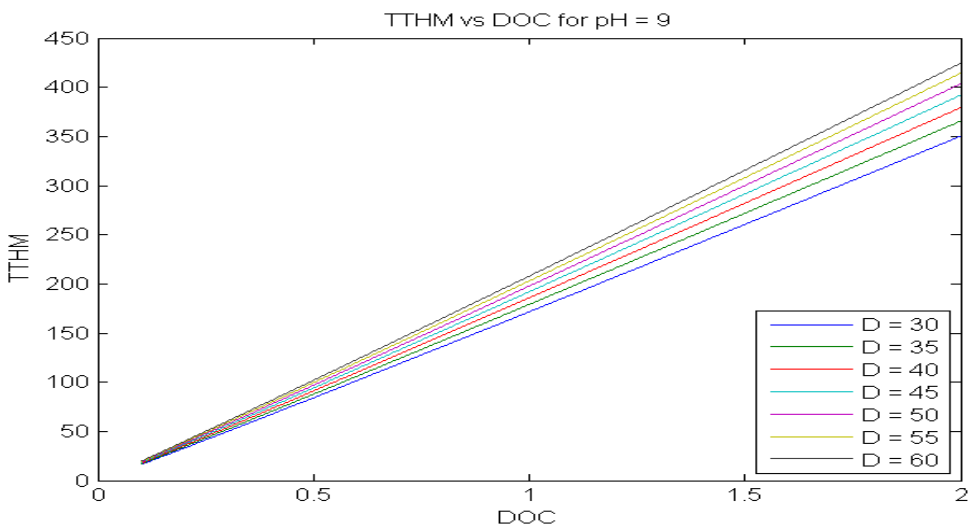

Fig.5: Effect of DOC and Chlorine dose on THMs formation at pH=9

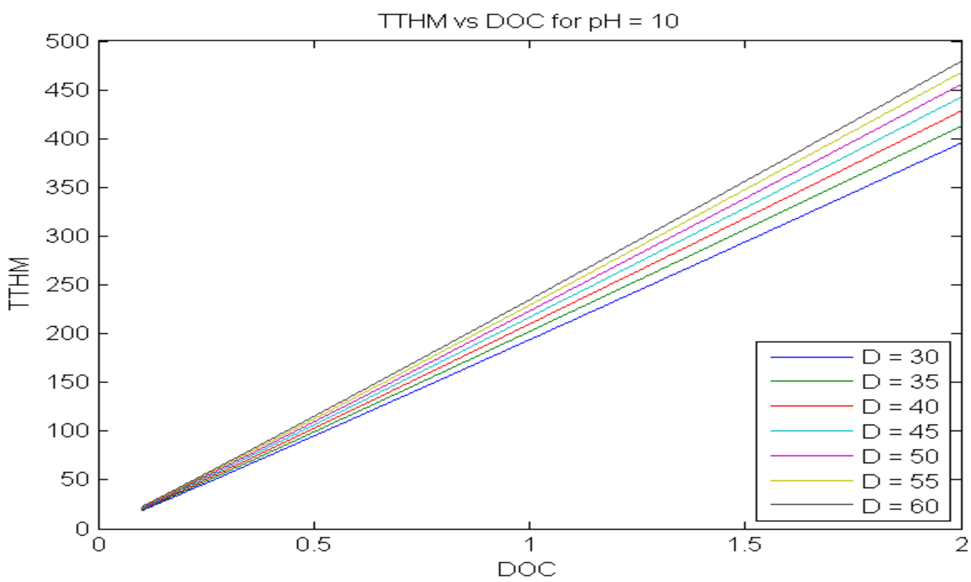

Fig.6: Effect of DOC and Chlorine dose on THMs formation at pH=10

below the WHO guide line (180ppb) values. Figure shows that strong correlation between DOC and THMs (r^2 =0.86). It may be observed that textile liquid wastes content a lower value of DOC ranged 0.6 to 2 mg/l approximately. Trihalomethanes (THMs) formation increases significantly with the increase concentration of DOC and increasing pH. But THM concentration is independent of pH at concentration above 150ppb. The pH value is 8.5 at 150 ppb concentration of THM. Curves have been generated in Matlab software to find out the concentration of THM for different chlorine dose, pH and DOC values. The concentrations of THM in the outlet stream of different ETPs can be found out using these curves. The results are very close to the practical measured values.

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STUDY ON INDUSTRIAL WASTE MANAGEMENT SCENARIO OF BSCIC AREA OF RAJSHAHI CITY

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ABSTRACT
The waste treatment and management of BSCIC, Rajshahi does not follow any rule. There is no ETP of any industry. The reason of not having ETP is most of the industries produce little amount of wastewater. They discharge their wastewater in nearby pond or in pit and dump solid waste at road side or City Corporation's dustbin. The silk industries dump their waste in pit and nearby pond. The food industries dump their waste as fish feed. The marble industries use their waste as construction materials. Wastes of plastic and recycling industries dump their waste nearby ponds. Metal industries dump their wastes at roadside. Chemical industries dump their waste by digging pit. And all of these industries dump their waste without any treatment. Therefore, immediate necessary action needs to be taken by the authority to improve the situation.

Keywords: Industrial waste; wastewater; management; treatment

INTRODUCTION
The term industrial waste refers to all wastes arising from industrial operations or derived from manufacturing processes. Industrial wastes encompass solids, liquids, gases, and sludge. Industrial wastes can be characterized according to whether they are hazardous or non-hazardous. Although the literature suggests that the majority of industrial waste generated in developing countries is non-hazardous, hazardous waste still represents serious environmental and health threats to these countries (Polprasert and Liyanage, 1996). Usually untreated industrial wastes are disposed of unsafely through illegal dumping, open-dumps, lakes, and rivers in developing countries (Mato and Kaseva, 1999). Additionally, hazardous and non-hazardous wastes are often not segregated and are mixed together with domestic waste at disposal site (Mato and Kaseva, 1999). In combination or separately, these actions create serious environmental risks (such as contamination of groundwater and soil from landfill leachate), and create great health risks to firm employees, municipal workers, and waste pickers who collect and work with waste.
Rajshahi is one of the divisional city. Like Dhaka and Chittagong, Rajshahi is not developed in industrial sector yet now. The industries are located throughout the *zila* but around 32% are found within the four *thana* that make up the RCC area and employ over 25000 people. The Bangladesh Small and Cottage Industries Corporation (BSCIC) established an industrial estate with 325 plots in Sopura, on the northern edge of Rajshahi City in an area of just under 96 acres. Of these, 173 have been filed and the others have remained vacant for 42 years (RDA vol.-I 2004, p. 14). It is therefore clear that Rajshahi is not a major industrial area like Dhaka, Narianganj or Gazipur but it is famous for its silk and it is still likely that industrial waste may have a significant effect on agricultural production where wastewater is being used. Two of the major industrial silk mills have a combined annual production capacity of 290000 yards of silk (RDA vol.-I 2004, p. 23).
Nowadays managing wastes become most important urban environment problems because of the increasing population and more industrialization. The volume and composition of wastes generation is increasing due to the effect of population growth (Rajshahi 1.89 million in 1901, 2.27 million in 2001 and 2.60 million in 2011 (BBS, 2013) and expanding economics and the infrastructure necessary to manage the ensuing problems is inadequate. As the developing city of Rajshahi, the main industries, which have been developed here, are one Jute mill, 12 garments factory (for local use), 620 Rice and Oil mill, 689 Handloom, 13 Plastic industry (BBS, District Statistics 2011), seven Rubber and plastic

industry, 26 Cotton and spinning mill, one Cigarette factory, eight Match factory, 10 Glass factory, two Soap factory, nine Iron and Metal factory, 39 Dairy product, 2238 Food Industries, one Pharmaceutical (BBS, 2006). The industries are located within the district but around 32% are found within the four Upazila that make up the Rajshahi City Corporation area and employ over 25000 people. The Bangladesh Small and Cottage Industries Corporation (BSCIC) established an industrial estate with 325 plots at Sopura, at the northern edge of Rajshahi City in an area of just under 96 acres. Of these, 173 have been filed and the others have remained vacant for 42 years (RDA, 2004). Two of the major industrial silk mills have a combined annual production capacity of 290000 yards of silk (RDA, 2004). Therefore, the main economic activities are in this industrial zone which environmental situation needs to be assessed and improve as required.

METHODOLOGY

In Bangladesh as well as in Rajshahi, there is limited research and paucity of literature information on industrial waste management. So, information was collected from research institutions, government and non-government organizations involved with industries and industrial waste management. Field investigation through questioners and field observations were conducted. The existing situations were ascertained through a critical review and analyses of the information extracted from documents and informants discussed with, which was collected from expertise on that area. Technical officer of BSCIC gave a list of industries of that area. Each of these industries were visited several times as required and following data were collect: industry name, owner, address, category, type of waste generated, quantity of waste generated, origin of waste, collection, storage and dumping or treatment system of waste.

RESULTS AND DISCUSSIONS

In order to assess the relationship between firm ownership and waste minimization behavior, the participating firms consist of both state-owned enterprises and private ventures. Even though anticipated at the time of selecting the study participants, none found joint ventures, “Share Company”, among medium to large scale industrial firms operating in the BSCIC. Participating industries included: Sopura Silk Factory, Usha Silk Factory, Regent Alluminium, Polash Metal Industry Limited, Kezin Chemical Limited, Haque Rice Mill, Rajshahi Misty Bari, Bishal Food Industries Limited, Verona Marbel Industries Limited, Modern Plastic Industries Limited, Taskin Industries. The information that was collected are name of the industry, owner of the industry, address of the industry, type of the industry, types of waste generate, quantity of waste, treatment and disposal of waste.

Survey on Waste Management in Sopura Silk Factory

Sopura silk factory is one of the large silk industries in Rajshahi city situated at B-74, BSCIC industrial estate. The silk yarn is purchased from market and produce mainly Shari. The produced Shari is also printed in this industry at dying section. Through this production and printing process, liquid waste of about 20 liters is produced every day with some solid waste. The solid waste is disposed of through the municipal service. However, liquid wastes (dying effluent) are stored in storage tank through a pipe line. The dying activity and effluent storage are shown in Fig. 1.

Fig. 1: Dying effluent production and storage

The liquid wastes are kept in storage tank for some days and finally disposed in trench which is shown in Fig. 2.

Fig. 2: Disposal of effluent from storage tank

Survey on Waste Management in Usha Silk Factory
Usha silk factory is also large industry like Sopura silk factory and same type of products are produced. Dying and printing are the major function to produce the finish product after weaving the cloth. This industry is situated in BSCIC industrial estate at plot no. A-235. In this factory there is no dying section. Most of works are done with handloom. Just yarns are washed in the barrel type container. Every day 10 to 15 liter dying effluent is produced and dumped in a nearby pond without treated. Effluent production and disposal are shown in Fig. 3.

Fig. 3: Washing drum and pipe line for dumping at pond

Fig. 4: Dust production and storage

Survey on Waste Management in Verona Marble Industry

This is the so far only marble and granite industry in Rajshahi situated at plot No. 206 in BSCIC industrial estate. The dust and powder type wastes of about 25 kg are produced for shaping the marble and granite with block cutter machine. The produced powdered wastes are initially submerged under water in storage tank to protect the spreading and flying around. The tank is usually filled up by 30 tons of stone crushing. The wet dust is removed from tank every month and dumped in road side municipal bin. Sometimes this waste is reused in construction work by public. Fig. 4 shows the marble cutting and dust storage tank.

Survey on Waste Management in Modern Plastic Industry

There are some plastic industries in Rajshahi produce finish product from new and recycled raw materials. This is a plastic recycling industry situated at plot no. A-167 in BSCIC industrial estate. Both solid and liquid wastes are produced from washing and shredding of refuse plastics. About 500 liter liquid waste is produced per 300 kg plastic shredding and washing per day. The wastewater is disposed of in nearby pond without treatment. Waste production and disposal is shown in Fig. 5.

Fig. 5: Liquid and solid wastes production and dumping at nearby pond

Survey on Waste Management in Palash Metal Industry

Palash Metal Industry is situated at plot no. A-98 in BSCIC industrial estate, Sopura, Rajshahi. Mainly ashes and coal are major wastes produced during processing of metals. About 100 kg of wastes are produced per day in this industry and disposed of at the road side. The municipal wastes collection vehicle comes and collects the waste to final disposal site. Metal processing wastes are shown in Fig. 6.

Fig. 6: Metal processing and disposal of metal processing wastes at road side

Summarization of results

From above discussion and study we see that the industrial waste treatment and management of BSCIC, Rajshahi does not follow any rule for protection of public health and environment. These industries produce comparatively little amount of wastes and do not have any standard effluent treatment plant (ETP). Therefore, they dump their waste usually at nearby pond, road side or in trench. Some of industries dump their waste in City Corporation's dustbin. Wastes of "Verona Marbel Industry" are occasionally used as construction materials. Wastes from different food industry are used as food of fish (results are not shown in this paper). Wastes from chemical industry and silk industry dump in trench or pond.

CONCLUSIONS

Rajshahi, like most developing industrial cities, lacks the infrastructure, financial resources, and institutional capacity necessary to effectively manage industrial liquid and solid wastes as well as adequately control the pollution. There is no ETP of any industry because they produce small amount of waste. There is also problem of lacking of space for ETP. As a result environment is getting polluted day by day. In terms of waste minimization activities, the survey found that all interviewed firms had not adopted waste minimization measures.

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ENVIRONMENTAL IMPACT ASSESSMENT OF LEATHER PROCESS USING IMPACT 2002+ METHOD

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ABSTRACT
Life cycle assessment (LCA) is the commonly used decision support tool for quantifying and evaluating environmental impacts of any product, process or activity. This paper constructed inventory of rechroming process for both full-chrome (FCR) and retanned (RR) leather as a basis to analyze, compare and propose further improvement actions. The functional unit is 1 square meter leather and impact assessment conducted based on IMPACT 2002+methodology. In this method, data was inventoried and assembled according to life cycle assessment (LCA) methods principle and requirements of ISO-14040/44, 14067 standards. All procedure was carried out using leading LCA software SimaPro. Results indicated that, FCR process has more than 1.8 times higher impact on aquatic ecotoxicity and non-carcinogens but RR has 4.7 times higher on aquatic acidification and 1.45 times higher on Aquatic eutrophication. In addition, FCR has 1.8 times higher impact on damage category ecosystem quality and human health. Comparing all impact and damage categories, FCR process has higher environmental burden than RR process.

Keywords: IMPACT 2002+; impact assessment; SimaPro software and environmental impact

INTRODUCTION

The leather tanning process is composed of several batch stages associated with the consumption of large amounts of freshwater as well as the generation of liquid and solid wastes. The wastewaters are characterized by significant organic load and remarkably high concentrations of inorganic compounds such as chromium, chloride, ammonia, sulfide, and sulfate (Tünay, 1995, Ates et al., 1997). Among these, tanning agents from chromium metal poses a challenge to the future sustainability of the leather industry with a growing number and layers of non-tariff barriers, including environmental considerations and eco-criteria emanating from major export markets. Rechroming uses a significant amount of chrome tanning agent and subsequently a greater chance of releasing into environment. A common retannage for chrome tanned leather is more chrome tanning which is done usually to increase the shrinkage temperature and chromium content; to even up the color; to change the reactivity of leather and to modify the properties of leather (Covington, 2009). On the other hand, Leather which has been subjected to an additional tannage with similar or other tanning materials is called retanned leather (leather terminology, source: IULTCS). A useful tool to evaluate the environmental burdens associated with a product, process or activity is life cycle analysis or assessment (LCA). The objectives of this environmental management tool are the identification and quantification of the input and output flows of the process: energy and materials used and wastes released into the environment (Consoli et al., 1993). The application of LCA in process selection, design, and optimization is gaining wider acceptance and methodological development (Azapagic, 1999). The life cycle assessment framework consists of four phases. They are: goal definition and scoping, inventory analysis, impact assessment and improvement analysis. The definition of the scope of the LCA sets the borders of the assessment – what is included in the system and what detailed assessment methods are to be used (Azapagic, 1999). The second step (inventory analysis) includes inventory of the inputs such as raw materials and energy and the outputs such as wastes and emissions that occur during the life cycle. The third step (impact assessment) is integration of inventory elements into an assessment of environmental performance which requires the emissions and material used to be transformed into estimates of environmental impacts. The results of this stage of LCA are termed as 'ecoprofile'(Joseph & Nithya, 2009). The final step is interpretation of the results of impact assessment and suggestions for improvements(Azapagic, 1999). Earlier LCA of two representative leather articles of Bangladeshi tannery has been done from environmental perspective (Ahmed & Chowdhury, 2016). In addition, a similar study conducted for pretannage process using Chrome and Aluminium tanning agents (Chowdhury et al., 2015). The present study investigated the environmental impact of Rechroming process of both full-chrome and retanned leather. It will help to identify environmental burden and scope of improvement of the concern process.

METHODOLOGY

In this study, data was inventoried and assembled according to life cycle assessment (LCA) methods principle and requirements of ISO-14040/44, 14067 standards. All procedure were carried out using leading LCA software SimaPro (PRé, 2013). The impact assessment was conducted based on IMPACT 2002+ methodologies. As mentioned earlier, the life cycle assessment framework consists of four phases namely goal definition and scoping, inventory analysis, impact assessment and improvement analysis.

GOAL AND SCOPE DEFINITION

The goal of this study is to determine and compare the environmental burden of the most polluting leather process Rechroming of representative leather article full-chrome and retanned leather which will help to identify impact of different impact categories. Therefore, to find out where the environmental performance can be improved. Moreover it serves as a source of information for other tanneries or industries which may be interested to study the impact of their processes by applying the LCA methodology. Vegetable tanned leather is rechromed to increase the thermal stability and strength. Leather which has been tanned first with vegetable tannin and then re-tanned with chromium salts is called semi-chrome leather and the tannage is called semi-chrome tannage (leather terminology, source: IULTCS). Range of thickness of curst leather does not vary substantially from one article to the other. It was assumed based on in house observation. The functional unit chosen is 1 square meter leather. Therefore all the emissions are calculated in relation to the production of 1 square meter leather.

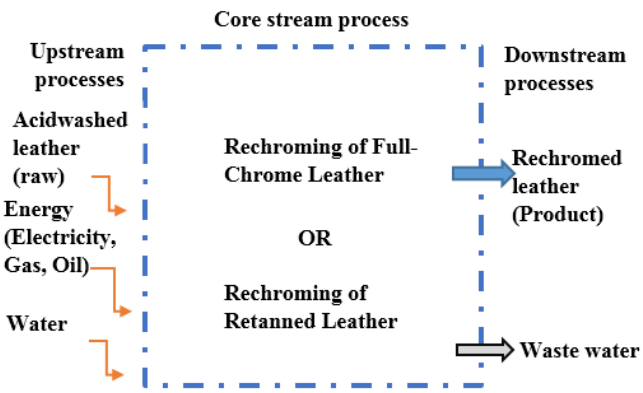

Figure 1: system boundary for both FCR and RR processes

According to the system boundaries illustrated in Fig. 1 and table 1, both differ in amount and types of tanning and other performance chemical agents. Preceding major upstream processes like slaughtering, preservation, presoaking, soaking, liming, deliming, bating and pickling are same for both leather except chrome tanning (FCL) and pretannage (RL). Data are based on Bangladeshi system that reasonably approximate this country's practices. All data used here are less than 10 years old to provide a reasonable approximation of current practices and energy systems. Data concerned to rechroming of both leather processes taken directly from production of stated articles in a representative tannery.

LIFE CYCLE INVENTORY

An analysis of the physical and chemical characterization of wastewater emissions of the leather processes was performed. The major tests conducted were chemical oxygen demand (COD), chloride, SO_4^{2-}, TS, TDS, pH, NH_3-N, NO_2-N, NO_3-N, PO_4^{3-}, total chromium. Data collection included annual wet-salted raw hides/skins consumption, input chemicals consumption, water and steam consumption, tannery solid waste generation, electricity, fuel oil consumption for generator and steam boiler but will not be showed in this study. Tests were conducted at Environmental Engineering laboratory, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).

Table 1: Input chemicals consumption for both process FCR and RR (per meter square of leather)

Input as chemicals			
FCR	Quantity in kg/m^2	**RR**	Quantity in kg/m^2
Total water	2.691	Total water	1.943
Relugan RF (water-soluble Acrylic co-polymer tanning agent)	0.030	Derugan 3080 (Mixture with glutaraldehyde)	0.030
Formic acid	0.001	Provol BA (based on natural phospholipids with synthetic softeners)	0.006
Tankrom AB (Basic chromium sulfate)	0.090	Basic chromium sulfate	0.045
CP super (Chrome Syntan)	0.060	CRO chrome syntan	0.045
Sodium Formate	0.030	Sodium Formate	0.024
Atlasol 177C (based on bisulfited oil, fatty alcohols and synthetic lubricants)	0.012	Atlasol 177C	0.006
Sodium Bi carbonate	0.006	Sodium Bi carbonate	0.006
		Adusin (syntan)	0.030
		NH	0.012
		Basyntan AN (condensation products of aromatic sulphonic acids)	0.030

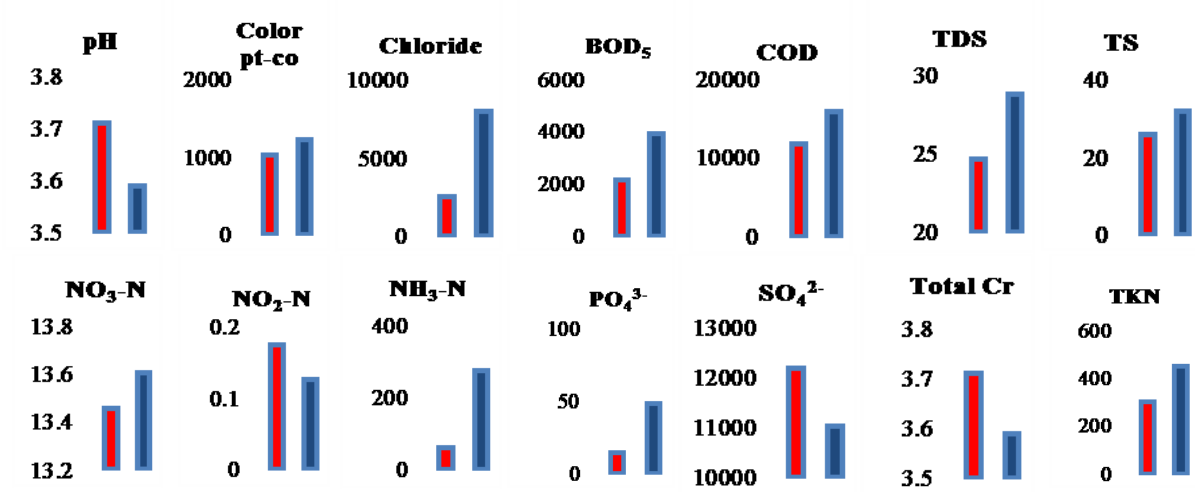

Fig. 2: comparative output results of both FCR and RR process

The samples being analyzed were waste liquors of presoaking, main soaking, liming, deliming and bating, pickling, pretannage (retanned) and chrome tanning (FC), acidwash (both) and rechroming (both) but has not been shown except FCR and RR process. Table 1 shows the input of both systems which in part represent the recipe for the studied processes but order of chemical addition, time etc. ignored.

According to the Fig. 2, RR contributed much in color, chloride, BOD_5, COD, TDS, TS, NO_3-N, NH_3-N, PO_4^{3-} and TKN. Among these, NH_3-N is about 4.7 times, PO_4^{3-} is 3.5 times, chloride is 3.2 times higher. In contrast, total chromium, SO_4^{2-} and NO_2-N of FCR are slightly higher than RR.

RESULTS AND DISCUSSIONS

The impact assessment of characterization and damage categories comprises the results and discussion. In addition, scope for improvement also belongs to this part.

IMPACT ASSESSMENT

The impact assessment was conducted based on IMPACT 2002+methodology. SimaPro has been used to analyze and compare these two processes. This method links all types of LCI results via several midpoint categories like carcinogens, non-carcinogens, respiratory inorganics, respiratory organics, ionizing radiation, ozone layer depletion, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nitrification, land occupation, global warming, non-renewable energy consumption and mineral extraction to four damage categories (human health, ecosystem quality, climate change and resources). Linking to midpoint is associated with certain conversion factors for each pollutant and conversion to damage categories is also associated with damage factors (Humbert et al., 2011).

CHARACTERIZATION ASSESSMENT

Fig. 3 shows the relative contribution to the following impact and damage categories namely human health and ecosystem quality. According to Fig. 3, Kg equivalent of a reference substance expresses the amount of a reference substance that equals the impact of the considered pollutant (e.g. TEG-Triethylene glycol) in the midpoint categories. PDF.m^2.y (Potentially Disappeared Fraction of species disappeared on 1 m^2 of earth surface during one year) is the unit to measure the impacts on ecosystems. DALY (Disability-Adjusted Life Years) characterizes the disease severity, accounting for both mortality (years of life lost due to premature death) and morbidity (the time of life with lower quality due to an illness, e.g., at hospital)(Humbert et al., 2011).

Aquatic Ecotoxicity

This category is dominated mostly by FCR and this process contributes about 1.8 times higher. According to Fig. 3, both processes contributed 9384 and 5223 kg TEG water respectively. The ecotoxicity of these processes mentioned above is due to the associated heavy metal chromium emission into water.

Aquatic Acidification

This category is dominated mostly by RR process and this contributes about 4.7 times higher. According to Fig. 3, both processes contributed 6.26E-04 and 1.34E-04 kg SO_2 equivalent respectively. The aquatic acidification of these processes mentioned above is due to ammonia emission into air and water and ammonia as N.

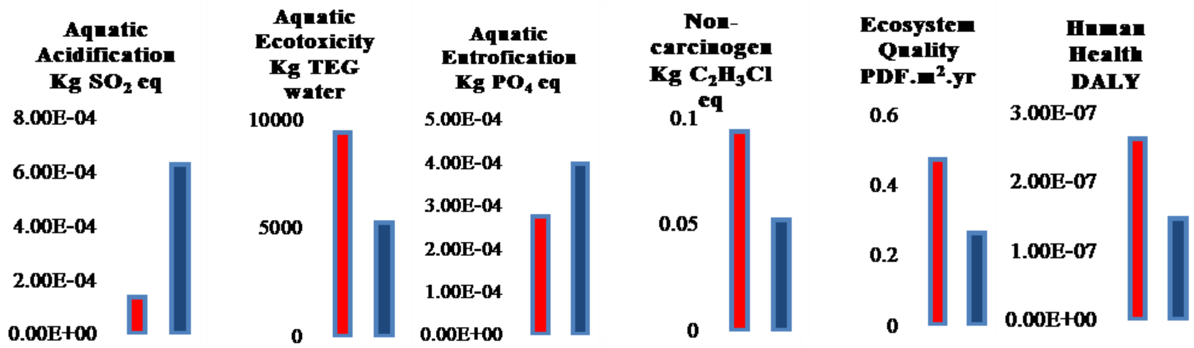

Fig. 3: characterization and damage assessment of both FCR and RR processes

Aquatic Eutrophication

According to Fig. 3, the amount of kg PO_4 emitted by FCR and RR are 3.97E-04 and 2.73E-04 respectively. Noticeably, RR process is 1.45 times greater than FCR process. The aquatic eutrophication of these processes mentioned above is due to higher COD and PO4 discharge into water.

Non-carcinogens

FCR process contributed about 1.80 higher compared to RR process which are 0.09 and 0.05 Kg C_2H_3Cl eq respectively. Non-carcinogens effect of these processes mentioned above is due to the associated heavy metal chromium emission into water.

DAMAGE ASSESSMENT

All midpoint categories except aquatic acidification and aquatic eutrophication have been grouped into four damage categories namely climate change, human health, ecosystem quality and resources. These two midpoint categories are represented separately from the four damage categories.

Ecosystem Quality

The damage category ecosystem quality is the sum of the midpoint categories aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nitrification and land occupation. According to Fig. 3, major contribution to this category comes from FCR followed by RR which are 0.47 and 0.26 PDF.m^2.yr. respectively. FCR contributes about 1.80 times higher.

HUMAN HEALTH

The human health category is the sum of the midpoint categories carcinogen and non-carcinogen, respiratory organics and inorganics, ionizing radiation, ozone layer depletion. This damage category followed the same trend as Ecosystem quality. According to Fig. 3, the contribution of both processes are 2.61E-07 and 1.45E-07 DALY respectively.

SCOPE FOR IMPROVEMENTS

It is clearly indicated in the characterized values the company has impact on aquatic ecotoxicity which results increased contribution to ecosystem quality damage category. Aquatic acidification, aquatic eutrophication and Non-carcinogen take the next position. Effluent treatment plant will significantly reduce environmental load of the following parameters. Chemical modification of chromium tanning salt can be one of the options for enhancing the uptake of chromium. Synthetic tanning material based on chromium improved significantly (90%) chromium uptake (Lofrano et al., 2013). Enhancement of chromium uptake in tanning using oxazolidine and a decreasing of the chromium load in wastewater can be achieved (Sundarapandiyan et al., 2011). Modification of process such as reduction of float is another tool for improving the chromium uptake. Carrying out chrome tanning without float and increasing the temperature at the end of the tanning process brought about 91% reduction in chromium discharged (Lofrano et al., 2013). Phosphate and ammonia as N mostly associated with increased use of syntans and fatliquors.

CONCLUSIONS

In this study, major emissions considered by IMPACT 2002+ method were heavy metal chromium discharge into water, high COD, PO_4^{3-} and ammonia as N wastes produced in rechroming process. These emissions are responsible for the contribution of the concern process to significant toxicological impacts namely aquatic ecotoxicity, aquatic acidification, aquatic eutrophication and non-carcinogens which eventually contributed to damage categories human health and ecosystem quality. The main impact categories associated with FCR leather are non-carcinogens, aquatic ecotoxicity and RR process is dominated by aquatic acidification and aquatic eutrophication.

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TOXICITY AND ENVIRONMENTAL IMPACT ASSESSMENT OF HEAVY METALS CONTAMINATED SOIL OF HAZARIBAGH TANNERY AREA

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ABSTRACT
Present study investigated the soil pollution at Hazaribagh tannery area in terms of heavy metals contamination and their impact on ecosystem and human health. The soil was slightly alkaline (pH 7.6). Concentrations of six heavy metals (Cr, Pb, Ni, Zn, Cd and Cu) were determined and they ranged over the following rounded intervals: Pb: 16-130 mg/kg; Cr: 35- 23149 mg/kg; Cu: 33- 301 mg/kg; Zn: 54-1034 mg/kg; Ni: 3-20 mg/kg and Cd was below detection level. The average concentrations of all heavy metals in the soil samples were lower compared to EU and others guidelines except chromium which was found to be about 29 times higher than the guideline value (EU). Toxicity Characteristics Leaching Procedure (TCLP) test indicated that Pb and Zn are the potential threat of ground water pollution. In addition, heavy metal uptake beyond standard limit by Basella alba (Vine spinach) also posed a potential threat to human and herbivorous animals. To quantitatively assess the environmental burden of the heavy metals associated with soil, the IMPACT 2002+ methodology was used under the SimaPro software environment. Impact results indicated that studied metals have impact on Aquatic ecotoxicity, Terrestrial ecotoxicity and Non-carcinogens midpoint impact category which led to impact on Ecosystem Quality and Human Health damage category.

Keywords: Soil pollution; heavy metals; TCLP; IMPACT 2002+

INTRODUCTION

Leather industry in Bangladesh is considered as considerable growth and investment potential, located in the southwestern part of the Dhaka city on the area of 25 ha in the Hazaribagh area, within one and half kilometer northeast of the River Buriganga (Shams et al., 2009). Tannery industries have been vitally important to the economy of Bangladesh, yet they been proved to be detrimental to the environment mainly due to the discharge of huge quantities of untreated wastewater containing heavy metal chromium (Ahmed and Chowdhury, 2016). About 220 metric tons of raw hides and skins are processed every day. Most of the tanneries follow chrome tanning process. After leather processing all the liquid waste and solid waste are discharged as green (without treatment) through drain in the low-lying areas and finally fall into the river Buriganga. As a consequence, heavy metals used in tanneries for tanning and or subsequent leather processing operations are accumulated in low-laying area or in river sediment. The tanneries discharge more than 22000 m^3 of highly toxic effluents and 1.6 tons chromium per day. About 1.25 t/days of chromium are disposed into Buriganga river and 0.35 t/day of chromium are settled into a lagoon of 25 ha which are suspected to be the source of chromium contamination of the groundwater (Karim et al., 2012). Previous studies showed that the subsoil of Hazaribagh tannery area is seriously contaminated with Cr, Zn, Cu, Pb, phenols and hydrocarbons (Karim et al., 2012; Shams et al., 2009). These heavy metals are very harmful, because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in biological systems (Wilson and Pyatt, 2007; Singh et al., 2004). Soil contamination by chromium is often irreversible and may repress or even kill parts of the microbial community (Viti and Giovannetti, 2008). Cr^{3+} is readily being converted into Cr^{6+} under natural conditions through various oxidation processes. $Cr^{6+}$is much more toxic than Cr^{3+} and mutagenic to most organism and humans (Ajmal et al., 1984).

Vegetables are often cultivated in some part of these contaminated area, as a result these metals may be taken up by the vegetable roots and incorporated into the plant tissue. Ultimately, these toxic metals can get entrance into the human body and lead to bio-accumulation and bio-magnification (Muchuweti et al., 2006). Hazaribagh has drawn a significant attention in the recent years due to high concern of soil, air, surface water pollution and also for potential risk of ground water pollution of Dhaka city. According to a directive of Bangladesh high court, the shifting process of tannery industry from Hazaribagh to new location at Savar is in progress. This area will be redeveloped after the relocation of the tanneries as a residential area having open space, health, and education facilities. However, the area should be cleaned up and remediated before starting the residential area. The present condition of heavy metals pollution and environmental risk assessment of this site is important for formulating a reclamation and clean up strategy. In this study, the extent of soil pollution was determined in terms of heavy metals contamination and their bioavailability in the soil. The purpose is also to determine the uptake of heavy metals by different parts of vegetables grown in contaminated area. In addition, an impact analysis of these heavy metals was conducted using IMPACT 2002+ in SimaPro software.

METHODOLOGY

Soil samples were collected from 11 sites of Hazaribagh, Dhaka. Among 11 sampling locations, location no. L1 to L9 are located in between western part of tannery industry and inner side of flood protection embankment whereas location no. L10 – L11 are in main tannery industries. Soil samples were collected from a depth of 5 to 25 cm. For heavy metal analysis of soil samples, 5 gm. lightly ground oven dried soil sample was digested with acid (HNO_3: HCl =1:3 volume ratio) for 24 hours, then added 350-400 ml distilled water and boiled for 2.5 hour and prepared a 500 ml solution. Finally, solution was filtered through 0.45 µm pore size filter paper and filtrate was collected for the determination of heavy metals (Cr, Pb, Cd, Ni, Cu, and Zn) by using Atomic Absorption Spectrophotometer (AAS) (Shimadzu AA 6800) (Juel et al., 2016; Choudhury et al., 2015). The Toxicity Characteristics Leaching Procedure (TCLP) in accordance with USEPA 1311 (USEPA, 1992) was used to evaluate the risk of heavy metals leaching and reaching to natural ground water.

Among the 11 sample sites, Basella alba (Vine spinach), a locally popular vegetable, was found to cultivate in two sites (L1 and L3). Vine spinach was then collected from these two sites. After collection, the plant samples were washed with distilled water and divided into two parts: i) leaf and ii) shoot. The sample was oven dried for 48 hours in aluminum bowl. For the digestion of plant sample, Approximately 2 gm. of oven-dried sample was taken in a volumetric flask and a few milliliters of distilled water was added, then 25 mL of nitric acid was added to the sample and kept overnight. The flask was heated to boil for 2 h, then after cooling 10 mL of perchloric acid was added to the flask and heated again for 1 h to boiling. If the color of the sample turns yellow, the digestion process is assumed to be completed; if color of the sample turns dark, 2 to 3 mL of nitric acid is added to the flask and heat is applied; the process is repeated until the sample color turns yellow. Finally distilled water was added up to the 200 mL graduation mark of the volumetric flask and filtered using a filter paper (0.45 lm) followed by analysis using an AAS (Shimadzu, AA6800) (Choudhury et al., 2015). The environmental impact assessment conducted based on impact 2002+ methodology using SimaPro. This software is integrated with various databases and impact assessment methods (PRé, 2013).

RESULTS AND DISCUSSIONS

Physical Properties of Soil

The average pH of the soil samples was found to be 7.6 which indicates slightly alkaline conditions. The high pH of the topsoil is caused by the disposal of tannery effluents containing a large amount of $Ca(OH)_2$ used in the liming process (Karim et al., 2012). Similar pH value of Hazaribagh soil was reported in other studies (Karim et al., 2012; Shams et al., 2009). The high organic content ranging from 3 to12%, was observed due to accumulation of organic substance of solid waste and tannery effluent.

Heavy Metal Content in Soil

The concentrations of heavy metals in the samples were compared with the European standards because there is no standard regulation for soil contamination in Bangladesh. The concentration of selected heavy metals (Pd, Cr, Zn, Cu, Ni and Cd) for each soil sample found in this study was shown in Table 1.

High amount of chromium ranging 34.85 to 23148 mg/kg was found to be distributed in the study area. It revealed that the concentration of Cr of all samples markedly exceeded the maximum permissible limit of 150 mg/kg (EU standard) except sample no. L7. Comparatively higher concentration of Cr was distributed in waste lagoon or inner side of embankment (L1 to L9), because tannery effluent often flooded this area due to blockage of cannel during passing to Buriganga river. Previous studies (Karim et al., 2012; Shams et al., 2009; Zahid et al., 2006) also reported high chromium concentration ranging 1000 to 30000 mg/kg in the topsoil of the Hazaribagh area. Most of the Cr accumulated in the soil was present as Cr(III) (Saha and Ali, 2001) and insignificant amount (maximum 1 mg/kg) of Cr was present as Cr(VI) (Shams et al., 2009).

Table 1: Heavy metal concentration in soil of Hazaribagh tannery area

Sample ID	Pb (mg/kg)	Cr (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Cd (mg/kg)
L1	61.25±1.2	1834.8 ± 3.67	304 ± 1.2	58.25 ± 7.4	8.45 ± 0.49	n.d
L2	59.6 ± 1.1	2438.9 ± 10.8	193.7 ± 1.13	271.8 ± 0.28	19.9 ± 0.42	n.d
L3	70.6 ± 1.1	1458 ± 3.67	250.9 ± 1.34	115 ± 0.28	8.65 ± 0.21	n.d
L4	52.4 ± 1.1	23148 ± 48.6	558.9 ± 2.75	66.3 ± 0.2	4.05 ± 0.07	n.d
L5	130 ± 0.77	2492.6 ± 10.8	1034 ± 14.56	301 ± 0.07	12.25 ± 0.21	n.d
L6	15.7 ± 1.5	294.6 ± 10.88	20 ± 1.2	30 ± 0.12	5.55 ± 0.07	n.d
L7	61.5 ± 0.1	34.85 ± 2.19	327.1 ± 2.67	323.2 ± 0.56	9 ± 0.56	n.d
L8	16.75 ± 0.77	115.8 ± 5.25	77.8 ± 2.26	32.5 ± 0.28	6.6 ± 0.14	n.d
L9	23.95 ± 0.77	12682 ± 51.56	53.75 ± 1.76	35.9 ± 0.14	3 ± 0.42	n.d
L10	41.9 ± 0.42	145.45 ± 7.28	127.5 ± 32.4	133.05 ± 2.1	9.25 ± 0.92	n.d
L11	62.9 ± 0.42	2888.9 ± 0.2	210.35 ± 0.77	75.5 ± 0.42	9.85 ± 0.35	n.d
China limit [a]	350	200	300	100	60	0.6
EU limit [b]	300	150	300	140	NA	3.0

[a] SEPA, (1995); [b] European Union, (2002); n.d: not detected; detection limit of Cd is > 0.001 mg/l

The analytical result revealed that the concentration of cadmium was below the detection limit in all soil samples. Pb contamination in soils has been seriously emphasized in recent years since this metal is very toxic for humans and animals (Rahman et al., 2012). The concentration of Pb and Ni in all soil sample, ranged from 15.7 to 130 mg/kg and 3 to 19.9 mg/kg, respectively, were below the EU and China limit (Table 1). The Zn concentration varied from 20 to 1034 mg/kg where Zn level in 4 sites (L1, L4, L5 and L7) was higher than the maximum allowable concentration of 300 mg/kg (both for China and EU limit). Similar pattern of Cu distribution was observed in the study area ranging from 30 to 301 mg/kg. The Cu concentration of 5 sampling sites exceeded the China limit of 100 mg/kg whereas this number reduced to 4 sites when compared with EU limit of 140 mg/kg.

Mobility of Heavy Metals

The mobilization of targeted heavy metals were measured in the leachates and compared with the total amount of metal present (HNO_3/HCl extraction) (Karim et al., 2012). The mean leaching concentration of Cr, Pb, Zn, Cu and Ni were 1.875 mg/kg, 3.365 mg/kg, 14.52 mg/kg, 2.205 mg/kg and 0.516 mg/kg, respectively. From the leaching test results shown in Table 2, a leaching of only 0.03% of the total chromium content was found. This indicated that only a small fraction of the chromium present in the topsoil of the Hazaribagh area is mobilized by rainwater. Similar leaching result was found by Karim et al., (2012). On the other hand, the concentration of Zn in the leachate was 14.52 mg/kg corresponding to 4.98% of the total zinc content, indicating most mobile metal in this study. High mobility of Zn was reported in the previous study (Rahman et al., 2012). The leaching concentration of Pb was found to be 3.365 mg/kg which is corresponding to about 6.13% of the total lead content. This indicates that Pb and Zn are the potential threat of ground water pollution though total content of these metals are much lower compared to total chromium content.

Table 2. Leaching of Cr, Pb, Zn, Cu and Ni under standard TCLP leaching test

Heavy metals	Average (mg/kg)	S.D	Leaching (%) (relative to HNO_3/HCl extraction)
Cr	1.875	0.860	0.03
Pb	3.365	1.418	6.13
Zn	14.52	12.210	4.98
Cu	2.205	1.540	1.64
Ni	0.516	0.436	4.41

Heavy metals in vegetables

Concentrations of heavy metals accumulated in leaf and shoot portions of the vegetables (Vine spinach) are presented in Table 3 and compared with the safe limit regulated by FAO/WHO, India and China for these elements in fresh vegetables. It is apparent for lead that concentration in both leaf and shoot greatly exceeded all the standards. In case of chromium, high concentration was found to accumulate in shoot compared to leaf and also exceeded both FAO/WHO standards and Chinese national food standards whereas high level of Zn accumulated in leaf compared to shoot that exceeded all the standards (Table 3). The higher concentration of Zn is found in vegetables compared to other metals analyzed in this study that support the bioavailability or mobility of zinc described in earlier part of this article. Though Cu and Ni concentration were below the FAO/WHO standards but exceeded the China national standards. Therefore consuming these vegetables grown the study area have harmful impacts on the human's health.

Table 3: Accumulation of targeted heavy metals (mg/kg dry wt.) in Vine spinach grown in study area

Metals (mg/kg)	Soil sample code L1		Soil sample code L3		Safe limit [a]	Safe limit [b]	Safe limit [c]
	Leaf	Shoot	Leaf	Shoot			
Cr	3	6.1	4.9	10.1	5	20	0.5
Pb	14	18.6	6.6	8.8	5	2.5	0.02
Zn	66.9	35.2	72.6	45.5	60	50	20
Cu	14	12.4	10.3	9.1	40	30	10
Ni	1.9	1.6	1.7	1.5	20	1.5	-

[a] FAO/WHO, (1999); [b] India limit (Awasthi, 2000); [c] Chinese national food standards, (2012)

Impact Assessment

Impact assessment is a technical quantitative, and/or qualitative process to characterize and assess the effects of the environmental burdens. The impact assessment of soil contaminated with heavy metals was conducted based on IMPACT 2002+ methodology. This method links all types of results via several midpoint categories like carcinogens, non-carcinogens, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nitrification, land occupation, global warming, non-renewable energy consumption and mineral extraction to four damage categories (human health, ecosystem quality, climate change and resources). Linking to midpoint is associated with certain conversion factors for each pollutant and conversion to damage categories is also associated with damage factors (Juel et al., 2016). SimaPro was used to analyze the impact of heavy metals measured from total extraction. It has been found that chromium, zinc and copper has impact in terms of aquatic and terrestrial ecotoxicity (contributing to the damage category of ecosystem quality) and non-carcinogens (contributing to the damage category of human health). The extent of impact with respect to the USEPA standard for all impacts and damage categories is shown in Fig. 1. Assessment has been done based on heavy metals (avg.) per kg of soil in the industrial area of Hazaribagh against corresponding EU standard. It can be seen that all emissions are below standard except chromium which is the one of the major chemicals used in leather production. Considering overall impact, the non-carcinogenic impact of Zn is much higher which is estimated to be about 9 times higher than Cr in the soil but the Aquatic ecotoxicity effect of Cu is much higher followed by Cr and Zn. In addition, in case of Terrestrial ecotoxicity, greatest contribution comes from Cr followed by Zn and

Cu. The damage category Ecosystem Quality is dominated by Cr followed by Zn and Cu and Human Health mainly controlled by Zn followed by Cr. This is mainly due to the toxic effect of heavy metals on the ecosystem (both aquatic and terrestrial) and human health. In Fig. 1, Kg equivalent of a reference substance expresses the amount of a reference substance that equals the impact of the considered pollutant (e.g. TEG-Triethylene glycol) in the midpoint categories. PDF·m^2·y (Potentially Disappeared Fraction of species disappeared on 1 m^2 of earth surface during one year) is the unit to measure the impacts on ecosystems. DALY (Disability-Adjusted Life Years) characterizes the disease severity, accounting for both mortality (years of life lost due to premature death) and morbidity (the time of life with lower

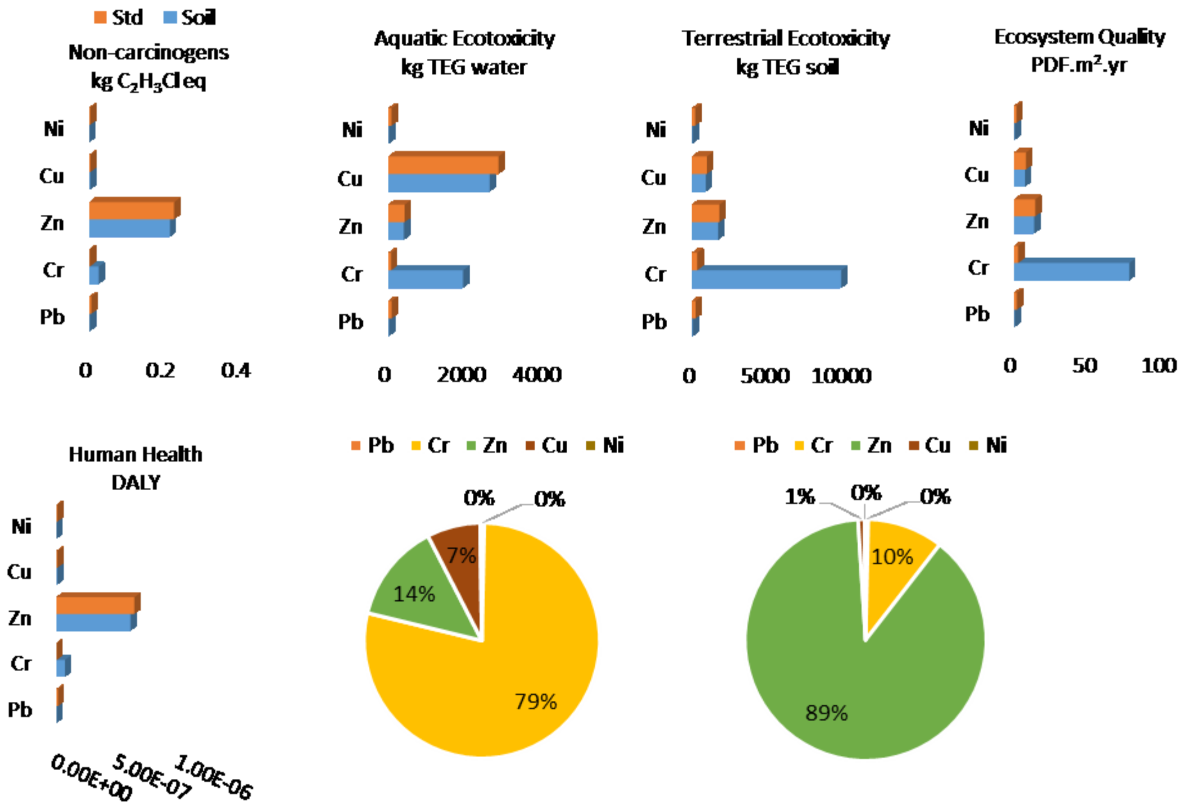

Fig. 1: The environmental impact (Non-carcinogens, aquatic ecotoxicity and terrestrial ecotoxicity) and damage assessment (ecosystem quality and human health) of heavy metals obtained from total extraction. Pie charts indicate the relative contribution of heavy metals over damage categories Ecosystem Quality and Human Health

quality due to an illness, e.g., at hospital)(Juel et al., 2016). The relative contribution of heavy metals over these damage categories has also been assessed. It has been estimated that Cr has higher order of toxicity (79%) in the Ecosystem Quality damage category followed by Zn (14%). On the other hand, Zn contributes the maximum (89%) to Human Health followed by Cr (10%). This assessment has only been done based on the total heavy metal content of the soil samples.

CONCLUSIONS

The uncontrolled release of heavy metals led to soil and groundwater pollution in the study area. In addition, heavy metal uptake by vegetables is another concern. Though total extraction showed that the average emissions into soil is under standard limit except Cr but all of them have impact on ecosystem and human health which has been confirmed by the impact assessment using SimaPro. It also showed that Cr has about 6 times higher impact on Ecosystem quality compared to Zn whereas Zn has about 9 times higher impact on Human Health compared to Cr. Results presented in this study show that Cr is the principal heavy metal contaminant in soil which is usually used as a basic chromium sulfate for the tanning of animal skins. Other sources of heavy metals weren’t traced.

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AIR POLLUTION IN CHITTAGONG CITY

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ABSTRACT
To maintain a peaceful and sound life as well as good health, knowledge about air pollution and its related aspects have become an essential part for human beings. Hence, the concentration of air pollutants in a few location of Chittagong city and the trends of air quality throughout the year for the change of meteorological parameter were investigated with the help of Department of Environment, Bangladesh Meteorological Department and Continuous Air Monitoring Stations (CAMS) of Chittagong city. It has been observed that the concentration of SPM exceeds both the national and international standards. From all the analysis it is clear that the air pollution in Chittagong city is lower considerably in the month April to September. The average Air Quality Index (AQI) value from the year 2013 to 2015 is increasing gradually which is the indication of increasing air pollution in Chittagong city. Therefore, it is suggested that Government of Bangladesh should take proper steps to control the air pollution of Chittagong city.

Keywords***:*** Air pollution; Air Quality Index; Standard particulate matter; $PM_{2.5}$; PM_{10}

INTRODUCTION
Clean air is essential to maintain the gentle balance of life on this planet, not just for humans, but wildlife, vegetation, water and soil. But at the same time polluted air, may develop more serious respiratory problems for human beings and also damage our living environment including plants and animals. Air pollution, especially in the large cities of Dhaka and Chittagong, is a major environmental hazard in Bangladesh. There are two major sources of air pollution in Bangladesh, vehicular emissions, and industrial emissions (M. S. Islam. 2014). These are mainly concentrated in the cities. Other than those there are many brick-making kilns operated seasonally, mainly in dry season all over Bangladesh. More or less all of these kilns use coal and wood as their prime sources of energy resulting in the emission of particulate matter, oxides of sulfur, and volatile organic compounds.

Chittagong city is situated on the right bank of the river Karnaphuly. There are various sources of air pollution in Chittagong city, among them unfit vehicles and industries are notable. The numbers of mostly reconditioned vehicles are increasing in every year. One third of these vehicles do not have any fitness certificate. Due to port facility, this city is attractive for the investors to build up industry. A number of 'Export Processing Zones (EPZ)' has been established by the local and foreign investors (BBS, 2010). Most of the industries are not following the environmental rules and regulations. Along with this many urban areas and shopping and recreational facilities are present within the boundary of the study area considered where human exposure to air pollution caused by vehicular induced turbulence. Though green landscape around Chittagong city and monsoon heavy rainfall helps to reduce the intensity of air pollution, a significant change in land uses and human intervention aggravate the degradation of air quality (Rouf et al., 2012).

The influence of poor ambient air quality on human health, agricultural production and damage to materials has been well documented in developing and developed countries. The children, elderly people or the people with heart or lung diseases when breathe polluted air may build up more serious respiratory problems. An estimated 15,000 premature deaths, as well as several million cases of pulmonary, respiratory and neurological illness are attributed to poor air quality in Dhaka, according to the Air Quality Management Project (AQMP), funded by the government and the World Bank (IRIN, 2009). The yearly economic loss associated with these health problems could range from a low estimate of $60 million to a high estimate of $270 million, equivalent to 1.7to 7.5% of the city's gross product (Rahman, S.M. 2010).

AIM & OBJECTIVES OF THE STUDY

The main objective of this study is to know the present air pollution condition of Chittagong city. However the individual objectives are listed as determination of the concentration of various pollutants like SOx, NOx and SPM, determination of the Air Quality Index (AQI) value, variation of Air Quality with meteorological parameters & comparison of all the parameters with standards.

METHODOLOGY

An air quality index (AQI) is a number used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. (https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf) The AQI category and health effect statement according to United State Environmental Protection Agency (USEPA) are described in Table 1.

The index for a pollutant is calculated using the mathematical expression:-

$$Ip = [(I_{Hi} - I_{Lo})/ (BP_{Hi} - BP_{Lo})]*(C_p - BP_{Lo}) + I_{Lo}$$

Where, I_p = the index value for pollutant P;

C_p = the truncated concentration of pollutant P;

BP_{Hi} = the breakpoint that is $\geq C_p$;

BP_{Lo} = the breakpoint that is $\leq C_p$;

I_{Hi} = the AQI value corresponding to BP_{Hi};

I_{Lo} = the AQI value corresponding to BP_{Lo};

Table1. Effects of Air Pollutants According to AQI (USEPA)

AQI Values	Description	Color code	Health Effects Statement
0-50	Good	Green	None
51-100	Moderate	Yellow	Unhealthy sensitive people should consider reducing prolonged or heavy exertion
101-150	Unhealthy for Sensitive group	Orange	Increased likelihood of respiratory symptoms in sensitive individuals
151-200	Unhealthy	Red	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly
201-300	Very Unhealthy	Purple	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.
>300	Extremely Unhealthy	Maroon	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.

RESULTS AND DISCUSSIONS

The average AQI of the year 2013, 2014 and 2015 is 127, 132 and 133 respectively. This is the indication of increasing air pollution in Chittagong city. Fig.1 to Fig. 3 represents the daily AQI trend from 2013 to 2015. In almost 90 percent cases the responsible pollutants for AQI calculation is $PM_{2.5}$.

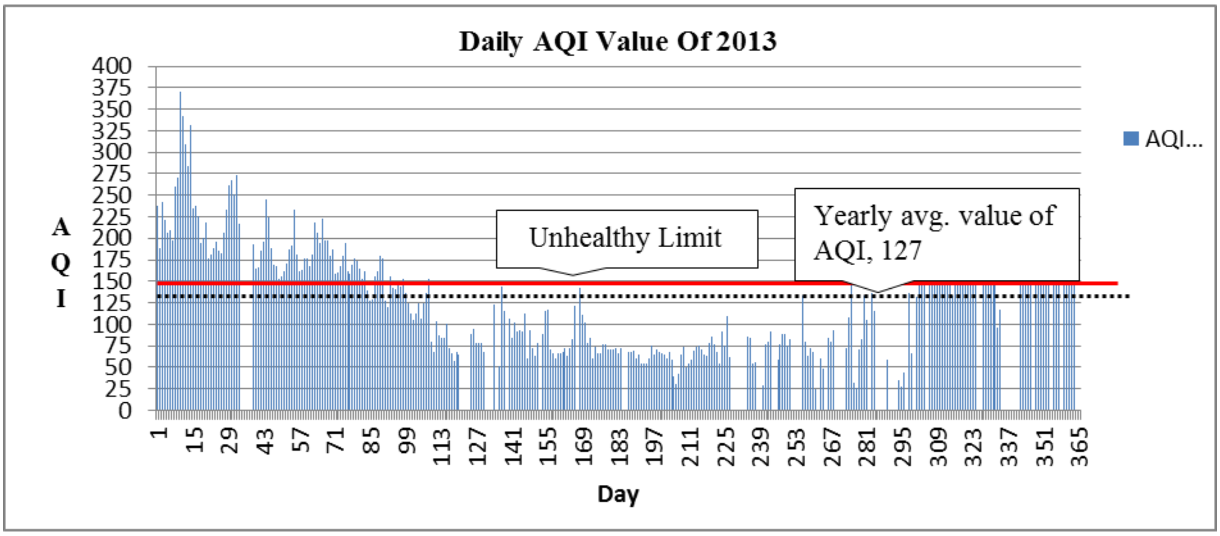

Fig 1: Daily AQI for the year 2013

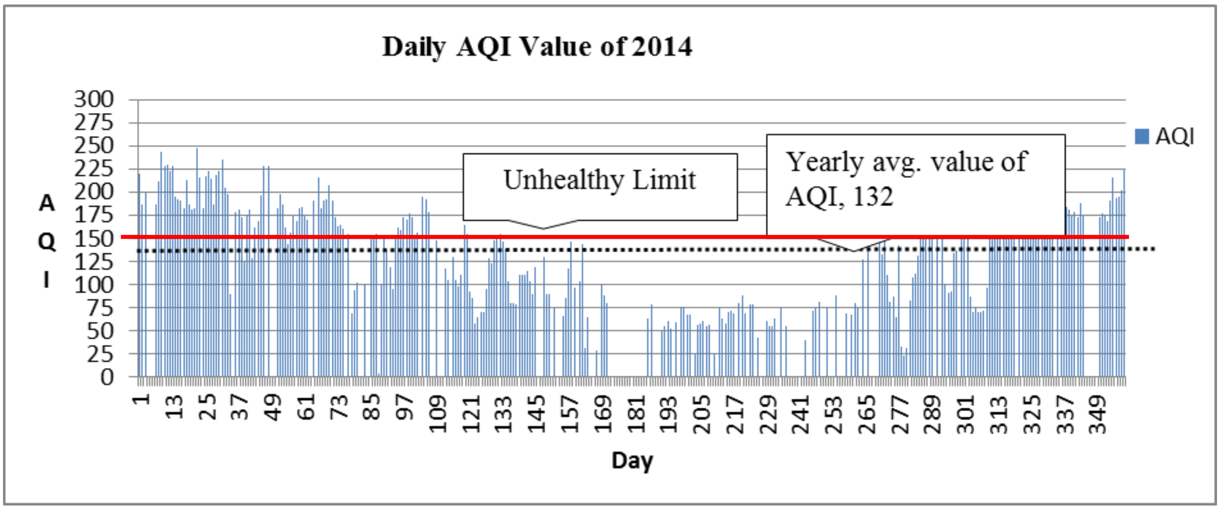

Fig 2: Daily AQI for the year 2013

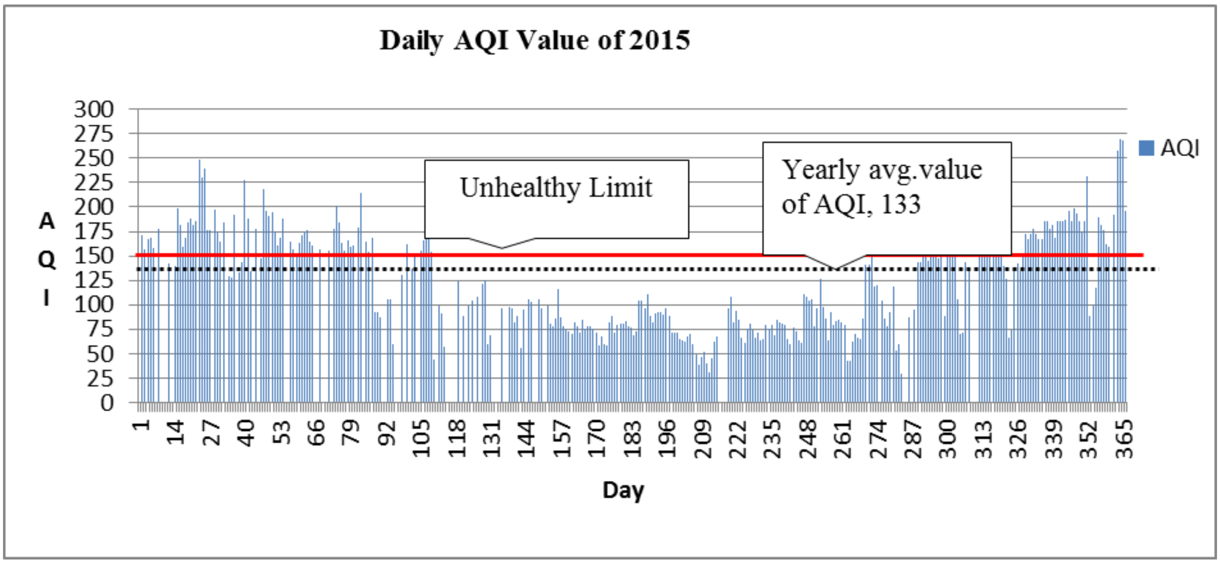

Fig 3: Daily AQI for the year 2013

The pollutants concentration largely depends on meteorological parameters. When the rainfall and wind speed is high specially in monsoon period the concentration of PM2.5 decreases. The time series plot of PM2.5 and metrological parameter presented in Fig 4 to Fig. 6, shows temporal (daily) variation of PM2.5 concentration with the change of intensity of metrological parameter over the sampling period. During monsoon period when rainfall and wind speed is high the concentration of $PM_{2.5}$ dwindles gradually. The middle portion of figure shows the lower concentration of $PM_{2.5}$. Here only the variation of $PM_{2.5}$ concentration with the change of meteorological parameters shows, because from study we found that in almost all the cases $PM_{2.5}$ is the responsible pollutants for AQI.

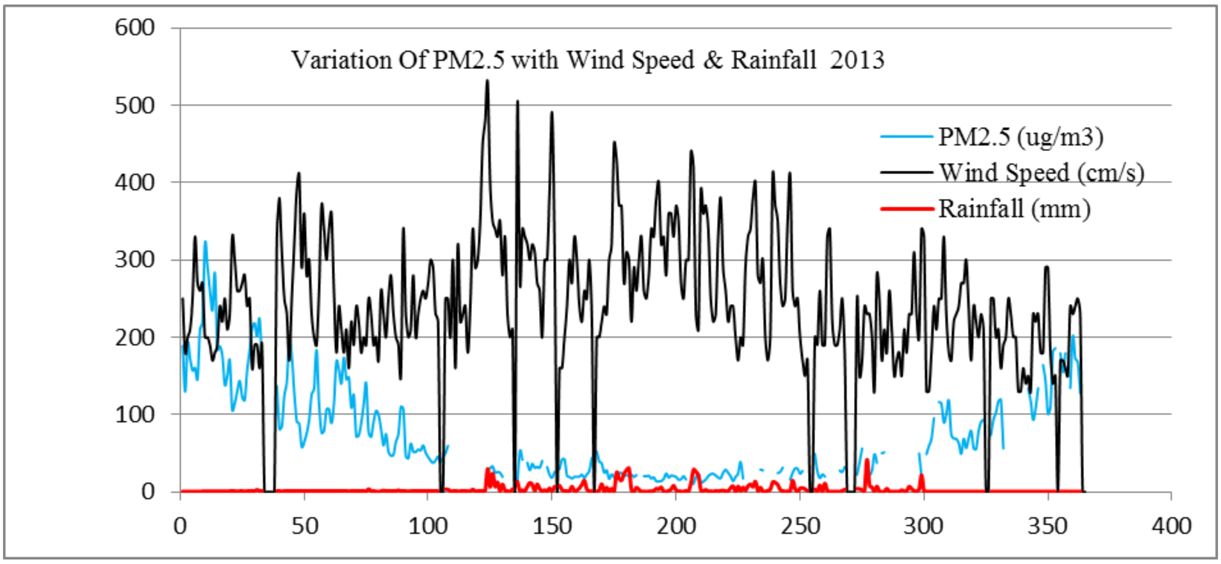

Fig. 4: Temporal (daily) variation of PM2.5 concentration with variable wind speed & rainfall in 2013

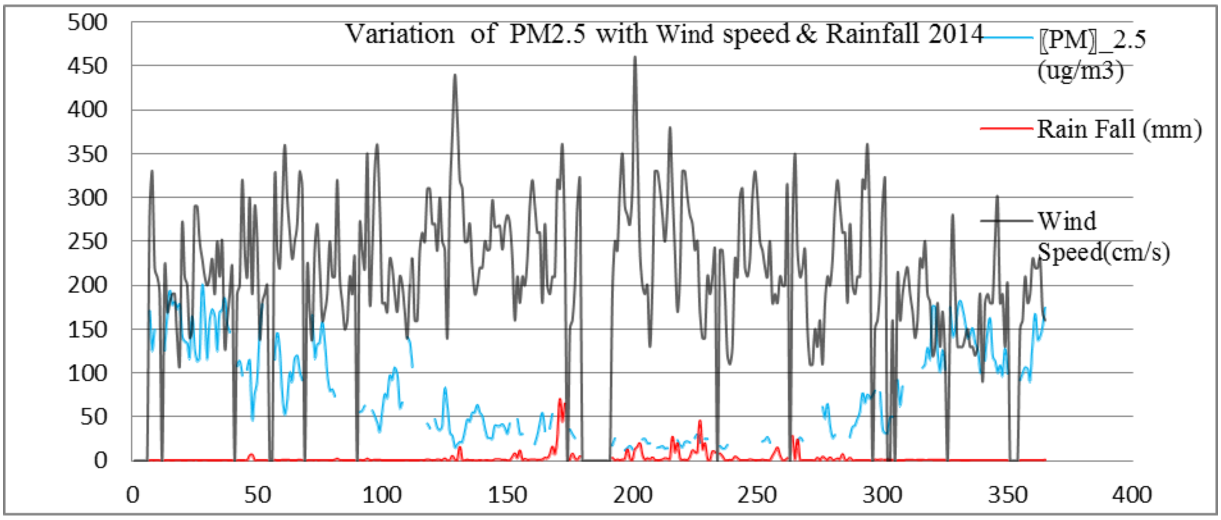

Fig. 5: Temporal (daily) variation of PM2.5 concentration with variable wind speed & rainfall in 2014

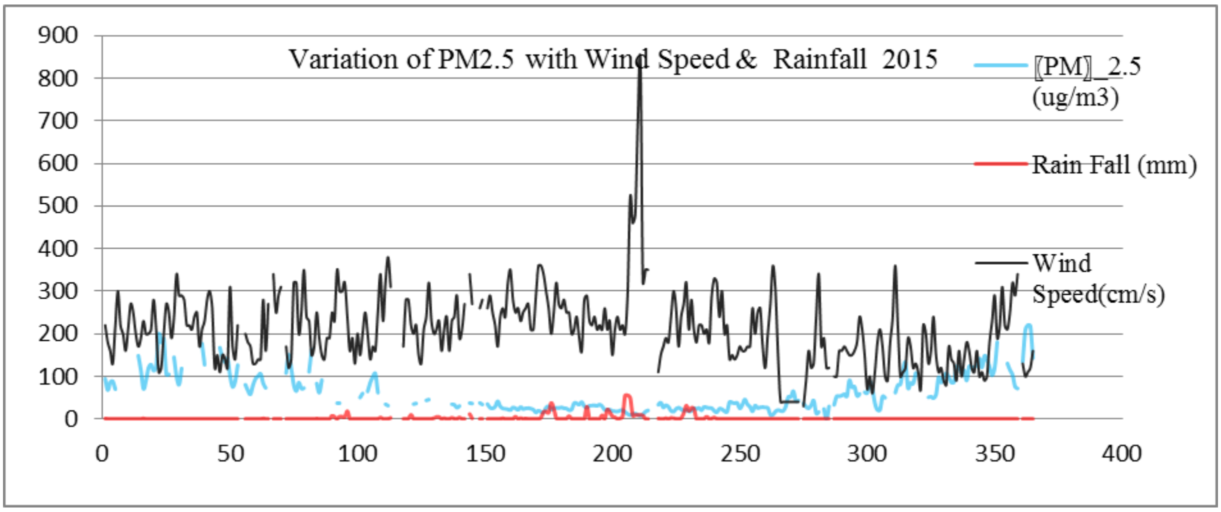

Fig.6: Temporal (daily) variation of PM2.5 concentration with variable wind speed & rainfall in 2015

Table 2 shows the concentration of various pollutants at some specific location of Chittagong city. The concentration of SPM exceeds both the national and international standards.

Table 2. Concentration of SO_x, NO_x, and SPM at three locations of Chittagong

Location	Date	SO_x(μg/m^3)	NO_x(μg/m^3)	SPM (μg/m^3)
Agrabad, Ctg.	20/05/15	64	40	520
New Market, Ctg.	10/06/15	56	32	410
A.K. Khan gate, Pahartali, Ctg.	05/08/15	….	….	250
Standard as per ECR 2005 in Bangladesh		Below 100	Below 80	Below 200

CONCLUDING REMARKS

Air pollution is an increasing threat to modern civilization. Due to the people's tendency to being modern and civilized urbanization and industrialization increases rapidly and a large variety of vehicles also increases. This large variety of vehicles causes large concentration of emission, which causes air pollution.

It has been found that the concentration of Standard Particulate Matter (SPM) in Agrabad, New Market and A.K. Khan Gate, Pahartali, Chittagong are 510,420 and 250µg/m^3, respectively, which was significantly higher than the standard value. From all the analysis it is clear that the air pollution in Chittagong city is lower during the month April to September due to rainfall and wind speed. The average Air Quality Index (AQI) value of year 2013, 2014 and 2015 are 127, 132 and 133 respectively, which means the average yearly air pollution condition in Chittagong city is unhealthy for sensitive group, according to USEPA. Almost all the cases the responsible pollutants for AQI value is $PM_{2.5}$. Therefore, it is suggested that if the generation of anthropogenic particulate matter can control, the air pollution in Chittagong city will be predominantly reduced.

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ENVIRONMENTAL IMPACT ASSESSMENT OF THE MURADPUR TO LALKHAN BAZAR FLYOVER BY LEOPOLD MATRIX & BATTELLE METHOD

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ABSTRACT

An efficacious transportation system is one of the pivotal prerequisites for the development of any sort of fast growing city like Chittagong, which is the commercial capital of Bangladesh. To foster the development as well as to ease the traffic congestion problem of this second largest city of Bangladesh, the Chittagong development Authority (CDA) has taken the initiative to construct Muradpur to Lalkhan Bazar Flyover. In this regard, the study focuses on the assessment of possible impact of the flyover on environment in order to promote sustainable development. The study is based on primary data which are analysed by using Leopold Matrix and Battelle Method to assess the possible impact of the aforementioned flyover. The findings show that the project will have the negative impact on the environment i.e., increased CO2, sound pollution, vibration, dust particles emission, traffic congestion etc. during construction and to mitigate those impacts some measures are recommended.

Keywords: Environmental Impact Assessment; Leopold matrix; Battelle method

INTRODUCTION

The frequent improvement in city infrastructure and rapidly increasing vehicular traffic, the infrastructure of road is severely affected. So, the vehicular speed is decreased significantly in the various roads, while put its junctions in serious pressure (Wilbur Smith Association, 2010). Where round about is not feasible due to space constraint than the construction of flyovers over congested traffic roads is considered an effective way of ensuring smooth traffic flow and avoiding unnecessary delays (Goyal et. all, 2008). The traffic congestion along the large circles such as GEC circle, 2 no gate, Muradpur and WASA are facing sever traffic congestion. So, cutting this congestion the Chittagong Development Authority (CDA) is built this Muradpur to Lalkhan bazar flyover (CDA, 2014). Environmental impact assessment (EIA) is done to assess the effects likely to arise from a major project (like flyover, road construction) significantly affecting the environment. It will ensure the sustainable development through sustainable form of development with several key issues (Glasson et al., 2005). The study will examine the impact of the flyover on environment impact in order to promote sustainable development with the help of Leopold matrix and Battelle method.

METHODOLOGY

The flyover project has several environmental impacts on its surrounding environment, society and wildlife. To assess the range of impact participatory approach has been applied so that, the affected groups can be easily identified. Further the causes and effect diagrams have been created using the perception of the respondents using these diagrams the primary and secondary affected group has been identified (Kumar, 2001). The Leopold matrix has been used to predict the impact on environment due to project activities. The matrix constituted is two dimensional for cross referencing. The project activities are kept in one axis and the environmental parameters were kept in another axis. The environment and social conditions are divided in three major groups. These are physical, biological and social environment. Physical environment are soil, water, air, noise and waste. Biological environment are birds, forest, wetland habitat and nuisance plant and the social environment are streetscape, employment, navigation, commercial facilities, service and utilities, industrial activities, land value, landscape and occupational safety. Environmental impacts due to flyover construction from start to finish, has been evaluated on project planning and design phase, construction phase and operation and maintenance phase. To assess the environmental impact there three steps has been followed. The boxes mark the corresponding boxes in the matrix with a diagonal line then the boxes with supposed significant interactions are slashed, the author evaluates each box by applying a number from 1 to 10 (1 is the minimum and 10 the maximum) to register the magnitude of the impact. In the final step is to calculate the real importance of the phenomenon. By this way the connection with the environment and which particular elements are particularly significant has been evaluated. The data has been collected through the questionnaire survey from the project spot and got them input on Microsoft excel for data processing to calculate environmental quality for indicator 'i' with project and without project then relative weight for the indicators has been calculated. The environmental impact unit values has been further calculated by using The Batelle method where the environmental impacts is split in major three categories. Which are Biological, Physio-chemical and Human interest (FAO, 2016)

$$EIU = \sum_{i=1}^{m} (Vi)_1 W_i - (Vi)_2 Wi \qquad (1)$$

Where,

$(Vi)_1$ =environmental quality for indicator "i" in the project conditions
$(Vi)_2$ =environmental quality for indicator "i" without the project
Wi =relative weight of the indicator "i"
m =total number of indicators

STUDY AREA

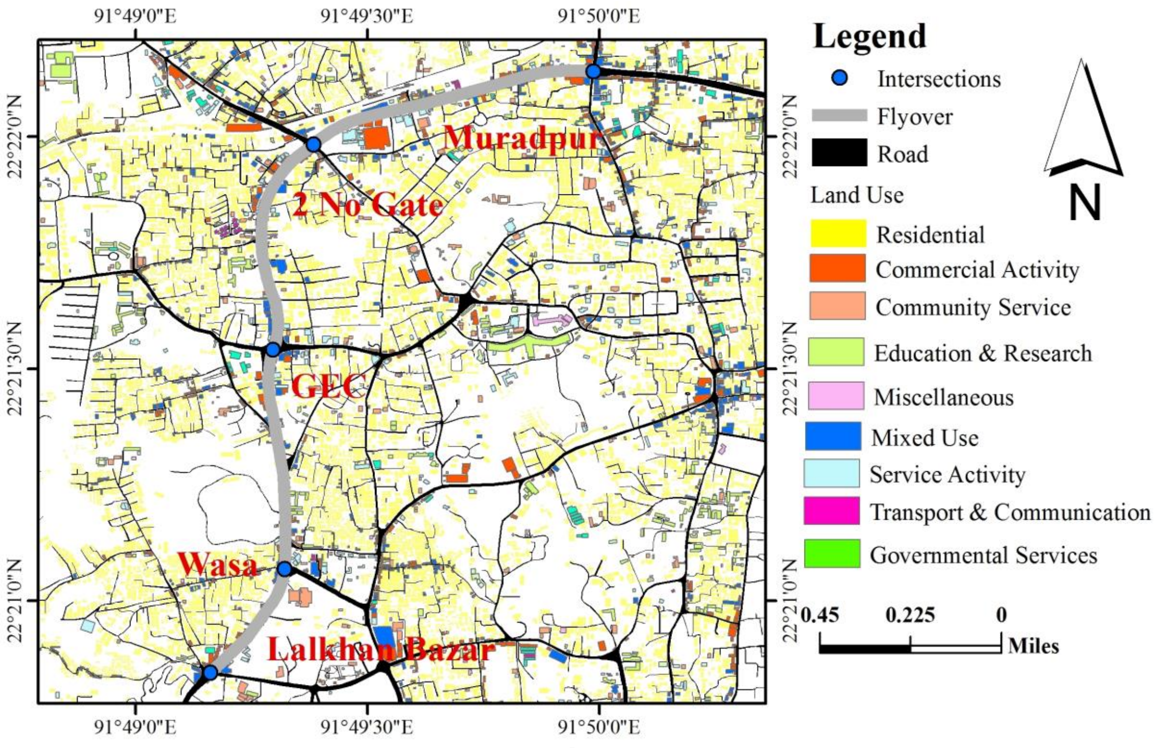

Fig. 1: Study Area Map

The flyover project named as Akhteruzzaman flyover which length is 3.5km and width is 17.5 meter with four lanes. The length of the loop is 1.7km and width designed as 7.5m, two lanes. The proposed construction cost has been declared as 15070.57 lakh taka founding partially by GOB, CDA. The project construction starter on july 2010 and estimated to be finished was 2013. The construction work has been seen ongoing process. According to the declaration of DOE, the project falls under Orange-B category with having several negative impacts on environment.

RESULTS AND DISCUSSIONS

Overall impact identification and prediction on environment

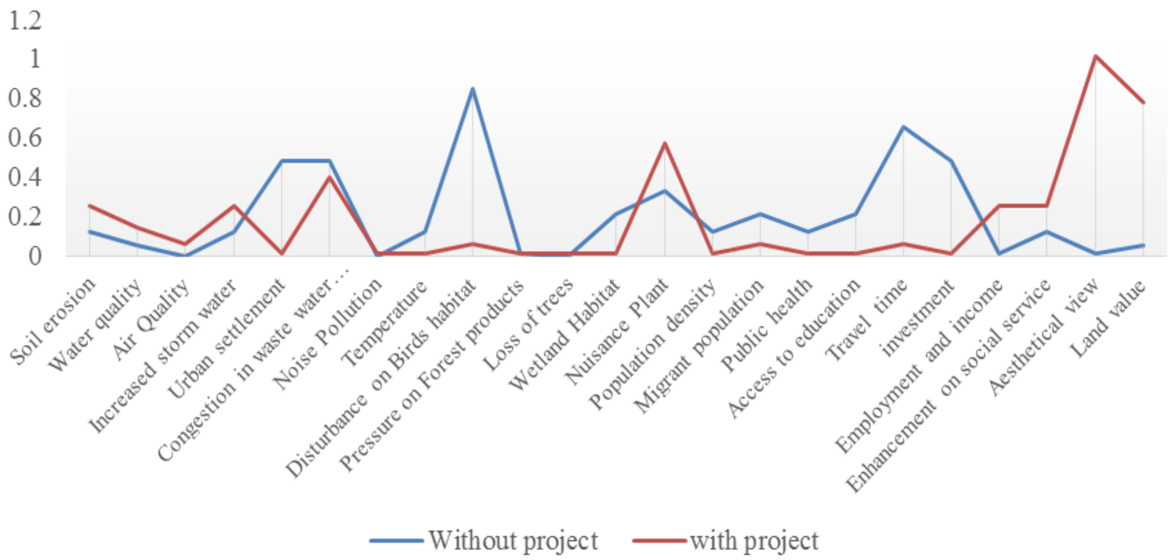

Fig. 2: Overall impact on environment by with project and without project

To assess Impact of the project, questionnaire survey has been conducted in study area. The survey data has been compiled with the help of Leopold metrics and further got input on Microsoft excel software. The value for with project and without project has been calculated by impact value metrics where positive signs are used for positive impact and negative sign indicates negative impacts. The value of Vi is achieved by summing up the impact values from the Leopold metrics. The value of Wi has been gained by multiplying the values of Vi by its corresponding weights. The value of ViWi is further plotted on the graph where two different ViWi value has been gained. One for with project and another from without project. These were outputs from Leopold metrics and further used as the input in Battelle method where the value of overall impacts is been found as negative (- 0.45333). This means that the project has overall negative impact on environment.

$$EIU=4.333-4.786667= -0.45333$$

On observing overall impact on environment due to project implementation the soil erosion has been increased, air quality degraded, more storm water entered into the drainage system, caused several disturbances on existing urban settlements, temperature has been increased, bird's habitat has been destroyed, public health also deteriorated due to project construction. When construction has been finished, employment and income enhancement in social services, aesthetical values and land value has been increased.

Causes and effect diagrams

On the way of construction of flyover, air pollution has been raised up due to several project activities. Burning of fossil soils, more carbondioxide and emission of sulfur dioxide, household cleaning etc has been working as the source of air pollution which causing the significant effect on vegetation growth, human health and wild life on the hills where human health causing short term and long term effects by causing several diseases on human body such as heart attacks, respiratory heart problem, asthma, pneumonia etc.

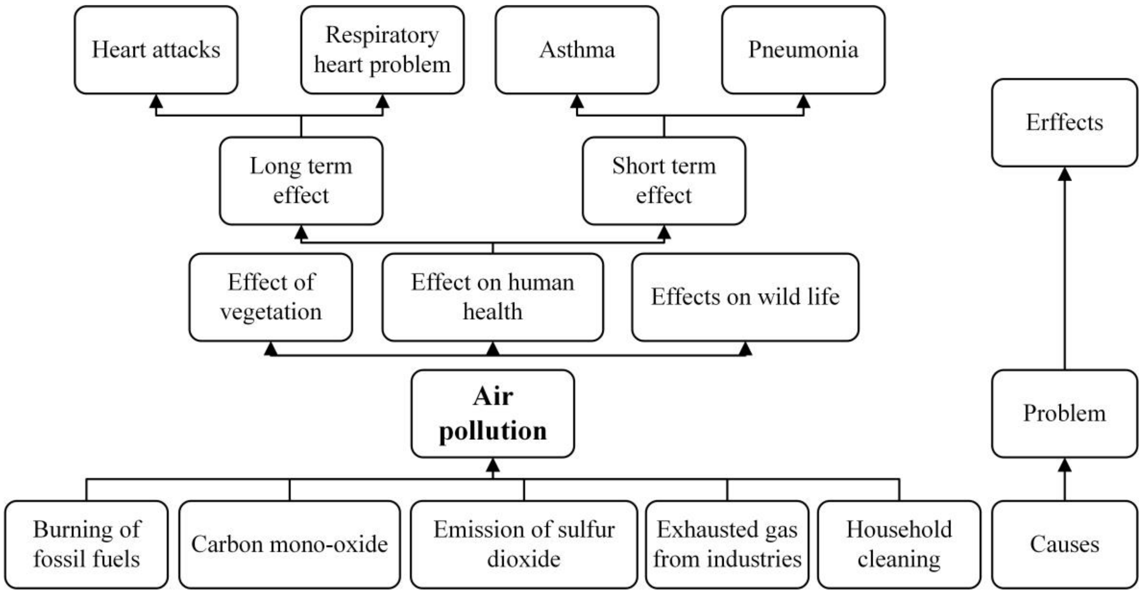

Fig. 3: Cause effect diagram of Air Pollution

Another significant environmental pollution has been raised up known as noise pollution. For several construction activities, transportation, social events, household chores etc are worked as the source of noise pollution which created the effect on human health and wildlife by causing hearing problem, sleeping disturbances, blood pressure level, psychological problem, trouble communication etc.

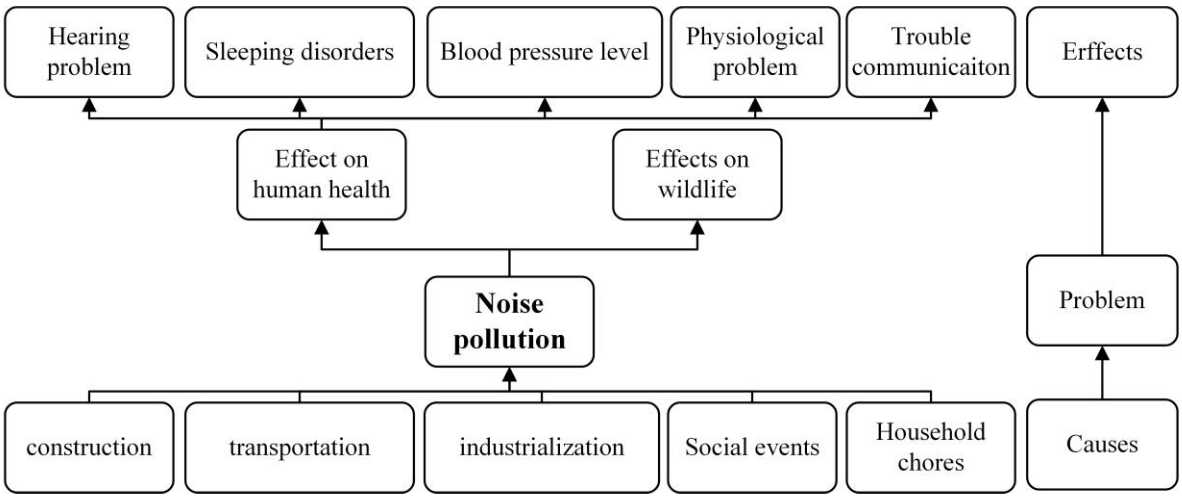

Fig. 4: Cause effect diagram of Noise Pollution

While implementing the project there are several changes in environment has been observed which causes are Lack of solid waste management can cause atmospheric pollution, lack of sanitation facilities creates different types of diseases which is harmful for human health, limited aware ness of environmental issues are responsible for atmosphere pollution, earth cutting & filling, uncontrolled discharge of polluting effluents of surface water and cutting down trees can formulate atmosphere pollution which causing the several types of effects on environment which are, increased health risk, decrease quality of human life, pollution increases chemical particles to air and Water pollution can be divided into two types such as drinking and low quality of irrigation water.

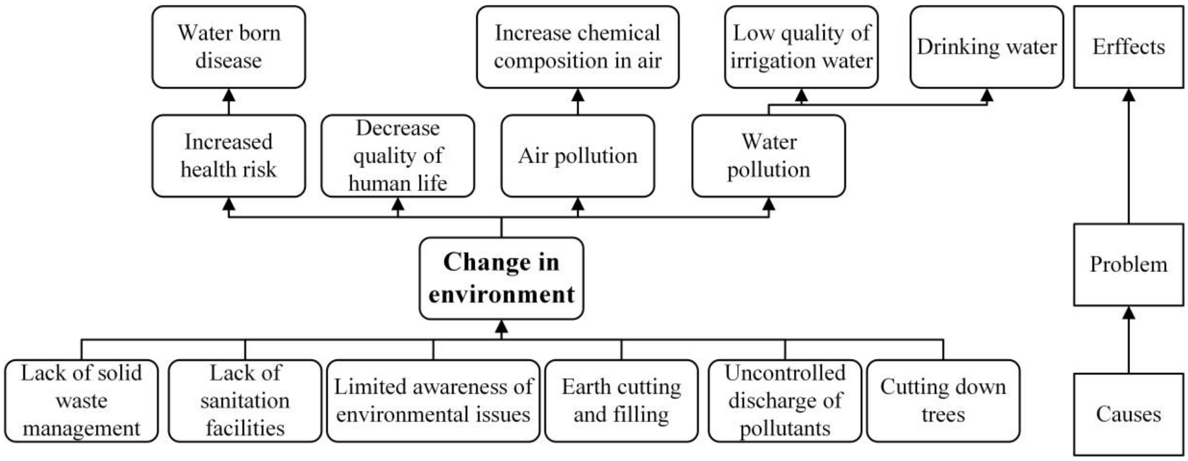

Fig. 5: Cause effect diagram on change in environment

ENVIRONMENTAL MANAGEMENT PLAN

Environmental management is an essential tool in relation to environmental management as it provides the basic information for rational management decisions. The provided information on the actual nature and extent of key impacts and the effectiveness of the mitigation measures which, through a feedback mechanism, can be taken into account in the planning and execution of similar projects in future.

Table 1: Environmental monitoring Plan during operation and maintenance period

Impact	Means of Monitoring	Frequency of Monitoring	Location	Implementing party
Accident	Ensuring traffic sings, road mark, bump, zebra mark, guard rail and pole, and curb stones etc. to be properly	Annually	On And below road of the flyover	Supervisor: RHD, Reviewer: Consultant, PAPs, Performer: Contractor
Air Pollution	Measurement of SPM, NOx, SO2, CO	Monthly	On And below road of the flyover	Supervisor: RHD, Reviewer: Consultant, PAPs, Performer: Contractor
Noise Pollution	Measurement of noise dB(A)	Quarterly	On And below road of the flyover	Supervisor: RHD, Reviewer: Consultant, PAPs,
Waste Disposal	Minimize volume to use silt basin before disposing	Daily	On And below road of the flyover	Supervisor: RHD, Reviewer: CCC, Consultant, PAPs,

CONCLUSIONS

There is no alternative to reduce traffic jam of the Chittagong city this flyover is become the first priority. It will reduce traffic jam of GEC circle, 2 no gate, Muradpur and WASA circle. Although, this project has some negative impact on its surrounding environment. Finally, this flyover project categorize into red category. So, the report guides those procedures of project activities so that there is least amount of negative impact on environment which reduce economic loss so as to ensure sustainable development. There also respective authorities assigned with schedule and responsibilities to take action to mitigate the negative impacts of the project. This management measures which comes from feedback, can be taken into account in the planning and execution of similar projects in future.

ACKNOWLEDGMENTS
At first all praises belong to Almighty Allah, the most Merciful, very kind to man and his action. We would like to express our gratitude to our parents and other family members from the core of our heart for their love. This dissertation is done as a departmental project work of Environmental Planning and Management Studio. We want to specially thank to all of our friends for helpful and provide encourage to accomplish the dissertation. There is no word to express our profound gratitude and indebtedness to our teacher of Dept. of URP, CUET for their valuable advice, comments, sympathetic co-operation and systematic guidance at all stages of this field work & this report. Finally, our special appreciation goes to all the dwellers of the Chittagong city for their response and co-operation provided during the survey work.

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WATER QUALITY ASSESSMENT OF "KARNAFULLY" RIVER FROM SHIKALBAHA POWER STATION TO THAI FOOD KHAL DURING FLOOD TIDE AND EBB TIDE

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ABSTRACT

Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. Water quality is the key of environmental concern because of its important provision of water for drinking and domestic purpose, irrigation and aquatic life including fish and fisheries. In the Chittagong city and surrounding area of the Karnafully River are polluted by faecal contamination, saline instruction, as well as by agro – chemical, industrial waste and large amount of suspended sediment carried out by upstream flow to the Bay of Bengal through the Karnafully river. Surface water quality is likely to be deteriorated further in future industrial activity intensifies, disperses and agricultural extend abundantly with the increase of population. To investigate water quality of Karnafully river which is locate in Chittagong district, samples are collected about from 200 m up stream and 200 m downstream from the connecting cannel of the Karnafully river in both condition (flood and ebb tide) and tested by standard methods analysed subsequently. From the analysis of water quality parameters a conclusion can be added either the water can be used for drinking, domestic and irrigation purpose or not.

Keywords: Karnafully river; industrial activity; surface water quality; water quality parameters; upstream; downstream

INTRODUCTION

Water pollution is a phenomenon that is characterized by the deterioration of the quality of water as a result of various human activity1. There are other minor sources that contaminate surface water extensively2.

The Karnafully, Halda and other rivers of Chittagong division are showing gradual decline in water quality. The water quality of Karnafully river is degrading day by day as industrial wastes are dumped directly without going through any purification process. According to Ahmed 3, Sylhet pulp and paper mills at Chhatak, Karnafully paper mills at Chandragona, Fertilizer factory at Fenchugonj and Ghorashal, Hazaribag tanneries in Dhaka contributed to the depletion of fisheries resources of Surma, Karnafully, Kushiara, Sitalakhya and Buriganga Rivers, respectively. The USA National Water Commission stated that water gets polluted if it has been not of sufficiently high quality to be suitable for the highest uses people wish to make of it at present or in the future4. Usually these waters do not remain fit for human consumption and for the life of plants and animals5. There are many waste products of industries which is potentially dangerous to the enviromnent. In Bangladesh a few of the different industries treat their effluent before discharging it in the environment. Any stream has its own self-purification process. But if the pollutant is more enough then stream self-purification system will not work. These types of polluted water cannot be used for drinking, domestic and irrigation purposes. So it is required to assess the quality of Karnafully river water either it is up to the mark for using those purposes.

The objectives of this study are:

1) To determine the causes that how Karnafully river is getting polluted day by day.
2) To determine the various essential physical and chemical parameters to assess the water quality of Karnafully river from Shikalbaha Power Station to Thai Food Khal during flood tide and ebb tide.

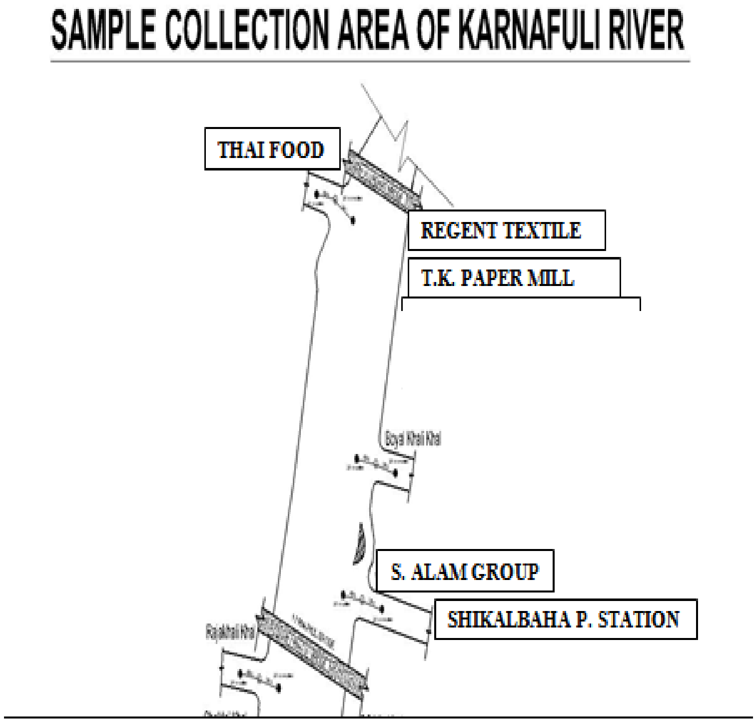
3) To compare the results with the Bangladeshi standards.
4) To predict the environmental effects of emerging man-made contamination.

METHODOLOGY

- ➢ The whole study area (from Shikalbaha Power Station to Thai Food Khal) is surveyed. How the water gets polluted is analyzed firstly. The industries located beside the river are identified.
- ➢In this study the samples are collected from 05 stations (from intake point to 200m up and 200m down) at Karnafully river during flood tide and ebb tide.
- ➢Among the various parameters 10 water quality parameters are tested.

Collection of samples

Surface water samples from different places of karnafully river were collected for study. A cross sectional descriptive study was conducted in karnafully river. Data collected from towards of bay of bangle to captain lake by cluster sampling in this area we have collected the samples from 05 stations. Samples were collected in amber color 1.5L plastic bottle cleaned by rinsing thoroughly with 8M HNO_3,followed by repeated washing with distilled water. the surface water samples were collected under one meter below from the water surface. Before and after the sample collection, the cap was locked sufficiently so that no air space can be remained inside. Proper labeling was made in each sample by monitoring the name and the location of sampling side, date, and time of collection. Samples were collected early in the morning and in the afternoon in high tide and low tide. The collected water samples were immediately to the laboratory of the Mohara Water Treatment plant for the analysis.



RESULTS AND DISCUSSIONS

Table 1: Water quality of the Karnafully River at different locations

	Water Quality Parameters(Concentration Present)									
Name of the station	pH	Iron (mg/l)	Electrical Conductivity (EC) at 25^0 C(µS/cm)	DO (mg/l)	Total Hardness (as $CaCO_3$) (mg/l)	BOD (mg/l)	Salinity (mg/l)	TDS (mg/l)	Temperature (˚C)	Alkalinity (mg/l)
1.1Shikalbaha Power Station ;(Flood Tide-200 m Up-Stream)	6.25	0.43	17936	3.95	768	121	7.2	9075	26	10
1.2 Shikalbaha Power Station;(Flood Tide-200 m Down Stream)	7.33	0.75	17725	3.86	689	128	6.8	8986	26	31.90
1.3 Shikalbaha Power Station ;(Ebb Tide-200 m Up-Stream)	6.75	0.40	17690	3.92	794	134	6.9	9121	26	12
1.4 Shikalbaha Power Station;(Ebb Tide-200m Down Stream)	6.29	0.49	17886	3.98	698	138	6.7	9052	24	38.90
2.1 S.Alam Khal ;(Flood Tide-200m Up-Stream)	6.30	0.52	18570	2.98	580	212	6.8	9386	26	12
2.2 S.Alam Khal ;(Flood Tide-200 m Down-Stream)	7.39	0.77	18486	2.87	654	198	6.5	9475	26	29.4
2.3 S.Alam Khal ;(Ebb Tide-200 m Up-Stream)	7	0.43	18181	2.92	545	218	6.7	9275	26	12.7
2.4 S.Alam Khal ;(Ebb Tide-200 m Down-Stream)	6.15	0.37	17995	2.89	570	216	6.6	8891	24.6	38.90
3.1 T.K.Paper Mill Khal;(Flood Tide-200 m Up-Stream)	6.35	0.28	19220	1.59	675	348	6.8	10510	26	14
3.2 T.K.Paper Mill Khal ;(Flood Tide-200 m Down Stream)	7.19	0.69	19650	1.45	693	356	6.8	9831	26	37.2
3.3 T.K.Paper Mill Khal ;(Ebb Tide-200 m Up-Stream)	7	0.34	19524	1.42	690	352	6.7	9512	26	15.6
3.4 T.K.Paper Mill Khal ;(Ebb Tide-200 m Down-Stream)	7.25	0.72	19675	1.56	702	349	6.5	10317	24	33.9
4.1 Regent Textile Khal ;(Flood Tide-200 m Up-Stream)	7.08	0.67	19171	1.02	745	393	6.7	10491	26	122.8
4.2 Regent Textile Khal ;(Flood Tide-200 m Down-Stream)	7.12	0.48	19386	1.12	695	389	6.6	10120	26	27.2
4.3 Regent Textile Khal ;(Ebb Tide-200 m Up-Stream)	8.2	0.56	19532	1.08	768	387	6.7	10328	26	124.2
4.4 Regent Textile Khal ;(Ebb Tide-200 m Down-Stream)	7.10	0.45	19612	1.11	688	391	6.6	9895	24	26.8
5.1 Thia Food Khal ;(Flood Tide-200 m Up-Stream)	6.15	0.60	17890	2.59	759	256	6.7	9185	26	123
5.2 Thia Food Khal ;(Flood Tide-200 m Down-Stream)	7.16	0.49	17786	2.63	779	262	6.6	8372	26	8.67
5.3 Thia Food Khal ;(Ebb Tide-200 m Up Stream)	6.72	0.46	17699	2.57	802	266	6.8	8511	26	125
5.4 Thia Food Khal ;(Ebb Tide-200 M Down Stream)	7.59	0.58	17886	2.61	845	259	6.7	8431	24	9.76

GRAPHICAL REPRESENTATION

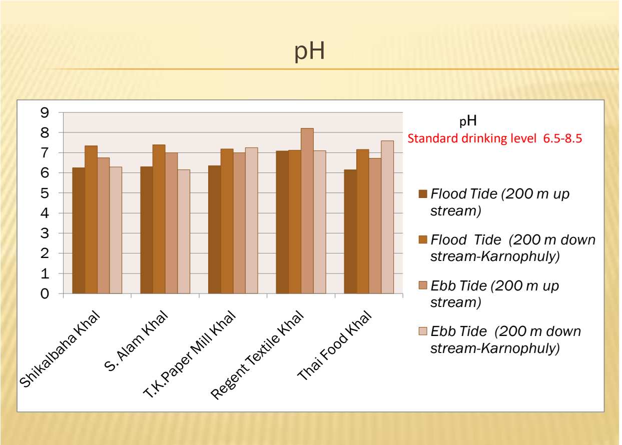


Fig.1: Variation of pH at different stations

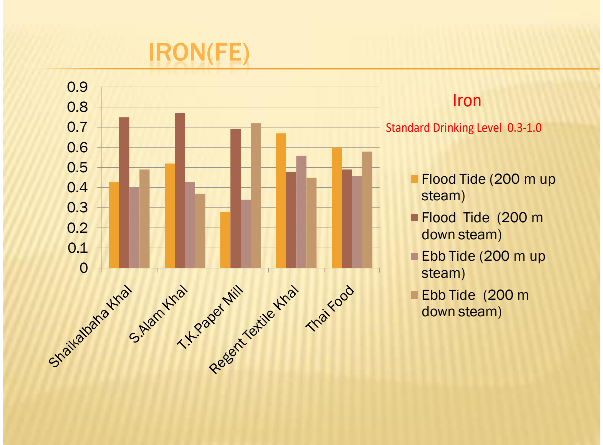


Fig.2: Variation of Iron at different stations

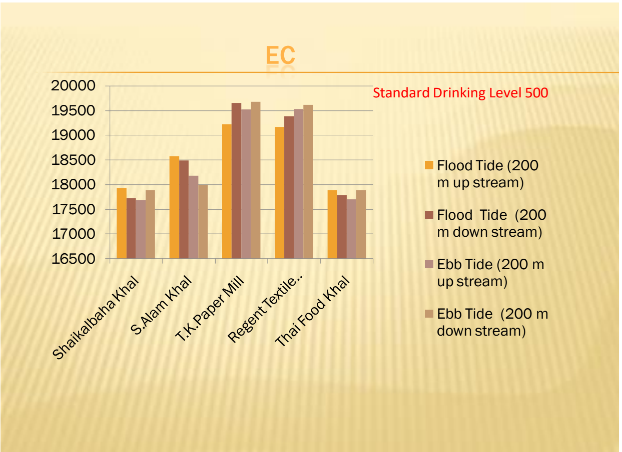


Fig.3: Variation of EC at different stations

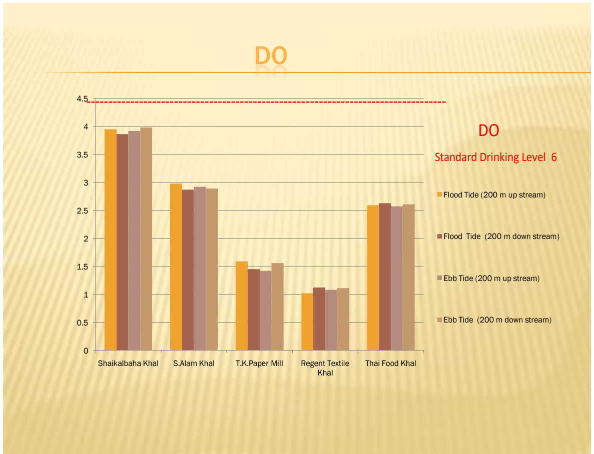


Fig.4: Variation of DO at different stations

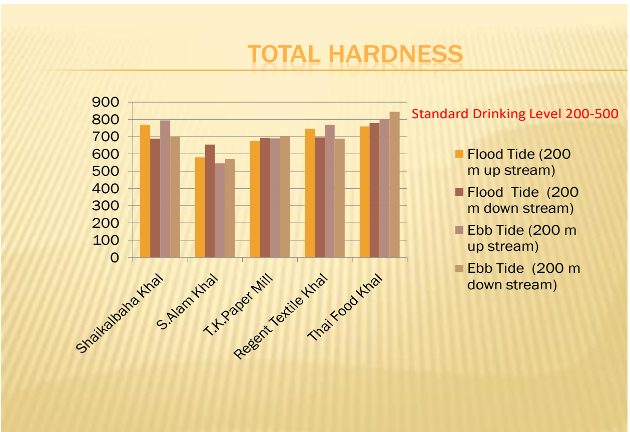


Fig.5: Variation of Total Hardness at Different Stations

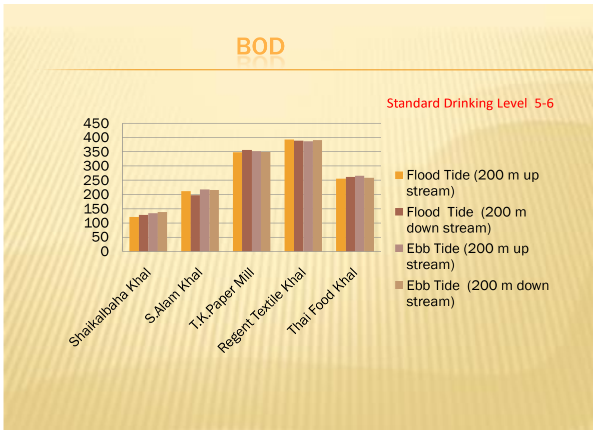


Fig.6: Variation of BOD at Different Stations

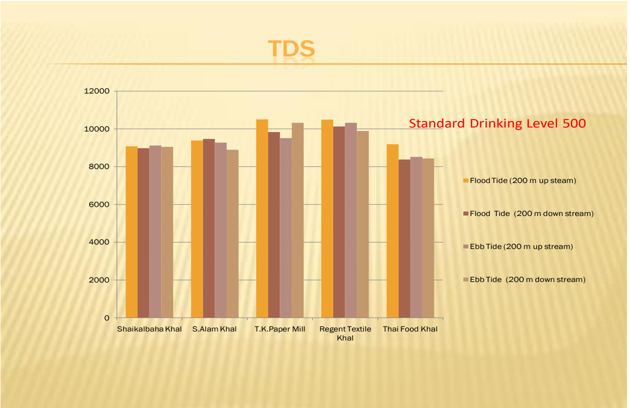


Fig.7: Variation of TDS at Different Stations

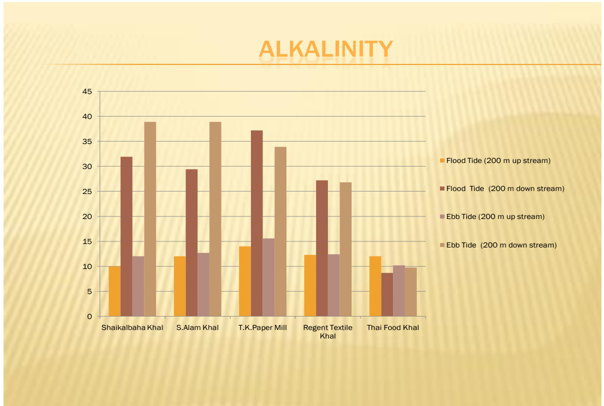


Fig.8: Variation of Alkalinity at Different Stations

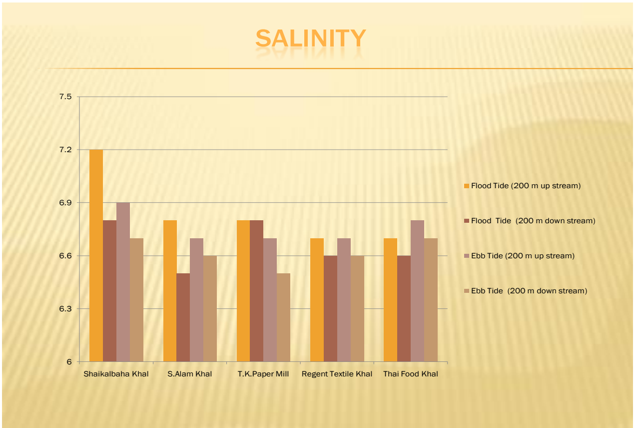


Fig.9: Variation of Salinity Different Stations

DISCUSSION

Temperature: Ambient temperature (AT) of the KARNAFULLY River water Table 1 shows that at most sampling time ambient temperature was found between 250C - 260C. Highest temperature (260C) was found at low tide.

pH: The descriptive statistics of the surface water pH value (Table 1) shows that most of the samples were found in the alkaline pH range i.e. within the CCC limit. Highest value (8-2) was found at ebb tide at Regent Textile point and lowest value (6.15) was found at flood tide at Thai Food point.

Electrical conductivity: Highest value (19675 µS cm-1) was found at T.K.Paper Mill point at low tide and lowest value (17690µS cm-1) was found ebb tide at Shikalbaha point.

Total dissolved solids (TDS): Highest value (10510 mg L-1) was found at flood tide at T.K.Paper Mill point and lowest value (8372 mg L-1) was found flood tide at Thai Food point.

Dissolved Oxygen (DO): Lowest value of DO 1.02mg/L-1 was found at flood tide at Regent Textile point and highest value of DO 3.98 mg/L-1 was found at ebb tide at Shikalbaha point.

Total Alkalinity: Highest value (38.90 mg/L-1) was found at ebb tide in at Shikalbaha point and lowest value (8.67 mg/L-1) was found at flood tide at Thai Food point.

Total Hardness: Highest value (845 mg/L-1) was found at ebb tide at Thai Food point and lowest value (545 mg/L-1) was found at ebb tide at S.Alam point.

Biochemical Oxygen Demand (BOD): This is a water quality parameter for organic mater in water, which is empirical in nature. Highest value (393 mg/L-1) was found at flood tide at Regent Textile point and lowest value (212 mg/L-1) was found at flood tide at S.Alam point. Higher values are found for most of the points except River mouth and Kaptai.

Iron: Highest value (0.77mg/L-1) was found at flood tide in the at S.Alam point and the lowest value (0.34 mg/L-1) was found at ebb tide at T.K.Paper Mill point.

Salinity: Highest value (7.2 mg/l^{-1}) was found at flood tide in at shikalbaha point and the lowest value (6.5 mg/l^{-1}) was found at flood tide at s.alam point.

CONCLUSIONS

The present physicochemical study of surface water resources of Chittagong division discloses the status of water quality of this division. It also identifies the sources and intensity of pollution load on surface water resources of this region. Karnafully, the principal river of this division is severely polluted from anthropogenic sources. From the present physicochemical study of surface water resources of the Chittagong region, it can be concluded that the condition of the Karnafully River is critical and Halda River may be affected by the polluted Karnafully River water. The Karnafully River water quality significantly varied with seasons, tide conditions and locations. From the location dependent variation it can be concluded that effect of sea water reaches up to the Kalurghat point. So there is possibility of destroying biodiversity of the Halda River by the intrusion of polluted Karnafully River water in the pre-monsoon period at high tides. Due to this, spawning of carps are decreasing gradually and lesser quantities of fish eggs are being harvested nowadays. Decreasing trend of DO of the Karnafully River water was observed. Minimum DO value found for the Karnafully River water indicates the critical condition of this river. Only tidal cycle keep the KARNAFULLY River alive. If there were no tidal cycle, the Karnafully would have been turned into a dead river like Buriganga and Turag of Dhaka. Higher BOD values found at regent textile & T.K. Paper Mill points of the Karnafully River and wastes and effluents of the industries and Chittagong City Corporation area, respectively. Higher values may be due to the washing out of fertilizer from agricultural fields and detergents used in household purposes which ultimately disposed off into the river water.

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APPLICATION OF KITCHEN WASTE IN BIOGAS SYSTEM: A SOLUTION FOR SOLID WASTE MANAGEMENT IN CHITTAGONG

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ABSTRACT

Bangladesh, a developing country, having a population over 170 million produces almost 2200-2400 ton waste per day per city. In this rapid growth in population and demand, it's becoming a challenging task to manage waste that are being produced daily by the authorities. It is estimated that solid waste generation will be 30 thousand tons/day by the year 2020 in Bangladesh. Solid waste can be a potential source of energy in the biogas plant that produces natural gas as well as electric power. In this paper implementation of kitchen waste in biogas plant is discussed to promote a well-established waste management system in this country. We conducted a study for appropriateness of kitchen waste for biogas plant in Chittagong and its potential as alternative energy source. In Bangladesh, kitchen waste contributes to about 50% of the total solid waste in urban area. Under Chittagong City Corporation, around 40 million people generate daily 80 to 85 MT organic wastes from kitchen waste. Biogas potential from these huge wastes approximates to 5100 to 5300 m^3 which can eventually use as cooking gas and also used for power generation. Utilizing kitchen waste in the biogas plant may reduce the burden of solid waste and could be one of the potential sources of renewable energy in Bangladesh.

Keywords: Solid waste management; kitchen waste; biogas; Chittagong

INTRODUCTION

Chittagong port city is not only the second largest metropolis city but also the commercial capital and economic gateway of Bangladesh and is expanding rapidly as well as experiencing huge increase in solid waste. City corporations are unable to carry out a desired level of service with the existing solid waste management system in Bangladesh. Chittagong city contributes about 15% of the total waste. It is estimated that solid waste generation will be 30 thousand tons/day by the year 2020 in Bangladesh. This incapability is managing the excess load of waste produced is creating a threat to the overall sanitation. Biogas is one of the most effective solution to get rid of the problems such as waste management, sanitation problem, excess demand of gas etc.

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. Biogas contains around 55-65% of methane, 30-40% of carbon dioxide (Gautam et al., 2008). The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ at around 55% methane content) (Ravi et al., 2013). The gas can effectively be utilized for generation of power through a biogas based power-generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility (Ziana et al., 2015).Kitchen waste is the best alternative for biogas production which contains organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several order of magnitude. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases.

Methodology

The study was conducted at five different residential areas (Chadgaon Residential Area, Eastern Refinery Colony, Jamal Khan Area, GEC Area and Tigerpass Area) under Chittagong City Corporation (CCC) of Bangladesh. The study was conducted from April to August 2016, to understand the quantitative and qualitative aspects of residential solid waste generation. The methodology adapted in this study is a combination of empirical and case study method. This study involved a review of the related literature, design of the survey plan, and implementation of the personal interview survey. A structured questionnaire was designed, pre-tested, and modified to collect household level data on socioeconomic and daily solid waste traits. Data were also collected through both direct observations and interviews with household members to find out the amount of kitchen waste generated in Chittagong city and also find out the composition of kitchen waste generated from a selected areas in Chittagong city. Adequate calculation also has been done to find out the amount of biogas produced from these waste and also the amount of LPG gas that can be reduce by using biogas.

Result and Discussion

Household waste mainly consists of kitchen waste. It can be divided into food leftovers and peelings or pieces of vegetables and fruits. The food leftovers consisted of rice, pieces of meat, vegetable, potato chips, and fish residue. Orange and banana peelings were also merged into the food remains. Fruit and vegetable waste was also obtained during the waste collection period. A Map of the selected residential areas is given below.

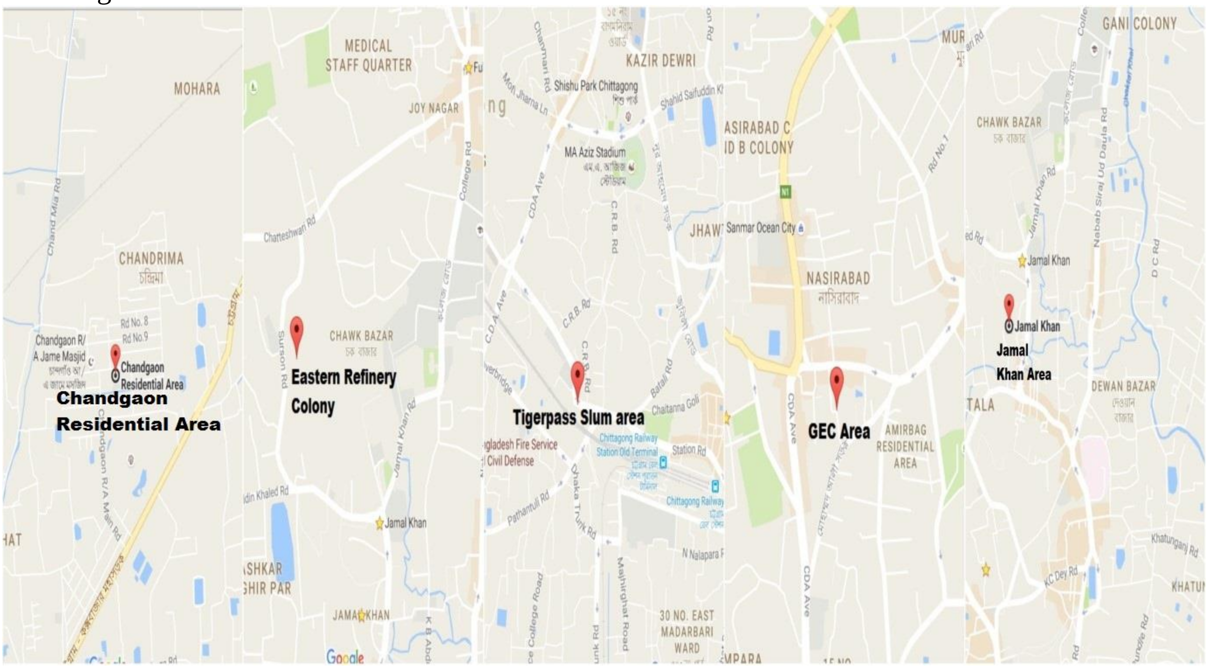

Fig.1: Selected study area

Obtained kitchen waste generation in different types of residential areas and composition of kitchen waste is listed in the Table 1 and Fig.2.

Table 1: Kitchen waste generation rate in Chittagong City Corporation

Sample area Type	**Locations**	**Population**	**Mass (kg)**	**Generation Rate (kg/c/day)**
Residential Area	Chadgaon Residential Area	51	15	0.29
Colony	Eastern Refinery Colony	459	112.16	0.24
Apartment	Jamal Khan Area	53	16.4	0.31
Unit Family Dwelling	GEC Area	16	5.6	0.35
Slum	Tigerpass Area	10	2.3	0.23

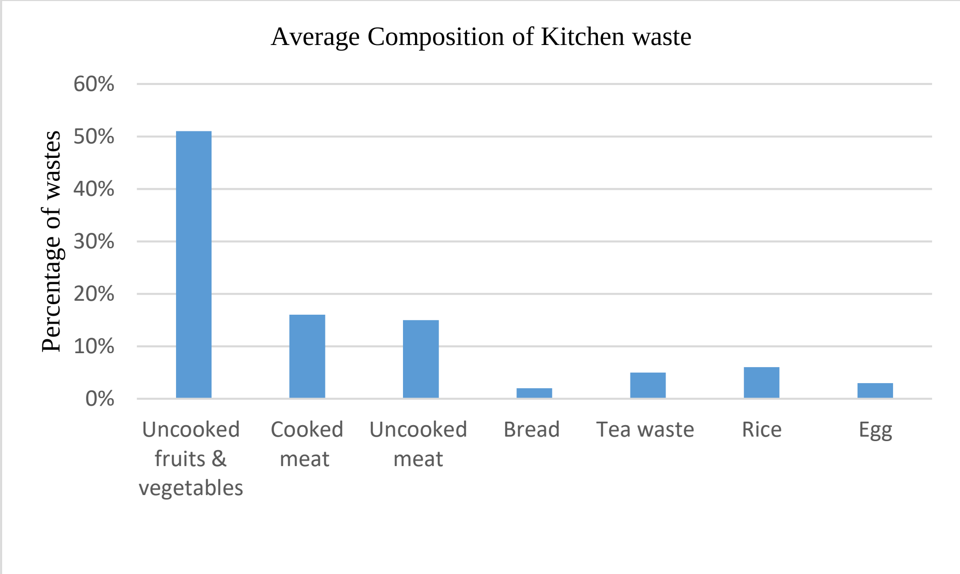

Fig. 2: Average composition of kitchen waste

In this study modified ARTI technology has been used for further calculation of biogas production. Modified ARTI is a compact biogas plant which uses kitchen waste as feeding material (Agrahari,et al., 2013). The slurry of feeding materials goes to the anaerobic decomposition to biogas for cooking, replacing Liquid Petroleum Gas (LPG) or Kerosene. It is a floating drum biogas plant. It consists of 1000 L capacity digester of simple water storage tank and 750 L capacity of gasholder which is placed upside down in the digester. When gas starts to generate, the gasholder rises to a certain limit. It then falls down to the lower limit after burning all gases present in the gasholder. Kitchen waste can be useful under community level biogas program, where LPG gas can be saved. In this study, we have taken of kitchen waste and water in ratio of 1:1.4.

Table 2: Elements of biogas production from kitchen waste

Characters	Quantity
Ratio (Kitchen Waste: Water)	1:1.4
pH	7-7.8
Amount of kitchen waste	10 kg
Amount of water	14 kg
Total biogas production	0.12785 m^3

From the chart we can say that for 10 kg kitchen waste production of biogas is 0.12785 m^3. Therefore, 1 kg kitchen waste can produce 0.012785 m^3 biogas. From Table. 1 if we consider Chadgaon Residential Area with 51 people producing 15 kg kitchen waste then biogas production will be 0.1918 m^3. As all the waste components will not produce biogas in the same rate so we can consider 60% of the total biogas can be used for cooking purpose. Therefore the production of biogas from kitchen waste will be 0.115 m^3 or 115 kg which is equivalent to 29 kg LPG gas per day.
It will be an efficient way to use kitchen waste in production of biogas, as it can possibly reduce the demand of gas and also help to maintain a sustainable environment.

CONCLUSIONS

The concept of kitchen waste for biogas production offers an effective waste management and resource development solutions with positive measures for the economy and sustained energy security. This study helps to the management of an organic waste generation in urban areas as well as saves the consumption of LPG gas and money in the long term. The relevance of biogas technology in Bangladesh lies in the fact that it makes the best possible utilization of various organic wastes as a renewable and perpetual source of clean energy in the rural and provides environmental sanitation. The objectives of the study were largely met, giving what may be considered as baseline data on the kitchen waste generation and management in the residential areas of Bangladesh.

ACKNOWLEDGMENTS
In the name of God, the most gracious, for giving us the courage and determination to complete this study. We are also thankful to Port City International University Chittagong.

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OXIDATIVE TREATMENT BY HYDROGEN PEROXIDE FOR THE REMOVAL OF COD AND SULPHIDE FROM TANNERY LIMING WASTEWATER

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ABSTRACT
A simple oxidative treatment study using hydrogen peroxide solely was performed in batch mode for the removal of COD and sulphide from extremely polluted tannery liming effluent. This study investigated maximum COD removal of 92.71% with the optimum influencing parameters of oxidation processes as time (150 min.), temperature (35^0C to 40^0C), pH of the sample (7) and amount of H_2O_2 (2.5mL/100mL). The removal of BOD_5 was attained 82.33% in the above optimum experimental conditions. This study also explored that maximum sulphide removal efficiency of H_2O_2 was 99.09% from 4329 mg/L to 39.39 mg/L for 40 minutes of oxidation using 2.5mL of H_2O_2 per 100mL sample at 40^0C temperature where initial pH of wastewater was 8. Kinetics analysis based on Pseudo first and second order model revealed that the oxidation process for COD removal followed second order kinetics model. The obtained values of COD and BOD after the oxidative treatment were 2799.36 mg/L and 971.85mg/L respectively whereas the values of the raw effluent were accordingly 38400mg/L and 5500mg/L. This oxidative treatment technique would be able to contribute the reduction of environmental threats of tannery liming effluent as it could significantly reduce the COD loads and sulphides.

Keywords: Tannery wastewater; liming wastewater; COD; sulphide; oxidative treatment

INTRODUCTION

Tanneries convert raw hides and skins which are largely composed of the protein collagen into leather by several chemical and mechanical operations (Das et al., 2008; Covington, 2011). Liming is a tannery operation under the beam house sub-process where hides and skins are treated with milk of lime with the addition of sodium sulphide to remove keratinous matters, interfibrillary soluble proteins and natural fats and to bring the collagen to a proper condition for satisfactory tannage (Dutt, 1999). The immensely alkaline highly turbid foul smelling liming effluent is characterized by high concentration of sulphides and extreme level of suspended solids, BOD and COD creates severe health problems to the human, damages aquatic life and destroys oxygen dependent plants and microorganisms (UNIDO, 2003; Paredes and Banchon, 2015).

The low biodegradable complex natured tannery effluent creates not only unfavourable environmental outcome but also technological difficulties to treat it to discharge (Lofrano et al., 2013; Banuraman and Meikandaan, 2013). From this point of view a number of researches on oxidation and advanced oxidation processes (AOP) carried out for tannery wastewater treatment around the world with their effectiveness of the removal of sulphides and COD. The most commonly investigated oxidative treatment technologies for the conversion of COD and sulphides into stable inorganic compounds from tannery wastewater were UV, H_2O_2/UV, TiO_2/UV, O_3, O_3/UV, Fenton, Photo-Fenton, Electro oxidation, Electro-Fenton, Catalytic oxidation etc (Rameshraja & Suresh, 2011). Almost all the previous peroxide oxidation studies for tannery wastewater were done with the composite effluent using H_2O_2 along with different catalysts. Due to efficient performance of hydrogen peroxide as a strong oxidant the compatibility of this oxidative treatment has been investigated here for the removal of COD and sulphides from liming effluent.

The main objective of the study was to simple oxidation of segregated liming wastewater using only H_2O_2 for the removal of COD and to optimize the oxidation process parameters specific for liming effluent. Evaluation of the removal efficiency of BOD was also aimed to the research. This study was also focused on the identification of the removal efficiency of sulphide by H_2O_2 through the oxidation process. Chemical kinetics study of H_2O_2 oxidation for COD removal was also a target of the research.

METHODOLOGY

Materials & Analytical methods

Liming wastewater for this study was collected from a tannery located at Nowapar in Jessore district. Collected samples were then characterized in the laboratory. Hydrogen peroxide used in this study was of commercial grade and purchased from a local scientific store in Khulna. In this study COD, BOD_5, TDS and TSS were measured by the methods 5220C, 5210B, 2540C and 2540D according to standard methods (APHA, 1997). Sulphide concentrations were measured using SLC 202 method (SLC, 1996). Other parameters were measured instrumentally. Examined parameters of the raw liming wastewater are represented in Table 1.

Experimental procedures

This oxidative treatment was done in batch process taking 100 mL of samples for each batch with continuous stirring in a magnetic stirrer at various experimental conditions. In the first part of the study different influencing parameters on COD removal by H_2O_2 oxidation was investigated and optimized. Dosage of hydrogen peroxide was investigated from 0.5mL to 3mL with a gradient of 0.5 mL where further increase of dosages were not tested due to avoid vigorous chemical reactions and accidental hazards. The effect of pH was checked and optimized from 7 to 11 by controlling with dilute nitric acid. Different temperatures (30^0C, 35^0C and 40^0C) were tested for getting most favourable one. Samples were withdrawn from all of the above mentioned experimental conditions at 30, 60, 90, 120, 150 and 180 minutes interval, filtered through 0.45μm filter paper, diluted to 100 times by distill water and immediately taken for COD determination. Based on the maximum COD removal efficiency (% of COD removal) operational parameters were optimized. The removal efficiency of BOD_5 was also investigated at the optimum experimental conditions of COD removal.

Table 1: Analysis of liming wastewater

Parameter	Values
pH	12.30
Turbidity (NTU)	7700
Salinity (ppt)	34.8
Conductivity (mS)	53.1
Sulfide(mg/L)	4329
TDS (mg/L)	34660
TSS (mg/L)	27900
Chloride (mg/L)	54.98
DO (mg/L)	0.01167
BOD_5 (mg/L)	5500
COD (mg/L)	38400
BOD_5/COD	0.143

The evaluation of the removal efficiency of sulphides during oxidative treatment were done using six different dosages of H_2O_2 from 0.5mL to 3mL at different temperatures from 35^0C to 40^0C with the initial pH of the sample ranging from 7 to 11 for 10 to 60 minutes of oxidation.

RESULTS AND DISCUSSIONS

Removal of COD by H_2O_2 oxidation

Effect of amount of hydrogen peroxide on the removal efficiency of COD

The effect of hydrogen peroxide dosages on COD removal was investigated for six dosages from 0.5mL to 3.0mL at oxidation time from 30 minutes to 180 minutes while pH of wastewater was maintained at 7. The results represented in the [Fig. 1] revealed that in most of the cases with the increase of the amount of hydrogen peroxide and oxidation time the removal efficiency of COD increased. According to [Fig. 1] for all of the H_2O_2 dosages most of the COD degradation occurred in first 30 minutes of reaction where the greater value 56.25% and lower value 33.33% were observed for 2.5 mL and 0.5 mL of dosages. In each time interval starting from 0.5 mL to 1.5 mL the removal efficiency of COD increased significantly after that for 2.0 mL and 2.5 mL it raised slowly and reached to the maximum for 2.5 mL. Further increase of hydrogen peroxide dosage from 2.5 mL to 3.0 mL could not increase the process performance rather than the removal percentages of COD started to decrease. This inhibition effect may be due to the contribution of residual hydrogen peroxide to COD. In this experimental condition maximum removal of COD (92.71%) was achieved for 2.5 mL of H_2O_2 so, this dosage was selected as optimum and was taken in the following runs.

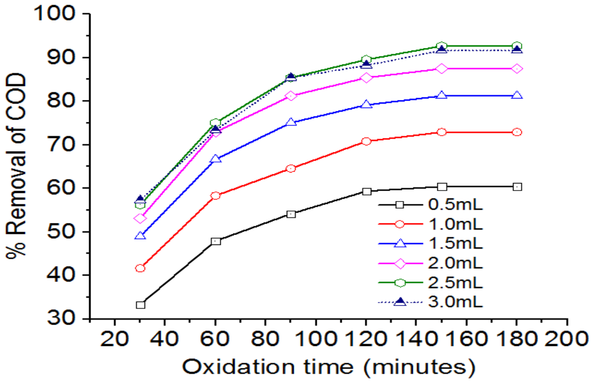

Fig. 1: Effect of Dosages of H_2O_2 on the removal efficiency of COD (pH = 7, Temperature = 35 °C)

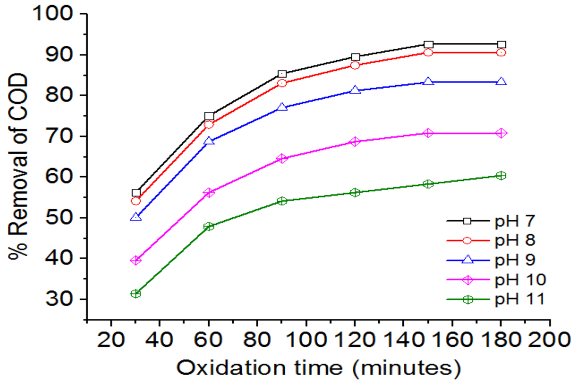

Fig. 2: Effect of pH on the removal efficiency of COD (Dosage of H_2O_2 = 2.5mL/100mL sample, Temperature = 35 °C)

Effect of pH on the removal efficiency of COD

The experiments for the evaluation of the influence of pH on COD removal efficiency were done for different pH values (7, 8, 9, 10, and 11) at various reaction times from 30 minutes to 180 minutes. [Fig. 2] represents the experimental results from where it is seen that COD removal efficiency decreased with the increase of pH whereas for every pH values the efficiencies increased with times and reached maximum at 150 minutes of oxidation. It is also observed from [Fig. 2] that for each oxidation times the percentage removal of COD was higher for pH 7 that started to decrease slowly from pH 8 to 9 and significant decrease of the results were noticed for pH values 10 & 11. Various researches revealed that oxidation by H_2O_2 is a free radical based reaction and the formation of free radical is affected by pH values. This is may be the cause of the decrease of removal efficiency at higher pH values. The experimental data in the above mentioned figure illustrates that maximum 92.71 % of COD removal was obtained at pH 7 for 150 minutes of oxidation, for this reason pH 7 was taken as optimum for COD removal for this study.

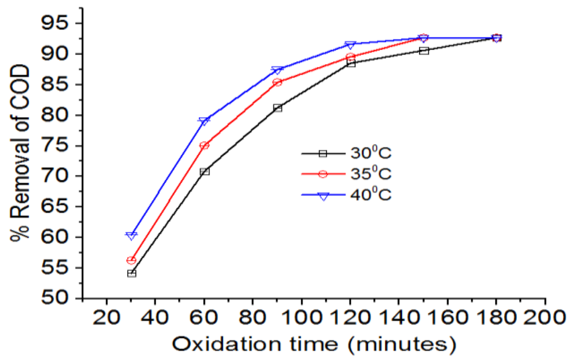

Fig. 3: Effect of Temperature on the removal efficiency of COD (Dosage of H_2O_2 = 2.5mL/100mL sample, pH = 7)

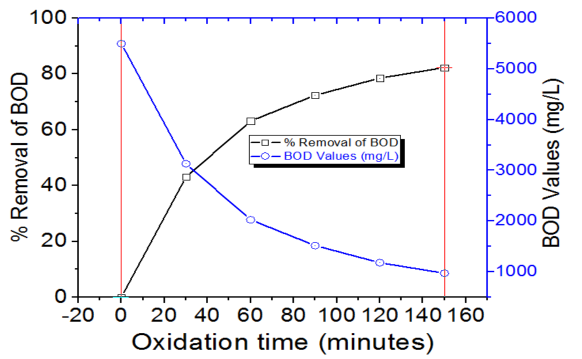

Fig. 4: Removal of BOD_5 during oxidation (Dosage of H_2O_2 = 2.5mL/100mL sample, pH = 7, Temperature = 35 °C)

Effect of oxidation temperature on the removal efficiency of COD

[Fig. 3] shows the effect of temperature on COD removal efficiency. The graph is plotted by the data received from a series of experiments at different temperatures 30 °C, 35 °C (room temp.) and 40 °C. It is observed form the [Fig. 3] that the removal efficiency of COD increased with the increase of temperature as the removal efficiency of 54.16% was for first 30 minutes of oxidation at 30^0C which rose to 56.25% and 60.42% for 35^0C and 40^0C respectively and this increasing trend was also found in other reaction times. This increasing trend may results from the acceleration of free radical formation from H_2O_2 at higher temperatures that improves COD removal. The noticeable fact of the results was that maximum COD removal efficiency of 92.71% was not changed with the change of temperature. So, little influence of temperature was evaluated in this study and 35 °C to 40 °C was optimized for COD removal from liming wastewater.

Removal efficiency of BOD by H_2O_2 oxidation

The removal efficiency of BOD was measured for 30 to 150 minutes of oxidation with 100mL of sample at optimum experimental conditions of COD. The double Y axis plot of the results in the [Fig. 4] depicts the percentage removal of BOD with times along with the corresponding residual BOD values in mg/L. The figure shows that with times BOD removal efficiency increased. Almost half of the BOD degradation occurred in first 30 minutes of oxidation and maximum 82.33% removal was attained in 150 minutes with the residual value of 971.8mg/L.

Removal of Sulphides by H_2O_2 oxidation

Evaluation of the different influencing parameters on the removal of Sulphides during oxidation

[Fig. 5] represents the dependence of pH varied from 7 to 11 on sulphide removal during 40 minutes of oxidation at room temperature with 2.5mL H_2O_2. According to the figure higher pH values show lower removal efficiency of sulphides. Minimum residual sulphide concentration (117.32 mg/L) was attained at pH 8 and the values were very close for pH 7 (156.28 mg/L) and pH 9 (136.51 mg/L) whereas negative process performance was noticed for pH 10 &11.

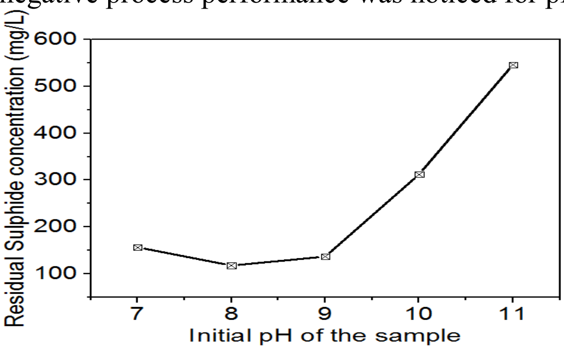

Fig. 5: Effect of pH on the removal of Sulphides (Dosage of H_2O_2 = 2.5mL/100mL sample, Temperature = 35 °C, Time = 40 minutes)

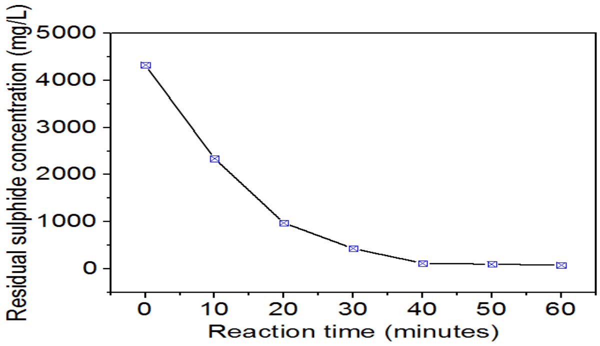

Fig. 6: Effect of Oxidation time on the removal of Sulphides (Dosage of H_2O_2 = 2.5mL/100mL sample, Temperature = 35 °C, pH = 8)

Behaviour of oxidation time on sulphide removal presented in [Fig. 6] tested for 10 to 60 minutes of oxidation at room temperature (35^0C) taking pH of the sample 8, dosage of H_2O_2 2.5mL. The figure shows that sulphides removed in an increasing trend with times and significant removal observed in 40 minutes of reaction where residual sulphide concentration was only 117.32 mg/L. In the additional reaction times sulphides removed slowly and reached to 77.92 mg/L of residual sulphides in further 20 minutes of oxidation.

Amount of H_2O_2 was identified to affect significantly on sulphide removal has been illustrated in [Fig. 7]. It is seen from the figure that starting from 0.5mL to 2mL of oxidant sulphides removed sharply compared to the subsequent dosages. As in the figure for the first 1mL of H_2O_2 residual sulphide concentration was 780.08 mg/L whereas for 2mL and 3mL of oxidant the values were 195.24 mg/L and 77.92 mg/L respectively indicating the removal of 584.84 mg/L of sulphides for additional 1mL (from 1 to 2 mL) and only 117.32 mg/L of sulphides for final 1mL (from 2 to 3 mL). [Fig. 8] shows the positive influence of the increase of temperature on sulphides removal. Minimum residual sulphide concentration 39.39 mg/L which is the notification of maximum removal efficiency was attained by oxidation at 40 °C.

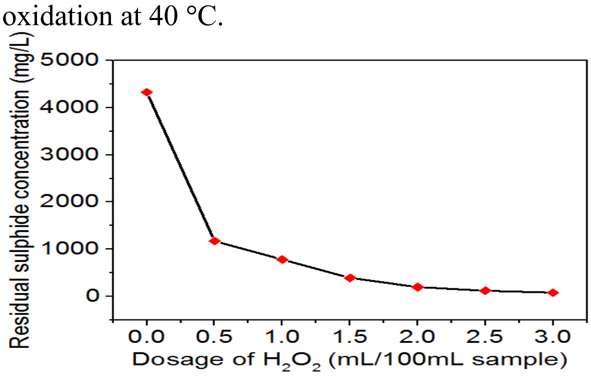

Fig. 7: Effect of dosages of H_2O_2 time on the removal of Sulphides (Time = 40 min., Temperature = 35 °C, pH = 8)

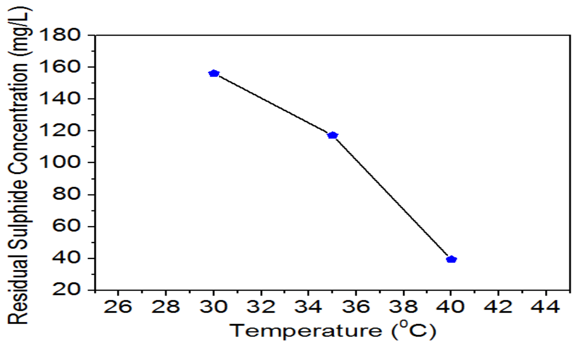

Fig. 8: Effect of Temperature time on the removal of Sulphides (Dosage of H_2O_2 = 2.5mL/100mL sample, Time = 40 min., pH = 8)

Kinetics analysis for COD removal in the oxidative treatment

In this research both first and second order kinetics model has been studied. Equation [1] represents first order kinetic model (Panizza & Cerisola, 2001) whereas according to (Haddad et al., 2014) second order kinetic analysis can be done by Eq. (2).

$$\ln\frac{C_0}{C_t} = k_1 t \qquad (1), \qquad\qquad \frac{1}{C_t} - \frac{1}{C_0} = k_2 t \qquad (2)$$

Where, C_0, C_t, k_1 and k_2 are COD concentration of raw sample (mg/L), COD concentration with times, first order rate constant (min^{-1}) and second order rate constant ($L.mg^{-1}.min^{-1}$) of the kinetics model respectively.

In this study kinetics analysis for COD removal was done for 30 minutes to 180 minutes of oxidation at temperature of 35 °C and 40 °C with the other previously optimized parameters. Based on the Eq. (1) and Eq. (2) data of ln (C_0/C_t) vs. t and ($1/C_t - 1/C_0$) vs. t were plotted for the study of Pseudo first order and second order reaction kinetics respectively. The linear plot of the kinetics model are shown in the [Fig. 09] and [Fig. 10].

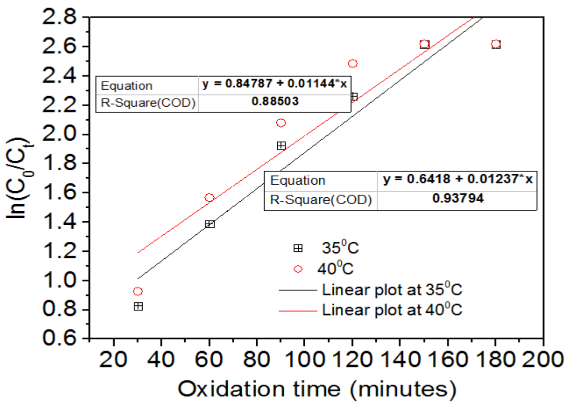

Fig. 9: Kinetic plots of first order model

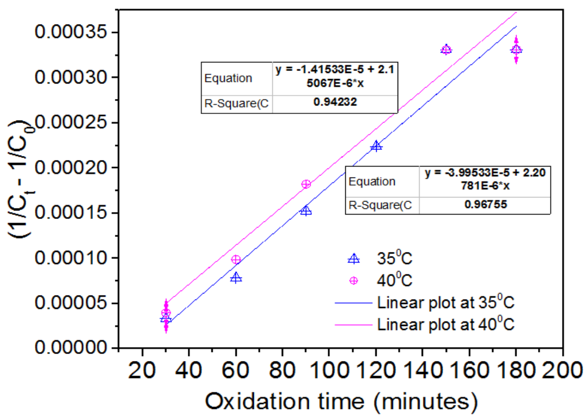

Fig. 10: Kinetic plots of second order model

From the equation of the straight lines of the kinetic plots rate constants k_1, k_2 and half times of first and second order reactions were calculated and the values are showed in Table 2. The data of kinetics study in the Table 2. Shows that reaction rate constants k_1 and k_2 decreased with the increase of temperature but the values were very close for each model that signifies little impact of temperature on the COD removal by H_2O_2 oxidation. Lower half times for second order model 11.78min at 35 °C and 12.11min at 40 °C supported the experimental results. In addition the greater values of coefficient of determination (R^2) 0.968 at 35 °C and 0.942 at 40 °C of the second order model than first order model (0.938 at 35 °C and 0.885 at 40 °C) are the indication of the better fit of the experimental data in the second order model. From the above explanation it can be concluded that the Removal of COD from tannery liming wastewater by H_2O_2 oxidation was a Pseudo second order reaction.

Table 2: The values of R^2, rate constant and halftimes for first and second order model

	Temperature (^{0}C)							
	35^{0}C				40^{0}C			
	R^2	k_1 (min^{-1})	k_2 ($L.mg^{-1}.min^{-1}$)	$t_{1/2}$ (min.)	R^2	k_1 (min^{-1})	k_2 $L.mg^{-1}.min^{-1}$	$t_{1/2}$ min.
First order model	0.938	0.012	-	57.75	0.885	0.011	-	63
Second order model	0.968	-	2.21*10^{-6}	11.78	0.942	-	2.15*10^{-6}	12.11

CONCLUSIONS

In this batch oxidative treatment study H_2O_2 was found as an effective oxidant for the removal of COD and sulphides from tannery liming wastewater. Oxidation occurred effectively at neutral pH and additional amount of H_2O_2 over optimum dosage was observed negative impact on COD removal while a little influence of the increase of the reaction temperature provided with the benefit of the greater degradation of COD at initial reaction times was noticed. The evaluation of the influencing parameter on sulphide removal revealed that the removal efficiency increased with the increase of temperature and the amount of oxidant and H_2O_2 was detected to work better at neutral to slightly alkaline pH range whereas most of the sulphide removal was noticed at 40 minutes of oxidation. Kinetics analysis of this study showed that the oxidative treatment could better be explained by Pseudo second order model.

ACKNOWLEDGMENTS
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ASSESSMENT OF INDUSTRIAL EFFLUENT POLLUTION IN KARNAPHULI RIVER

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ABSTRACT
Industry is one of the main resources of a country's economic development. Different types of industries have different system of productions and use different types of chemicals and raw materials. The untreated effluent from the industries rapidly pollutes the surface water. Hence surface water quality is degrading, people are depended on ground water for their daily water related activities which creates scarcity of water. Again the use of polluted surface water results in serious health hazards.As Chittagong is the port city of Bangladesh, various types of industries are established here due to having favorable environment. Most of the industries are situated on the bank of Karnaphuli river and do not have proper effluent treatment plan (ETP).Thus this river is getting polluted continuously by the untreated effluent of these industries.Study has been conducted in 'Kalurghat Heavy Industrial Area, Chittagong' by collecting effluent from nine industries and three stationary points on Karnaphuli river. Investigation shows that many industries don't have ETP, some have but these are not in operation. Physiochemical results show that the amount of Turbidity and TSS is very high though the heavy metal parameters are within Bangladesh standards. Thus effluent should be treated in a proper way to dispose in the river.

Keywords: ETP (Effluent Treatment Plant); river pollution; health hazard; confluence

INTRODUCTION
Bangladesh is a developing country with a population of almost 160 million. Due to industrialization & low labor cost industries are growing rapidly in Bangladesh especially in Chittagong. Kalurghat is a Heavy Industrial Area which is situated on the bank of Karnaphuli River in Chittagong. Chittagong is the economic capital as well as the port city of Bangladesh. Karnaphuli River has great importance in Chittagong because its water is used in different purposes like drinking, bathing, fishing, navigation, hydraulic power generation, irrigation etc. According to these purposes river water quality should be satisfactory but it is a matter of sorrow that the river water quality is getting worsen day by day by the untreated effluent thrown to the Karnaphuli River from different industries.

Most of the industries in 'Kalurghat Heavy Industrial Area' don't have a waste management facility like Effluent Treatment Plant (ETP). Some industries have ETP but they aren't in operation or the capacity of ETP is inadequate with respect to the effluent. Among them some industries aren't properly maintaining & operating the ETP, thus standard quality of disposed effluent isn't be maintained. Again there is no Central ETP in the area that's why untreated or partially treated effluent come from all industries are directly disposed of in the river & river water get polluted when the effluent feeds the river. Polluted water creates adverse effect on environment, human health, aquatic life & thus ecological balance get disturbed.

There are three major industrial zones in Chittagong. One is 'Chittagong Export Processing Zone (CEPZ)', second one is Baized Bostami Industrial Area and another one is 'Kalurghat Heavy Industrial Area'. Study area of this project is 'Kalurghat Heavy Industrial Area' which is situated on the bank of Karnaphuli River. Various types of industries are polluting the river water such as Dying Industry, Oil Industry, Resin Industry, Beverage Industry, Sea Food Industry etc. The study has been selected for three categories of total nine industries out of over hundred industries in Kalurghat Area.

Different types of Chemicals such as Acetic Acid, Sosa Ash, Mercury etc. ; Raw Materials such as Crude Palm, Vegetable oil, Lin seed etc. ; Heavy Metals such as Arsenic, Lead, Manganese Ore, Iron

Ore etc. have been extensively used in different types of industries. The toxic effluents coming from those industries have an adverse effect on environment.
River water has been continuously polluted by the poisonous mix of different types of chemicals, raw materials along with heavy metals. It has an adverse impacts on river water, aquatic life, human health as well as recreational activities.
Many research work was conducted on various stream in Bangladesh, which is effected by industrial effluent. A research work has been done of water pollution of Karnaphuli River by Rahman and Islam. They found that standard CO_2 and Alkalinity are very large in Karnaphuli River which is harmful for human and aquatic life. Other researchers, Khownain and Chowdhury of CUET, conducted a thorough study over Karnaphuli River regarding quality of water. They applied mechanical, chemical and biological method to investigate. They found that suspended solid and BOD is not in tolerable limit. They suggested that, there should be minimum three monitoring station which must be established at the origin and exit point of each prime river of Bangladesh with proper lab facility and human resource.
The aim of the study is to evaluate the effect of effluent pollution in Karnaphuli river & to find out some remedial measures., This study has revealed that the industries are involve in serious environmental hazard. So, adequate preventive measures should be taken in industrial activities with a view to ensuring a healthy environment & to control the river water pollution. And thus to assess the quality of industrial effluent & river water, to determine necessary steps to control this pollution, the study is being selected.

METHODOLOGY

Industries untreated & partially treated effluent to the environment causing pollution of nearby canals & rivers. These effluent also pollute natural water systems as well as ground water endangering human health and aquatic lives. They contain heavy metals like As, Cd, Pb, Hg, Cr, Ag, Cu, Zn etc. Some of them are toxic to plants and some others to both plants and animals. Study has been done on economic & industrial zone of Chittagong. After Field survey of study area & some industries have been selected. For the study, samples are collected from discharge point of industries as well as from different points in Karnaphuli River. Standard procedure were used to analyze the physical, chemical & heavy metal parameters of the samples.

Work Flow Diagram

The total work has been done by the following ways.

Laboratory tests include physical (Turbidity, TS, TDS, TSS), chemical (PH, Alkalinity, DO, BOD) & heavy metal (Pb, Mn, Zn, Cu, Na, K, Cd) tests.

Selection of the Area

There are three major industrial areas in Chittagong. One is ‘Chittagong Export Processing Zone (CEPZ)’, second one is Baized Bostami Industrial Area and another one is ‘Kalurghat Heavy Industrial Area’. Study area of this project is ‘Kalurghat Heavy Industrial Area’ which is situated on the bank of river Karnaphuli. Garments, textiles, washing, dying, chemicals, oil mills, plastic, painting, electronics, poultry, foods, cement etc. industries are present in this area. The industries dispose their effluent directly or indirectly in ‘Ispahani Khal’ which carries this effluent to the Karnaphuli River. The Study area has been presented in **Figure-1**.

Selection of the Industry

There are approximately eighty one industries are present in Kalurghat Heavy Industrial Area. The study has been carried out on nine industries categorized as dying industries which includes Choice Washing Plant, Sanji Textiles, C & A Textiles; chemical industries which includes Padma Resin, Hasan Oil Mills, S A Oil Refinery Ltd. and food industries which includes Meenhar Sea Foods Ltd., Chowdhury & Co., Polar Ice Cream.

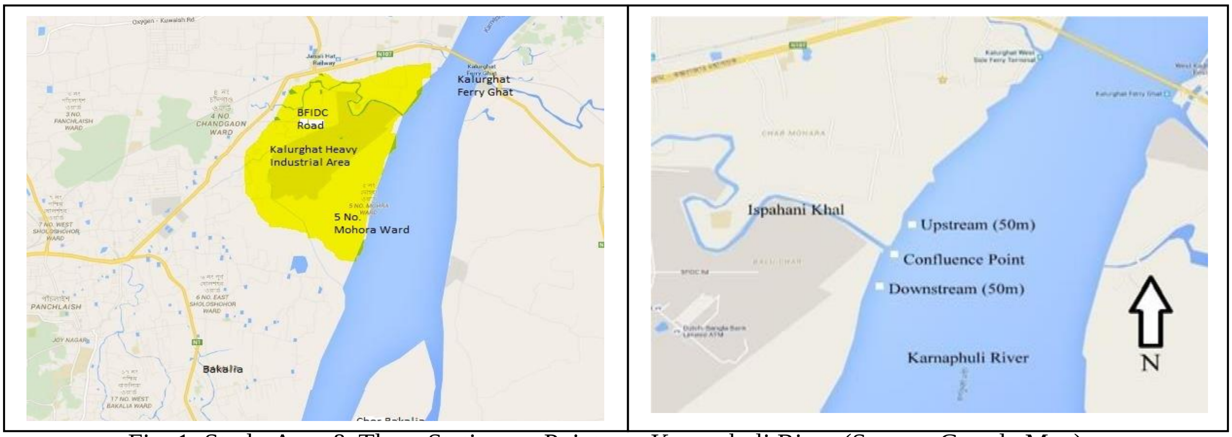

Fig. 1: Study Area & Three Stationary Points on Karnaphuli River (Source: Google Map)

Sample Collection

In order to evaluate the industrial effluent, samples are collected from the discharge point of different industries. To evaluate the river water quality, samples are collected from the confluence point of Ispahani khal & Karnaphuli River, 50m upstream & 50m downstream from the confluence point both at high & low tide condition as shown in Figure 1. Samples were collected in plastic bottles in pouring condition & those samples were tested in laboratory within 24 hours.

Laboratory Analysis of Effluent

1) Physical Parameters

***i)* Determination of Turbidity**

Turbidity may be due to organic or inorganic constituents. Organic particulates may harbor microorganisms. Thus turbid condition may increase the possibility for waterborne disease. Nonetheless, inorganic constituents have no notable health effects. The series of turbidity induced changes that can occur in water body may change the composition of an aquatic community. Turbidity is measured by 'Turbidity Meter' & expressed by the unit 'NTU'.

***ii)* Determination of Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS)**

These are very important parameters for water quality standards whose are evaluated within 24 hours. Unit of all these parameters are in mg/l.

Chemical Parameters

***i)* Determination of P^H**

P^H is the negative logarithm of the hydrogen ion activity in a solution, is determined by a potentiometric method, using a well-calibrated commercial P^H meter, as described in Standard Method 4500-H (Standard Methods, 1998). P^H measurements must be done at room temperature, or using a temperature compensating instrument. Samples are not filtered nor altered in any way prior to measuring. The result is reported as a number, usually to one decimal place. For the determination of P^H, P^H meter (for electrometric determination) was used. Sometimes P^H paper was used to determine P^H manually.

***ii)* Determination of Total Alkalinity**

The amount of alkalinity in water is typically determined by Standard Method 2320 (Standard Methods, 1998) and is reported as the equivalent amount of CaCO3 in milligrams per liter. The purpose of alkalinity testing is to assess the presence of alkaline materials or buffer systems that might interfere with desired chemical reactions, or might promote underside reactions, as discussed in the introductory section of this chapter.

iii) Determination of Dissolved Oxygen (DO)

Standard Method 4500-O describes two methods for determination of dissolved oxygen (DO) in water: Winkler's iodometric method and the electrometric method (Standard Methods, 1998). The iodometric method is very accurate and precise, but the electrometric method is far more convenient for field use and produces an electronic output that can easily be converted to digital form for microprocessor monitoring or control of wastewater treatment systems.

iv) Determination of BOD

One of the most important characteristics of wastewater is the amount of oxygen required to stabilize it. This quantity is called the oxygen demand, and is determined either as biological oxygen demand (BOD) or chemical oxygen demand (COD). BOD is the quantity of oxygen required to stabilize wastewater in the presence of bacteria that consume the chemical pollutants and oxygen in the sample and can be determined by Standard Method 5210 (Standard Methods, 1998).

Heavy Metal Parameters

There are many methods for metal determination (Standard Methods, 1998: section 3000). Some, for example as gravimetric, titrimetric or colorimetric methods are most effective at high metal concentrations. Others, for example atomic absorption (AA), inductively coupled plasma (ICP) or inductively coupled plasma mass spectrometry (ICPMS) are far more sensitive. The latter are used for typical textile applications, such as compliance testing for water quality or detection of trace impurities in high-volume raw materials. Metal ions of greatest interest in textiles are: antimony, arsenic, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, sodium, tin, titanium and zinc (Madan, 1987).

RESULTS & DISCUSSIONS

Physical Assessment

Industry name, category, their function, presence of ETP and all other details of physical assessment are summarized in **Table 1**.

Table 1: Summary of Physical Assessment of Different Industries

Category	Name of Industry	Function	ETP Present or Not	ETP in Operation or Not
Dying	Choice Washing Ltd	Washing	No	-
	Sanji Textile Ltd	Coloring	Yes	Yes
	C & A Textile Ltd	Washing	Yes	Yes
Chemical	Padma Resin	Gum Producing	Yes	No
	Hassan Oil Mills Ltd	Oil Refining	No	-
	S A Oil Refinery Ltd	Oil Refining	No	-
Food	Polar Ice-cream Ltd	Cold Storage	No	-
	Meenhar Sea Foods Ltd	Sea Food Processing	Yes	Yes
	Chowdhury & Co.	Sea Food Processing	No	-

It has been seen from table that most of the industries do not have waste management facility like ETP. Some of the industries have ETP but they are not in operation. Thus the standard quality of effluent can't be maintained. Similarly, same scenario can be explained for the whole Kalurghat heavy industrial area as well as industries situated on the bank of river Karnaphuli.

Experimental Assessment

In experimental assessment physical, chemical & heavy metal parameters are evaluated in the laboratory and presented in **Table 2**, **Table 3** & **Table 4** respectively along with Bangladesh standard for industrial effluents (ECR, 1997).

Table 2: Assessment of Physical Parameters

Name of Industry	Turbidity (NTU)	BD Std.	TS (mg/l)	BD Std.	TDS (mg/l)	BD Std.	TSS (mg/l)	BD Std.
Choice Washing Ltd	63	22-45	490	2250	380	2100	110	150
Sanji Textile Ltd	6.44		1180		800		380	
C & A Textile Ltd	3.38		710		660		50	
Padma Resin	2.64		4060		3570		490	
Hassan Oil Mills Ltd	54.1		3680		3140		540	
S A Oil Refinery Ltd	67		4300		3760		540	
Polar Ice-cream Ltd	89.5		3470		2610		860	
Meenhar Sea Foods Ltd	34.6		1160		810		350	
Chowdhury & Co.	22		980		716		264	
Tidal Condition in Karnaphuli River								
Upstream (50m)	212		843		596		247	
Confluence Point	235		830		630		200	
Downstream (50m)	341		1670		1360		310	
Non Tidal Condition in Karnaphuli River								
Upstream (50m)	230		920		655		265	
Confluence Point	252		870		613		257	
Downstream (50m)	298		846		582		264	

Table 3: Assessment of Chemical Parameters

Name of Industry	PH	BD Std.	DO (mg/l)	BD Std.	BOD (mg/l)	BD Std.	Alkalinity (mg/l)	BD Std.
Choice Washing Ltd	8	6-9	2.2	4.5-8	37	50	250	600
Sanji Textile Ltd	8		8		10		300	
C & A Textile Ltd	7		8.4		10		110	
Padma Resin	7		6		43.4		780	
Hassan Oil Mills Ltd	8		3.2		64		653	
S A Oil Refinery Ltd	8		2.8		54.7		708	
Polar Ice-cream Ltd	8		4.2		2.12		110	
Meenhar Sea Foods Ltd	6		9.3		4.7		20	
Chowdhury & Co.	6		5.5		4.8		36	
Tidal Condition in Karnaphuli River								
Upstream (50m)	7		9.6		6.4		62	
Confluence Point	8		8.8		6.6		70	
Downstream (50m)	7		7		7		68.9	
Non Tidal Condition in Karnaphuli River								
Upstream (50m)	8		9.6		6.4		61	
Confluence Point	7		8.5		6.4		69	
Downstream (50m)	7		7.3		7.1		67	

Table 4: Assessment of Heavy Metals of Karnaphuli River in Non-Tidal Condition (Confluence Point)

Parameters	Unit (mg/l)	Bangladesh Standards for Industrial Effluents
Pb	-	0.1
Mn	0.14	5
Zn	0.08	5
Cu	0.11	0.5
Na	15.2	-
Ca	13.6	-
Mg	12	-
K	5.66	-
Cd	-	0.5

From the Tables, it has been found that, Physical & Chemical parameters has been creating hazardous impacts on river, discussed as follows:

Impacts on River Water Quality

In the investigation we found that the industries whose have ETP have relatively good water quality than the industries whose have not ETP or have but not in operation. The value of P^H of maximum industries are satisfactory. Turbidity of river water is very high because most of the industry have opaque liquid effluent. The value of BOD_5, dissolved oxygen and alkalinity is relatively good with respect to river water quality standards. But the amount of total solids, dissolved solids and suspended solids are very high in amount which causes serious pollution in river water.

Impacts on Aquatic Life

Aquatic life is considered to be an endangered species because of improperly disposed of liquid effluent into the river water. When a toxic effluent harms one organism, it can end up destroying an entire food chain of aquatic life. Improperly disposed effluent pollutes marine life and kills sea mammals, corals, and fish. At the same time, birds are affected because they eat the fish from the river. Another example of aquatic pollution is with acid rain, which is the result of certain chemicals present in the effluent. Acid rain is responsible for leaching the soils toxic aluminum.

Impacts on Recreational Activities

Color appearance of river water attracts the visitors most. But day by day the color of Karnaphuli river water get worsen i.e. convert into grayish color. Nuisance is another problem for the visitors. Again root of plants are rotten for the toxic industrial effluent which reduces the natural beauty of river side. That’s why nowadays people gradually losing their interest for river riding which is a part of their recreation.

CONCLUSION

Export-Import of Bangladesh mainly depends on Karnaphuli River. Also it contributes in hydro-electrical power generation, fish industry, navigation and drinking water supply sectors. Whereas it is polluted by industrial effluents, waste water, oil dumping/spilling, silting, encroachment etc. for which industrial liquid effluent is the main reason, so a central ETP is now a crying need to save Karnaphuli River as well as to save the whole country. For each industrial area government can establish a Central Effluent Treatment Plant (CETP) and proper operation & maintenance of ETP should be monitored continuously. ETP must maintain the standard quality of effluent of all industries and adequate preventive measures should be taken in industrial activities to ensure a healthy environment.

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WATER QUALITY OF DND CANAL FROM THE PERSPECTIVE OF SAIDABAD WATER TREATMENT PLANT

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ABSTRACT
Water quality is an important factor for public health and also for aquatic life. More and more water quality issues are becoming a significant concern due to the growth of population, urban expansion and development. Thus, assessment of surface water quality has become an important issue. Water Quality Index (WQI) is a single number which were calculated in this study. The water quality data obtained from 4 sampling stations during one year monitoring period at DND canal is one of the important drinking water sources of the capital city of Dhaka, Bangladesh. The analyses of 18 water quality parameters were done for all water samples in Water Analysis Laboratory. It was found that DO, BOD, phosphate, colour, turbidity, Electric conductivity, hardness, chloride, free chlorine, salinity, TDS, TSS, NH_3, NO_2, NO_3, sulphate values which exceed the limit values given in the water quality standards are the major pollutants that affect the water quality in this Canal. For easy interpretation of the data, three different WQI models were applied for the selected parameters. The suitability of these WQI models is discussed with respect to their applicability in similar studies. For this study it is concluded that our WQI in the lab would provide the best results.

Keywords: Biochemical oxygen demand; turbidity; electric conductivity; hardness

INTRODUCTION
Fresh water resources are very limited in the world and preserving fresh water quality is important for public health and also for aquatic life. World health organization (WHO) reported that in developing countries over three million people die every year because of waterborne disease. Thus, proper assessment and reporting of surface water quality is an important issue. That is why our findings in this study revealed that the overall water quality in DND canal. Dhaka-Narayanganj-Demra (D.N.D) canal area is located between the cities of Dhaka & Narayanganj in Bangladesh and bounded by the Shitalakhya River. The main objectives of this study is to find out the reasons of polluting water, seasonal and spatial variations of water quality with selected parameters, environmental factors in the context of SWTP.

METHODOLOGY
To obtain such data, eight different sampling locations were chosen from four cross sections of the DND canal. Water quality monitoring has been carried out through collection and analysis of water samples at 8 different times (covering both dry and wet seasons) during the period from July 2013 to February 2014. Water samples were collected at the first week of each month .The collected canal water samples have been analyzed for a total of 14 water quality parameters including Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Color, Conductivity, Chloride, Hardness, Biochemical Oxygen Demand (BOD_5), Ammonia(NH_3-N), Total Dissolved solids (TDS) and Total Suspended Solids (TSS)and Nitrate (NO_3-N) for selected campaigns. These samples were analyzed by standard method in the Environmental Engineering laboratory.

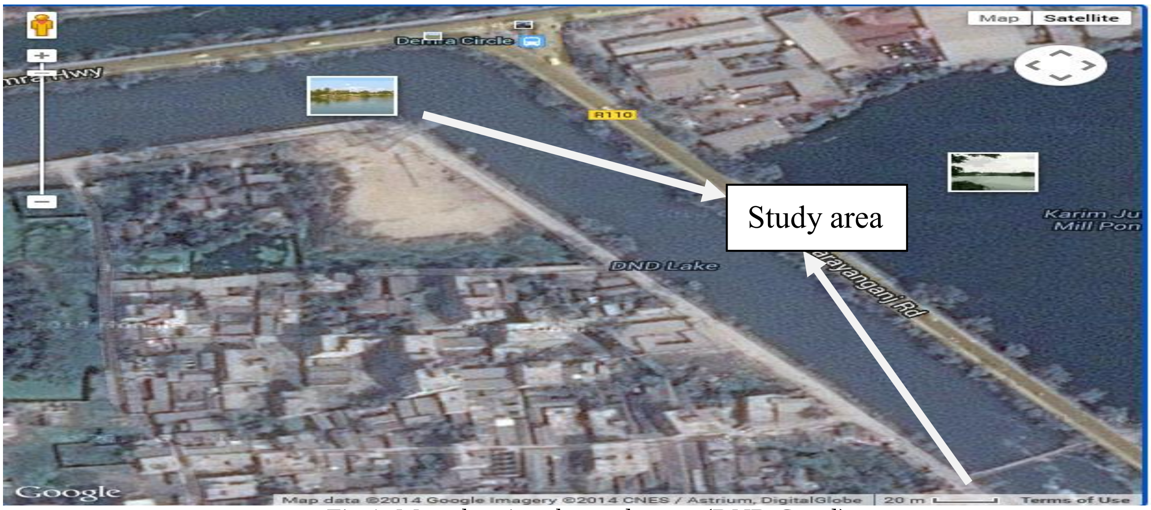

Fig.1: Map showing the study area (DND Canal)

Pollution Aspects of DND Canal:

The Pollution of the Lakhya River to a large extent comes from urban sewage which is leaking from the heavily polluted Norai Khal into the Balu River and further into the Lakhya River shortly upstream of the Sarulia intake pump station. Finally the polluted water enter DND canal from Shitolakhya River. The DND canal to some extent works as a treatment reactor. During the wet season there is most likely sedimentation of solids along the canal and in the dry season there is a growth of algae, which removes parts of the pollution in the water, but which also negatively influence the treatment process at the SWTP. However, this removal is to some extent counterbalance by a certain pollution coming from the human activity (bathing, washing etc) along the canal. Besides These some other problems are responsible for pollution as: ammonia, scarcity of DO (less than 5.0mg/l), turbidity, grater BOD, TDS, EC, hardness, sulphate, nitrate, presence of metal in water.

Sampling and Test of water:

Water quality refers to the chemical, physical and biological characteristics of water. It is most frequently used by reference to a set of standards against which compliance can be assessed. For assessment of water quality the sample of DND canal was monitored from July 2013 to Feb 2014, among the several sampling campaigns three were carried out during monsoon and four were dry season.

Selection of sampling point:

The number of sampling sites in a water body during any study depends on a number of factors such as possible spatial variation of pollutants, detection of pollutants, detection of pollutants peaks and frequency of sample collection and physical limitations of laboratory facilities. To assess the DND water quality numerous sampling areas are required but vast investigation was not feasible in this study due to time limitations. So, four cross-sections along the DND canal were selected for sampling locations for this study are Konapara, Basherpool, Loherpool & Staff quarter.

Laboratory work:

In Lab, waste water characterization studies were conducted to determine Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Color, Conductivity, Chloride, Hardness, Biochemical Oxygen Demand (BOD_5), Ammonia(NH_3-N), Total Dissolved solids (TDS) and Total Suspended Solids (TSS), Nitrate (NO_3-N), Nitrite (NO_2-N) and sulfate (SO_4^{--}) by the standard method.
In the lab the following instruments are used for measuring the water quality parameters-

Table 1: Instruments used in the laboratory

Parameters	Instruments
pH	Platinum Series pH Electrode , Model No-51910-88, HACH Instrument and Sension 156 Portable Multiparameter, Model No-54650-18, HACH
Electric Conductivity (EC)	Sension 156 Portable Multiparameter, Model No-54650-18, HACH
Salinity	Sension 156 Portable Multiparameter, Model No-5460-18, HACH
Dissolve Oxygen (DO)	Sension 156 Portable Multiparameter, Model No-5460-18, HACH
TDS (Total Dissolve Solid)	Sension 156 Portable Multiparameter, Model No-5460-18, HACH
Turbidity	Digital Turbidity Meter. Model No-331E, EI Instrument
Chloride	Digital Titrator, Cat. No- 16900-01, HACH Instrument
Color	Spectrophotometer, Model No-DR2800™, HACH Instrument
BOD_5	BOD Trak ™ II, Model No-DOCO22.53.90072, HACH Instrument

RESULTS AND DISCUSSIONS

This section describes the water quality characteristics of DND canal based on analysis of test results and for better understanding sample locations like Konapara, Basherpull, Loharpull, and Staff-quarter are expressed as numerical number 1,2 for konapara cross-section ; 3,4 for Basher pull cross-section ; 5,6 for Lohar pull cross-section and 7,8 for staff quarter cross-section respectively.

pH

pH is one of the most important factors, serving as an index for pollution. The resulting graphs show the variations along with collection points and time. Also represent the spatial variation and seasonal variations.

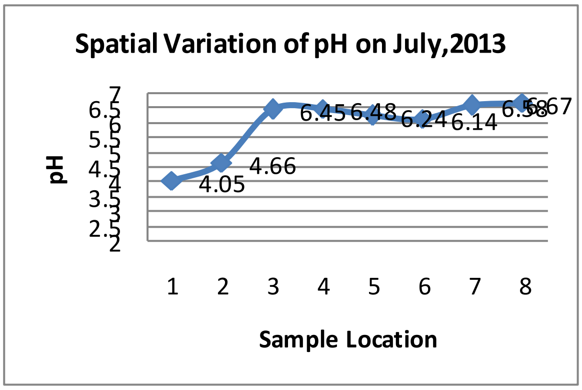

Fig. 2: Spatial variation of pH

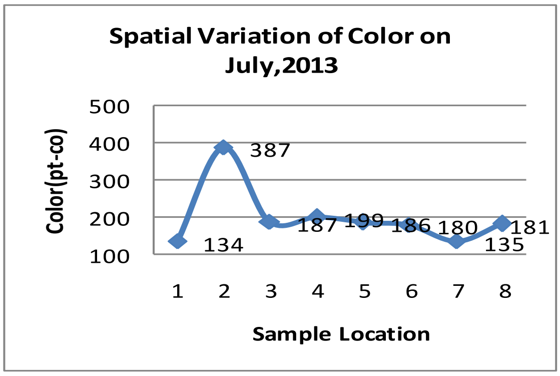

Fig. 3: Spatial variation of color

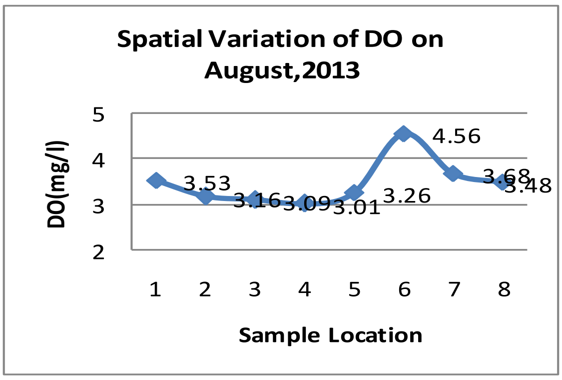

Fig. 4: Spatial variation of DO

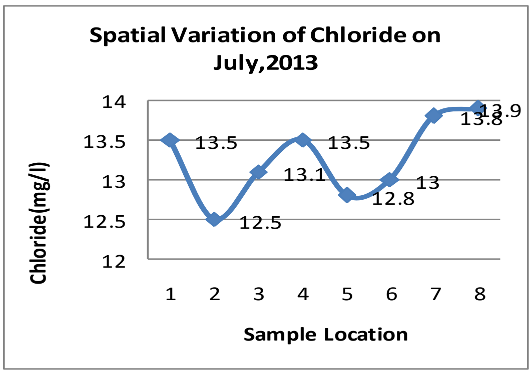

Fig. 5: Spatial variation of chloride

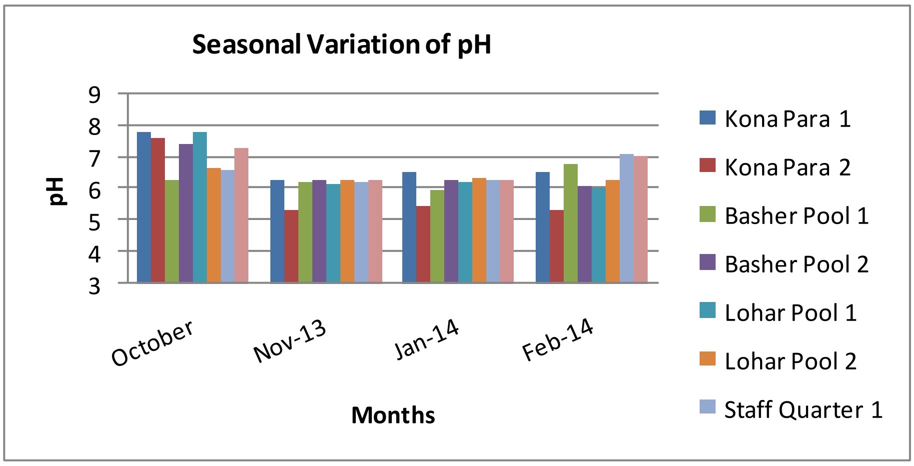

Fig. 6: Seasonal Variation of pH from October 2013 to February 2014

Color

During the study period, color has been recorded as a physical parameter at the sampling location. It has been seen that color of the river water undergoes darker with the advancement of dry season and in the wet season. In general the trend was observed like the value of color varies middle four points (Lohar Pool and Basher Pool). Color showed spatially varies significantly from upstream to downstream. The minimum color value is 3 pt-co in October 2013 and maximum color value is 387pt-co in July 2013.

Chloride

In July 2013 to February 2014, the most significant trend was observed that minimum chloride value is 12.5 mg/l in July 2013 and maximum chloride value is 16.9 mg/l in November 2013.It can be said that in dry season the value was much higher than wet season.

Electric Conductivity (EC)

Electrical Conductivity is an indirect measure of dissolved ions in water.

Dissolved Oxygen (DO)

The amount of dissolved oxygen (DO) in water is one of the most commonly used indicators of a canal`s health. As DO drops below 4 or 5 mg/l, the forms of life that can survive begin to be reduced. In the extreme case, when anaerobic conditions exist, higher forms of life are killed or driven off. Noxious conditions then prevail, including floating sludge, bubbling, odorous gases and slimy fungal growth. In general, the DO value of wet season (July, August and September) was high and DO value of dry season was low.

Hardness

In general the trend was observed like the value of hardness varies spatially in all locations. The value increases from upstream to downstream respectively. Also it is observed that the seasonal variation of free chlorine of different months in selected sample areas. In general, the hardness value of wet season (July, August and September) was low and hardness value of dry season (October, November, January and February) was high.

BOD_5

Normally, the BOD_5 value of wet season (July, August and September) is low. The BOD_5 value of dry season (October, November, January and February) is high. Normally the trend was observed like the value of BOD_5 varies spatially middle four points (Lohar Pool and Basher Pool). In November the value of BOD_5 shows low value because of sudden rainfall. The minimum BOD_5 value is 12mg/l in November 2013 and maximum BOD_5 value is 40.2 mg/l in October 2013.

Total Dissolved Solid (TDS)

Total Dissolved Solids is the concentration of all substances dissolved in water (solids remaining evaporation of a water sample) called total filterable residue. In general the trend was observed like the value of TDS increases in location 2 and 3 (Lohar Pool and Basher Pool). The minimum TDS value is 69.6 mg/l in August 2013 and maximum TDS value is 95.3 mg/l in November 2013. TDS value of wet season (July, August and September) was low and TDS value of dry season was high. Dilution of rainwater was most likely responsible for relatively low TDS values during wet season.

Total Suspended Solid (TSS)

In the month of August the TSS value was maximum and in October was minimum value. The minimum TSS value is 4 mg/l in October 2013 and maximum TSS value is 40 mg/l in August 2014. TSS value of wet season (July, August and September) was high and TSS value of dry season was slightly low.

Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eyes. In general the trend was observed like the value of turbidity increases from upstream to downstream. The value of turbidity is low in Location 2,3,4 every time because there was an outfall. The minimum turbidity value 4.02 JTU in October 2013 and maximum turbidity value is 79.01 JTU in August 2013. Here turbidity value of wet season (July, August and September) and turbidity value of dry season was mostly same.

Ammonia (NH_3-N)

Ammonia or (NH_3-N) is a compound of nitrogen and hydrogen with the formula NH_3. It is colourless gas with a characteristic pungent smell .Natural factors that can affect the concentration of ammonia include: algal growth, decay of plant or animal material and faecal matter. Other aspects of nitrogen cycling can also affect the amount of ammonia present. Ammonia can also come from domestic, industrial or agricultural pollution, primarily from fertilizers, organic matter or faecal matter. The ammonia concentrations of the four cross-sections along the DND canal varies from 1.2 mg/L to 0.15 mg/L . The high concentration of ammonia prevents efficient disinfection both in pre-chlorination and post-chlorination stages and thus makes it difficult to ensure the hygienic quality of water. The standard value of NH_3-N for Bangladesh standard for drinking water (ECR 97) is 0.5 mg/l & WHO guideline 1.5 mg/l. It was found the seasonal variation of NH_3-N of different months in selected samples areas. In general in wet season (July, August, & September) the NH_3-N values vary from 1.2 mg/L to 0.15 mg/L. It is significantly observed that except Konapara cross-section the other rest three cross-sections the values varies from 0.23 mg/L to 0.15 mg/L. In dry season NH_3-N value varies from 0.85 mg/L to 0.2 mg/L.

Nitrates (NO_3-N)

Nitrate is a tasteless, colorless and odorless compound that cannot detect unless water is chemically analyzed. According to the Guidelines for Bangladesh Drinking Water Quality, drinking water is safe if it has less than: (a) 45 mg/L nitrate or 10 mg/L of nitrate-nitrogen (Nitrate N),(b) 3.2 mg/L nitrite or 1 mg/L nitrite-nitrogen (Nitrite N).Nitrate does not interfere with the chlorination process, but high nitrate levels (above 12 mg NO_3) violate the WHO guidelines for Drinking Water Quality being potentially harmful for human beings for long time exposure and nitrate is a nutrient for algal at an equivalent level of ammonia. From analysis, it’s represented that the quantity of NO_3-N in DND canal along the four cross-sections varied from 1.2 mg/L to 0.4 mg/L.

Nitrites (NO_2-N)

EPA (Environmental Protection Agency) strongly encourages people to learn more about their drinking water, and to support local efforts to protect the supply of safe drinking water and upgrade the community water system. EPA requires all community water systems to prepare and deliver an annual consumer confidence report (CCR) (sometimes called a water quality report) for their customers by July 1 of each year. The major sources of nitrite in drinking water are runoff from fertilizer use; leaching from septic tanks, sewage; and erosion of natural deposits. Bangladesh standard for drinking water (ECR97) of NO_2-N value is less than 1mg/l besides WHO guideline 3 mg/l. Graph represents the seasonal variation of NO_2-N from the month of July 2013 to September 2013. Only in wet season NO2-N value is high its nearly 3 mg/l. Otherwise in dry season the range of value is low.

Sulfate (SO_4)

Sulfate is a substance that occurs naturally in drinking water. Of particular concerns are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations. Sulfate in drinking water currently has a secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L), based on aesthetic effects (i.e., taste and odor). EPA estimates that about 3% of the public drinking water systems in the country may have sulfate levels of 250 mg/L or greater. In Bangladesh standard for drinking water (ECR 97) of sulfate (SO_4) is 400 mg/l. From this analysis it was seen that wet & dry season sulfate (SO_4) value is nearly same. The average value 10mg/l, which is very low from standard value.

CONCLUSIONS:

The present study focuses on the assessment of the present water quality of DND canal, including seasonal and spatial variation and identification of pollution sources with wastewater out falls in the study area. DND canal water is used as drinking water source and treated in SWTP. The raw water is pumped from the Shitolakhya River into DND canal and from end of the DND canal the water is led by gravity through a closed culvert some meter to the inlet pump station of the SWTP. The pollution of the Lakhya River to a large extent comes from urban sewage which is leaking from the heavily polluted Norai Khal into the Balu River and further into the Lakhya River shortly upstream of the Sarulia intake pump station. Finally the polluted water enter DND canal from Shitolakhya River. If pollution rate of DND canal is reduced significantly then the water treatment efficiency would be much higher therefore, the treatment cost will be significantly reduced. So the study is created awareness regarding the environmental issues in DND canal through the actual determination of the water quality of DND canal in the context of SWTP. And some reasonable steps to be highlighted as given below:

(a). Existing land use pattern around DND canal should be changed.
(b). Illegal wastewater outlets and slums have to be removed from the bank of the canal.
(c). Prevent to discharge untreated sewage and other industrial waste water into canal.
(d). Avoid using canal banks as bathing & washing clothes.
(e). Moreover, existing laws and regulation should be implemented properly & suitable policy should make to raise the public awareness.
(f). There is an urgent need for introducing a pre-treatment for the water at Saidabad I and II as soon as possible and if possible optimize the operation of that plant to yield a better water quality during the dry season.

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ECONOMIC ANALYSIS OF GREY WATER USE-A CASE STUDY FOR A FIVE STORIED RESIDENTIAL BUILDING AT CUET

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ABSTRACT
Asia is being suffered by the scarcity of fresh drinking water due to increased urbanization & pollution. In Bangladesh, fresh drinking water also become unsuitable as water table is decreasing significantly day by day. It is however anticipated that among the day to day activities for fresh water uses, about 40% of water is used for non-potable purposes, for some of these may not have regular potable quality. In this line, the use of grey water got serious attention for its potential of non-potable purposes such as for irrigation, recreation, gardening, fish culture, toilet flushing etc. For residential establishment or building, a single pass sand filter along with sedimentation basin & chlorination chamber was designed using locally available materials with the aim of treating grey water thus to fit for non-potable domestic purposes such as toilet flushing, gardening & car washing. Economic analysis for non-potable uses of grey water was performed using project justification method. Total cost of installing grey water treatment train & total saving cost of using treated grey water for non-potable purposes was estimated using present day value. Though B/C ratio is less than 1, it is not the main concern where scarcity of fresh drinking water is more. By calculating payback period, it was found that grey water treatment system can be implemented economically for a 5-storied residential building.

Keywords: Grey water; fresh drinking water; non-potable purposes; 5-storied residential building; payback period

INTRODUCTION
An increasing global population coupled with growing urbanization in many countries already water source regions worldwide has led to increased demands on water supply (USEPA, 2004). The recycle and reuse of wastewater is considered as a strategy of water demand management (WDM) system. Reuse of wastewater minimizes the demand for the freshwater (Redwood, 2007). With the technological advancement and public acceptance, grey water seems to be a potential source of water saving (Al Jayyousi, 2003). Former studies reported that the amount of grey water produced in household is 55% - 65% of the total amount of waste water (Burnat et al. 2007). Grey water generated from sinks, baths, showers or washing machines can be treated onsite or offsite for non-potable use purposes such as irrigation, toilet flushing, car washing, dust control, soil compaction, in construction works, and in industrial processes like cooling boilers and other appliances (Almeida et al. 1999, Butler et al. 1995, Funamizu et al. 2001). Reuse of grey water in toilet flushing and gardening can save 31% - 54% of potable water in households (Christova-Boal et al. 1996). Quantity of grey water generation depends on the income level of the people. Households without in-house water connection produce grey water which is more concentrated than wastewater from wealthy areas, due to the lower water consumption and existing reuse practices (Hoffmann et al. 2011). Most grey water treatment technologies are consequential from conventional wastewater treatment and were not developed specifically for grey water treatment (Hoffmann et al. 2011). A principal concern for water reuse is the potential for the transmission of pathogenic micro-organisms from reuse applications (Asano et al. 2007). Knowledge of the pathogen content of grey water is limited. Specific pathogens & significant numbers of indicator bacteria have been reported indicating that the disinfection of grey water prior to reuse is essential to the risk of public health (Rose et al. 1991). For this reason, treatment of grey water by a low cost system is required to minimize the above problems. The objectives of this paper are:

1. To develop a cost effective treatment system using locally available material for grey water treatment train for a 5-storied residential building.
2. To design the grey water treatment approach for that building using AutoCAD.
3. To estimate the total cost of installing grey water treatment train for that residential building.
4. To estimate the total saving cost of using treated grey water for car washing, gardening & toilet flushing.
5. To estimate the payback period & cost-benefit ratio.

METHODOLOGY

Study area

Chittagong University of Engineering & Technology (CUET) was selected as the studying area. A five storied residential building of teacher's residential area was considered as the study area for this case study.

Background of Case Study

This case study is based on an experimental study which was carried out in CUET campus area. A small scale treatment train was introduced then. Sedimentation tank, filtration tank & chlorination tank was used as the treatment train. CUET campus area selected as study area. Grey water was collected from the residential area, hall, canteen & mosque. The collected water tested in the CUET Environmental Engineering laboratory. Then the treatment train was set up. A Single Pass Sand Filter which was made with locally available materials was selected. The lateral cross-sectional profile of single pass sand filter is shown in Fig. 1. The collected grey water was treated by this treatment train approach. The treated water was also tested in the same laboratory. It was found that the result was satisfactory (Hossain et al., 2015). On the basis of that result, this study was carried out for a 5–storied residential building of CUET campus.

Fig. 1: Lateral cross-sectional profile of single pass sand filter

Procedure

In this project, a case study was carrying on implementation of a grey water treatment train. The grey water treatment system was designed for a 5-storied residential building. The implementation of grey water treatment train for that building is shown in Fig. 1 & Fig.2. The figures show the ground floor plan & roof slab plan. Assuming each family has 5 members, grey water treatment system was designed for 50 members. Water consumption of a family having five members at Goran in Dhaka city is presented in Table 1 (Abedin and Rakib, 2013). Cost of separate plumbing system for the treatment system is presented in Table 2. Cost of installing grey water treatment train is presented in Table 3. Some examples of cost saving by using treated grey water are presented in Table 4. Pay back calculation of the installation cost of grey water treatment train is presented in Table 5. It is assumed that the treated grey water is used for toilet flushing, car washing and for gardening. Grey water cannot be stored for more than 24 hours treated or untreated. So, treated grey water must be used within 24 hours. So, every day the water tank has to be cleaned. The excess water is to be allowed for ground water recharge or the water can be drained out safely. As the water is treated, it will not cause any harm to the environment. Waste water pipelines are used to discharge the waste water except black water from any type of building. Black water is discharged separately. The waste water which was used to discharge directly to the environment is now being collected in a sedimentation tank which volume is 112.5 cft. The water is stored in that tank for 8 hours. The sedimentation tank is built under the ground level. Then the water is allowed to pass through the single pass sand filter by a 2 HP motor. The volume of the filtration tank is 138.58 cft. After filtration the treated grey water was stored in a chlorination tank. The chlorination tank is under the ground level. Volume of the chlorination tank is 100 cft.

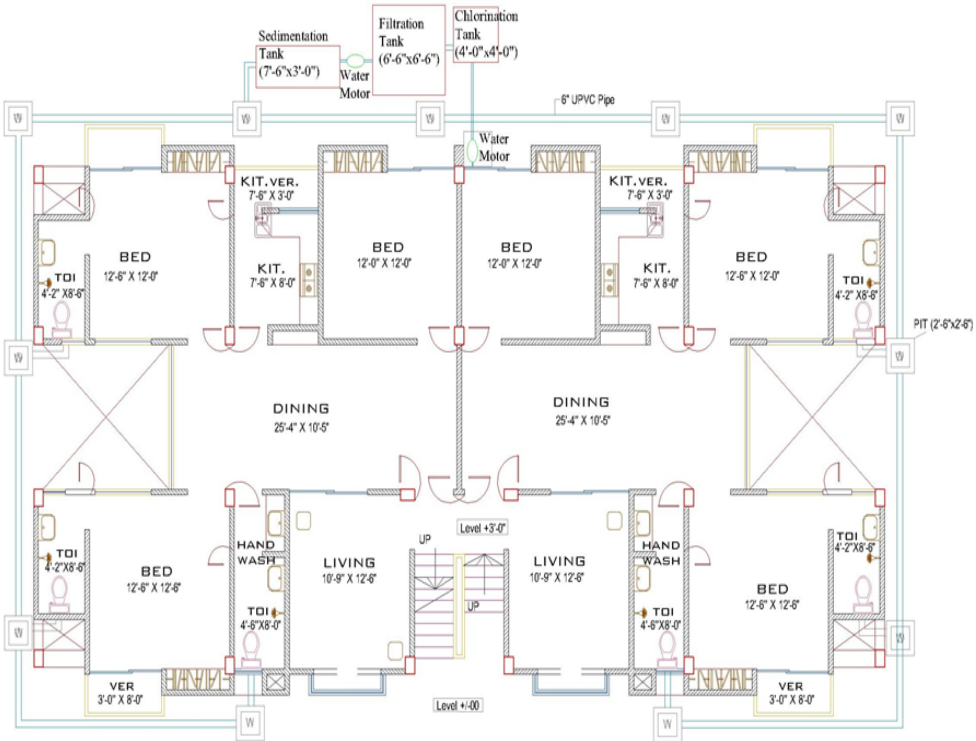

Fig. 2: Implementation of grey water treatment system for a 5-storied residential building (Ground floor plan)

Table 1 Water consumption

Area	Water consumption on Holidays (Liter/day)	Water consumption on Weekdays (Liter/day)
Family member	5	5
Bathing	300	280
Cloth washing	200	180
Dish washing	180	150
Hand washing	30	30
Ablution	70	45
Floor washing	80	80
Consumption(lpcd)	172	153
Total consumption (approximately for 50 members)	8600	7650

(Abedin and Rakib, 2013)

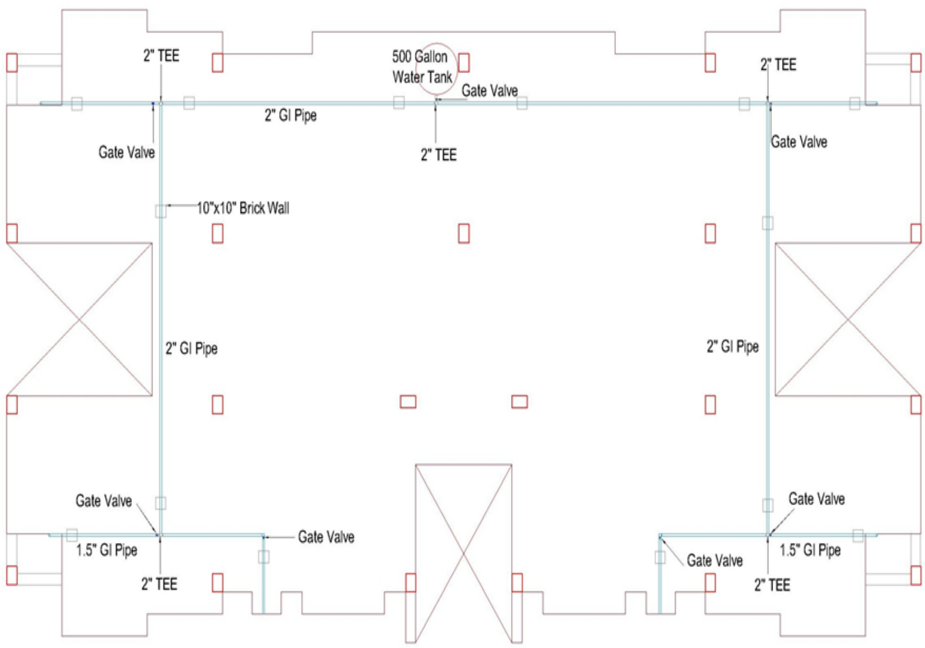

Fig. 3: Implementation of grey water treatment system for a 5-storied residential building (Roof slab plan)

Table 2: Cost of separate plumbing system for a 5-storied residential building

Name of materials	**Price (TK)**
Tank (500 litre)	3750
Motor (2 HP)	20,000
GI pipe	77036
Water tape	300
uPVC wastewater pipe	425
Elbow	902
Tee	3757.5
Bend	5365
Union	4785
Gate valve	5950
Reducer	450
Total=	1,37,964.5

Table 3: Cost of installing grey water treatment train

Name of Materials	**Volume (cft)**		**Price (TK)**
Sedimentation Tank	Cement (per bags)	43	43*400=17200
	Sand	79.6	79.6*20=1592
Filtration tank	Brick chips	159.2	159.2*95=15124
	Rod (kg)	22.39	22.39*81.91=1833.96
Wire Net			4*1000=4000
Water Tape			3*100=300
Concrete Block			50*10=500
Coarse Sand	69.31		69.31*65=4505
5 mm Gravel	6.93		6.93*160=1109
10 mm Gravel	20.8		20.8*180=3744
Earth work in excavation	212.5		212.5*0.3048^3*67=403.2
Brick flat soling			742.1
Shuttering works			4018.99
Plaster works			76089.84
2 HP motor			20,000
Labour Cost			2910
Total=			1,54,072.09

Table 4: Examples of cast saving from treated grey water reuse system

For Toilet Flushing		**For Gardening**	**For Car Washing**
Appliances	Standard toilet charges	Water required for vegetable garden = 630 gallons/ 1000 sq. ft. An approximate area of 100 sq. ft. is used for gardening. So, daily use (litres) = 238.5 Annual water use (litres) =87,052.5	Water required for a car = 60.6 litre/ vehicle There are three cars in this residential building (Assume) So, daily use (litres) = 181.8 Annual water use (litres) = 66,357
Litre/flush	6		
Flushes/person/day	4.8		
No. of occupants	50		
Total flush/day	240		
Daily Use (litres)	1440		
Annual Water use (litres)	5,18,400		

Table 5: Calculation of pay back period.

Parameters	**Amount (TK)**
Initial investment	292036.59
Annual cash flow	38,325
Pay back period (years)	7

RESULTS AND DISCUSSIONS

From the chlorination tank, the treated grey water is stored in an overhead tank on the roof by a 2 HP motor. The overhead tank is of 500 litres. Then the treated grey water is supplied to use for non-potable purposes like toilet flushing, gardening and car washing.

Total capital expenditure required for installing grey water treatment system, C = cost of installing grey water treatment train + Cost of separate plumbing system for a 5-storied residential building

=TK. 137964.5+ TK. 154072.09 =TK. 292036.6

If the life of the system, Y= 5 years, the annual depreciation charge = C/Y= TK. 58,407.32

If annual simple interest is 5%, then a locked up capital of TK. C would earn an average annual interest = (C/2)*(r/100) = TK. 7300

Total annual cost= C/Y+ (C/2)*(r/100) = TK. 65,708.233

Total water required for the five storied residential building for gardening, toilet flushing & car wsahing (for 1 year) = 518400+87052.5+66357= 671809.5 litres.

Total production of grey water (daily) = 8660 liters on holidays.

Loss (daily) = 1660 liters (approximately).

Total amount of treated grey water (daily) = 7000 liters.

Use of grey water for toilet flushing, car washing and gardening (daily) = 1860.3 liters.

Excess amount of treated grey water (daily) = 5139.7 liters.

Total amount of treated grey water (annually) = 2,555,000 liters.

These excess amount of treated grey water can be used for recharging ground water. Or it can safely exposed in the environment. It will not be a cause of theat to the environment

In the conventional system, a pump of 1.5 KW can fill up a tank of 500 litres within half an hour.

So, electricity required = 0.75 unit

Cost/unit = 10 BDT.

For 2,555,000 litres, total water production cost = 38,325 TK for 1 year.

Benefit/Cost ratio = annual benefit/ annual cost

= TK. 38,325 / TK. 65,708.233

= 0.5833< 1

Though B/C ratio is greater than 1, this treatment system has a considerable profit because cost per unit of electricity is increasing day by day in Bangladesh. In new future, when the water table will go down significantly then no doubt total cost by pumping would increase more along with fresh water scarcity. Generally lifetime of a building is 100 years and the pay back period of this treatment system is 7 years. So the treatment system will be more profitable with the time being along with payback period while sustainability of fresh water is really an issue where non potable water can be used for some aspects as discussed in Table 4.

Again, water from CWASA or DWASA is now available in a lower cost. But as the rivers which are main source of water is being polluted at an alarming rate, the treatment cost of the would be more than anticipation. Then the total cost of grey water treatment system would be less than total benefit. Hence, for the project justification only cost benefit ratio cannot be taken as an indicator.

CONCLUSIONS

Operating filter of this treatment system resulted in higher pollutant removal efficiencies as a result of the extended infiltration depth and three separate layers. Such a system would be suitable for the treatment of high strength grey water to reduce the organic load, nutrient load and pathogen load. However, the support and incentives of the local authorities to prioritize grey water interventions is essential to have a wider application of such filter systems. In addition, acceptability by the users and making the filters affordable may pose a challenge to their sustainability.

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VEHICULAR EMISSION INVENTORIES IN CHITTAGONG METROPOLITAN

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ABSTRACT

Chittagong, the commercial capital of Bangladesh, is experiencing crucial health impacts resulting from deficient air quality. Reliable emission inventory is essential prerequisites for assessments of health impacts and analysis of possible options for air quality management. In this study, emission inventory model has been developed for five pollutants, namely PM_{10}, $PM_{2.5}$, SO_x, NO_x and CO, considering vehicular emission in Chittagong city. Diesel driven vehicles (i.e. buses, trucks) emit majority percent emission which is near about 77 percent of total emission (5264.08 tons/year). The emission factor near about 300 (tons/km/year) for the roads Dewanhat to G. E. C. is higher than the other roads considered since the ADT in that location is higher. The model which is used in this study, when fully developed and calibrated, could become a very useful policy analysis tool for air quality management.

Keywords: Air pollution; vehicular emission, ADT, PM_{10}, $PM_{2.5}$

INTRODUCTION

Road transportation, especially motor vehicles, is one of the major sources of air pollution in all large cities of the world. Extensive research linked motor vehicle induced air pollution to premature mortality in the developed world (Small and Kazimi, 1995) as well as in the developing world.

On top of it, motor vehicles are also a crucial source of carbon emissions, a vigorous greenhouse gas (GHG), adversely affecting the climate system. In the developed countries, local air pollution from motor vehicles has received attention decades ago, and the problem is alleviating (or at least not aggravating significantly) because of the enormous policy measures taken.

The main focus now is the control of GHG emissions from the road transport sector. The situation is the opposite in many developing countries where local air quality is worsening, primarily because of increasing motor vehicle ownership resulting from a high economic growth and relatively lax emissions control. While, GHG emissions are also increasing and is of some concern, the priority to the policy makers in these countries or cities is reducing local pollutants from the motor vehicles in order to reduce adverse health impacts (Wadud et al.).

Chittagong city, the second largest and port city of Bangladesh is situated within the geographical coordinates 22°05'-22°22'N and 91°40'-91°52'E Fig. 1. More than six million people live in this city within the 304.5 km^2 area with a steady increase rate of 5 % (Miah. S. 2009). The study area is stands on heart zone of Chittagong city shows on Fig. 2. Table 1 shows the details of selected roads. Being a part of sub- tropic, this area is blessed with monsoon rain. The average annual rainfall is approximately 3000 mm. The average minimum and maximum temperatures are 16-35°C respectively. Humidity is high (85%) in summer and goes down up to 65 % in winter. Wind speed is maximum (12 km/h) in monsoon and summer, and minimum (5 km/h) during winter period (G. S. Sattar, et al. 2005).

There are several source of air pollution in Bangladesh among them unfit vehicles and industries are notable. The numbers of mostly reconditioned vehicles are increasing in every year, one third of these vehicles do not have any fitness certificate (Rouf et al., 2012).Upto years 2010, the total numbers of vehicles in Bangladesh were about 14, 98,244. This number increases and reach about 24, 63,298 in the year 2015 (BRTA). The growth rate of vehicles for last five years is 13.04%. A number of ‘Export Processing Zones’ (EPZ) have been established by the local and foreign investors. Most of the industries are not following the environmental rules and regulations.

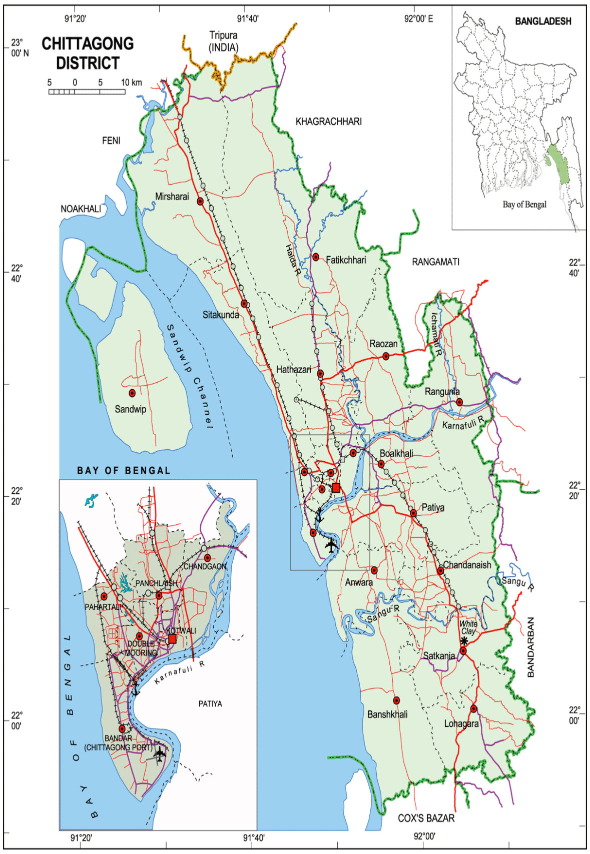

Fig. 1: Chittagong metropolitan area

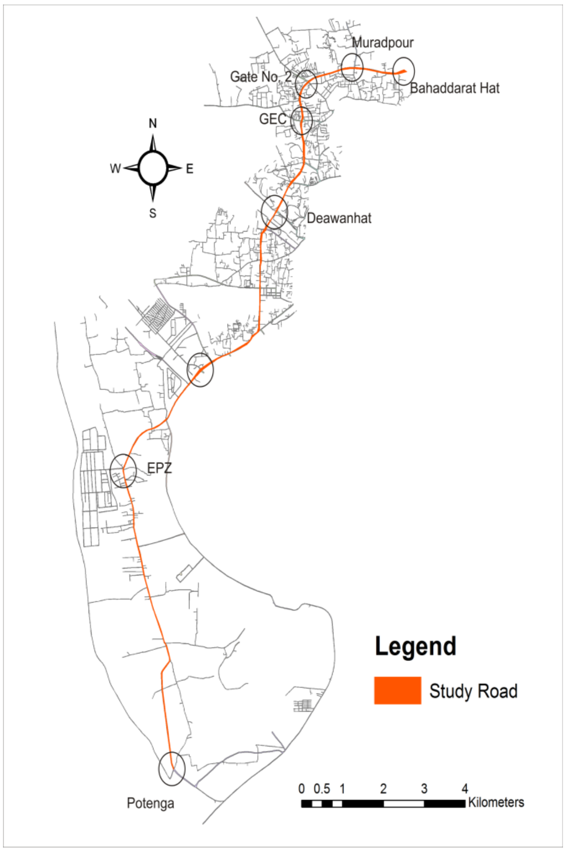

Fig. 2: Study area

Table-1: Selected Road Name & length of Chittagong City

Site No.	Site Name	Road Name	Length (km)	Latitude	Longitude	ADT	Road Type	Traffic Flow
1	Potenga to CEPZ	MA Aziz Road	4.4	22°17'30.27" N	91°46'56.81" E	34773	Secondary	Medium
2	CEPZ to Salt gola crossing	MA Aziz Road	1.5	22°17'39.03" N	91°46'57.13" E	25345	Secondary	Medium
3	Nimtoli to Salt gola crossing	Mooring Road	1	22°18'46.84" N	91°48'4.44"E	16044	Secondary	Low
4	Nimtoli to Alonkar Bus stop	Port Connecting Road	6.1	22°18'49.90" N	91°48'4.69"E	25695	Primary	Medium
5	Nimtoli to Barik Building	Mooring Road	1.3	22°19'8.89"N	91°48'42.40" E	12812	Secondary	Low
6	Barik building to Majir ghat road	Strand Road	1.8	22°19'14.94" N	91°48'53.33" E	41248	Secondary	Medium
7	Agrabad to Boro pole more	Agrabad Access Road	2.4	22°19'38.84" N	91°48'42.54" E	33739	Secondary	Medium
8	Agrabad to Barik building	Shekh Mujib Road	0.9	22°19'36.58" N	91°48'44.43" E	44699	Primary	Medium

9	Agrabad to Dewanhat	Shekh Mujib Road	1.3	22°19'39.80" N	91°48'44.56" E	65937	Primary	High
10	GEC to Dewanhat	CDA Avenue Road	2.8	22°21'31.77" N	91°49'16.78" E	83734	Primary	High
11	GEC to Probartak Mor	O. R. Nizam Road	1	22°21'32.93" N	91°49'19.77" E	17746	Diffuse	Low
12	GEC to A K Khan	Dhaka-Chittagong Hwy	5.4	22°21'32.85" N	91°49'14.72" E	20615	Secondary	Low
13	GEC to 2 No. Gate	CDA Avenue Road	1.2	22°21'35.04" N	91°49'18.06" E	55383	Primary	High
14	2 No. Gate to Oxygen	Bayazid BostamiRoad	3.5	22°21'59.85" N	91°49'21.35" E	44360	Secondary	Medium
15	2 No. gate to Probortak	Bayazid BostamiRoad	1.2	22°21'57.89" N	91°49'24.05" E	23850	Diffuse	Low
16	2 No. gate to Bahaddarhat	Dhaka-Chittagong Hwy	2.2	22°21'59.98" N	91°49'23.88" E	33285	Primary	Medium

METHODOLOGY

Like other busy city, the major sources of air pollutants in Chittagong city are motor vehicles, road dust and industries i.e. brick kilns, cement factories. In the present study, only the emissions from the motor vehicles/ traffic have been considered; efforts are underway to include other industrial emissions in the emission inventory.

Based on the road length in a particular area and the reported ADT, the activity level for each pollutant source (i.e. vehicle type) for each road was then calculated as follows:

A or VKT = L*ADT

Where, A = Activity level for each pollutant source for each road (km/day)

VKT = Vehicle Kilometers Traveled (km/day)

L = Road length (km)

ADT = Average Daily Traffic (traffic volume/day)

For vehicular emission inventory, the relevant emission factors (in gm/km units) for pollutants such as PM10, PM2.5, NOx, and SOx have been collected from available literature. Vehicular emission inventory requires estimation of the number of vehicles and/or traffic activity. Average Daily Traffic (ADT) of major roads measured by CUET has been used. Based on the length of road in a particular area and the reported ADT, the activity level for each pollutant source (i.e., vehicle type) for each road the total emission from different vehicle modes has been estimated for each road separately (T. Afrin et al., 2012). The formula used for emission estimation is given below,

Σ Emission Ei = Σ jΣ k [EFijk * Ajk]

Where, i = Type of Pollutant like PM2.5

j = Fuel Uses like CNG, Disel

k = Vehicle type like Car

EF = Emission Factor for each pollutant

A = Activity level for each pollutant source

RESULTS AND DISCUSSIONS

The estimated yearly vehicular emission for Chittagong city (specially the roads surrounding Air Port to Bahaddarhat) is considerably higher. Diesel driven vehicles (i.e. buses and trucks) are responsible for majority of PM_{10}, $PM_{2.5}$, SO_x, NO_x and CO emissions. Together buses and trucks account for about 95 percent of vehicular PM_{10} emissions, 60 percent of vehicular $PM_{2.5}$ emissions, 99 percent of vehicular SO_x emissions, 90 percent of vehicular NO_x emissions and 61 percent of vehicular CO emissions.

The ADT of different roads classified as primary, secondary and diffuse increased remarkably. The ADT in primary roads increased around 3 percent, secondary 4 percent and diffuse 7 percent than the previous study in year 2012.

Since the emission directly depends on the ADT, with the increased of ADT the per kilometer emission for all pollutants increased than the previous study. Vehicular PM_{10} emissions (tons/year) increased almost 14 percent, $PM_{2.5}$ emissions 4 percent, SOx emissions 62 percent, NO_x emissions 73 percent and CO emissions 0.05 percent than previous study.

Emissions that are released directly into the atmosphere from the tailpipes of cars, trucks etc. are the primary source of vehicular pollution. Since the rate of emission of NO_x from various vehicles is high, NO_x occupied half of the total emission which shows in Fig. 3. Fig. 4 shows the emission from specific vehicle categories where maximum portion is covered by diesel driven vehicles.

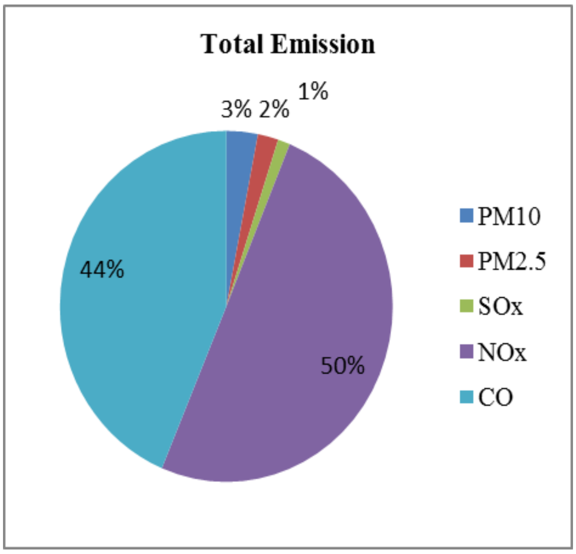

Fig.3: Total Concentration of various pollutants.

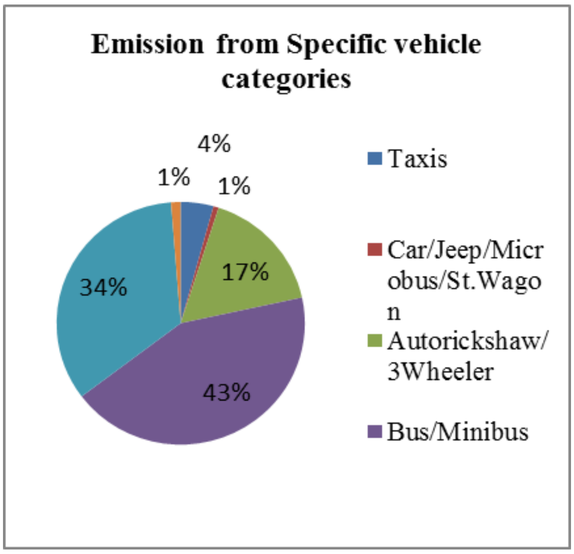

Fig.4: Emission contribution of various vehicles.

Fig. 5 and Fig. 6 shows the comparisons of average daily traffic (ADT) at different roads of Chittagong city and calculated emission factor with the present and previous study which is carried by Norwegian Institute of Air Research (NILU) in 2012 (Randall, S., et al.,2014).

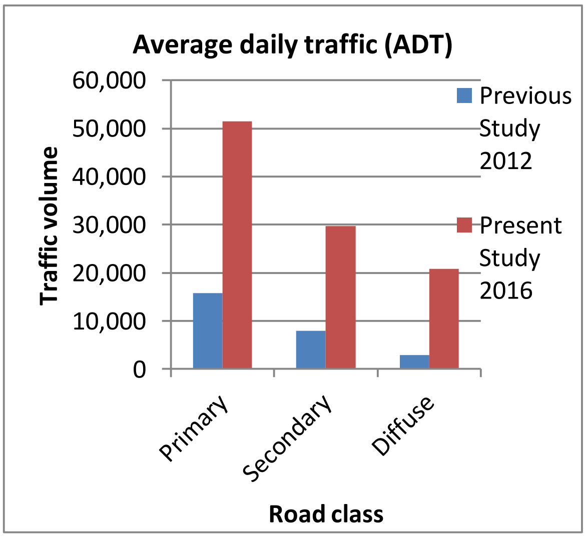

Fig.5: Comparison of average daily traffic with Previous study

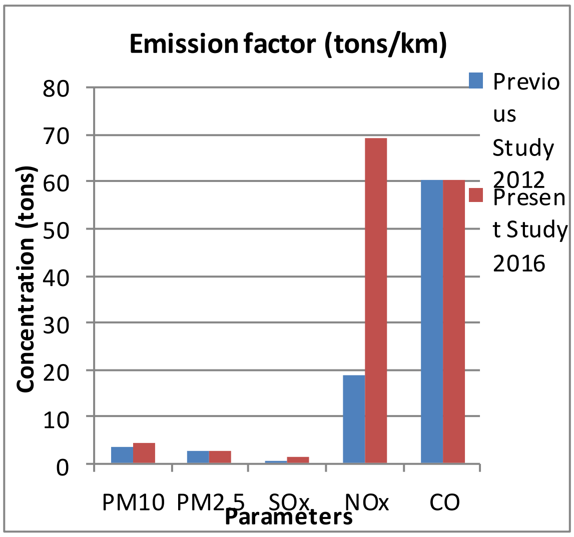

Fig.6: Comparison of calculated emission factor with previous study

[Fig. 7] shows the emission factor (tons/km/year) at several selected roads in Chittagong. The emission factor near about 300 (tons/km/year) for the roads Dewanhat to G. E. C. is higher than the other roads considered since the ADT in that location is higher.

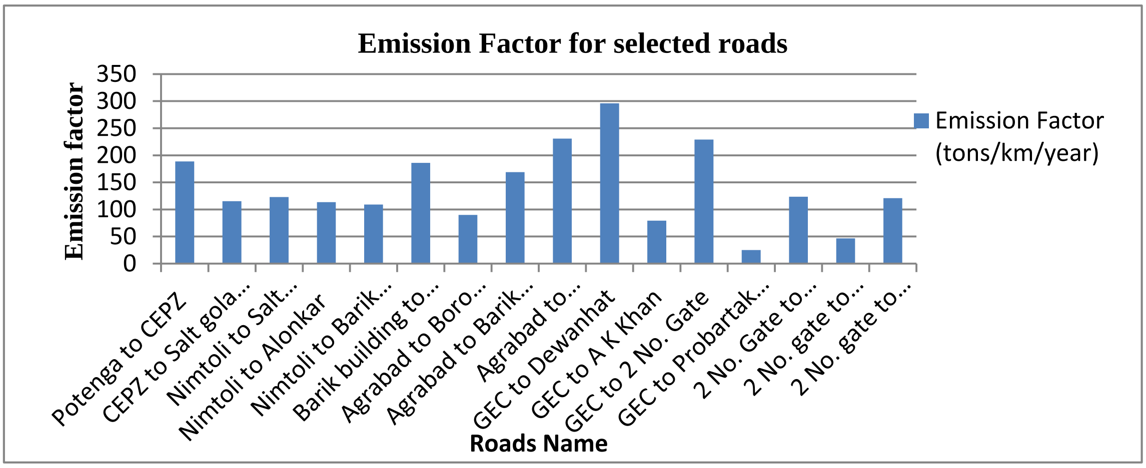

Fig.7: Emission factor (tons/km/year) at several selected roads in Chittagong

CONCLUSIONS

Bangladesh is developing day by day, as a part of its development process number of industries, vehicles infrastructures are increasing notably. Present study was on the emission inventory of Chittagong city, which shows that the ADT of different roads increased about 5 percent within four years that's why emission factor (tons/km) also increased than the previous study.

The developed emission inventory model is flexible such that it can input user defined parameters such as emission factors, activity rates (e.g. ADT for vehicle), fuel use etc. and can be easily updated as new information about the parameters become available.

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A REVIEW ON ENVIRONMENTAL POLLUTION FROM THE USE OF PESTICIDES IN BANGLADESH

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ABSTRACT
Pesticides are mainly used for agricultural use in Bangladesh to prevent vector-borne diseases of crops or plants that are common in the tropical climatic condition of the country. However, the long term use of pesticides on agricultural lands may have toxic effects on environment and public health. Depending on the typical physico-chemical and persistent properties of pesticides, it may travel far along different pathways to contaminate surrounding air, soil and water. In this backdrop, this paper presents a review done on several aspects of pesticide use in agriculture such as the fate of pesticides in environment, their persistent and detrimental effects on environment and several other relevant issues. The factors governing the leaching and transportation potentials of the toxic chemicals of pesticides to surface and groundwater are especially addressed. Attention has also been paid to reveal trends of pesticide use in Bangladesh based on different research findings and following discussions. This review also provides outlook on future actions necessary to protect agriculture and environment of Bangladesh from harmful effects of pesticides emphasizing on raising community awareness for limited use of pesticides, alternative organic agriculture options wherever feasible, national environmental legislations, regulations and monitoring mechanisms about pesticide use etc.

Keywords: Pesticide; environmental pollution; degradation; physico-chemical properties

INTRODUCTION

Pesticides are synthetic organic chemicals intentionally used for protecting crops, preserving foods and controlling plant pests (Chowdhury et al., 2013). These chemicals are used to control weeds in fields and unwanted or harmful pests siuch as insects and mites that feed on crops (USDA NRCS, 1998). Despite their ability to enhance the production and yield of food and fibers by preventing vector-borne diseases, intensive and unrestricted use of pesticide may pose serious threat to the environment and public health (Sitaramaraju et al., 2014; Damalas and Eleftherohorinos 2011; Dey 2010; Rahman and Alam, 1997).

There are various types of pesticides depending on the types of pest they control, and the majority of pesticides do not target the pest only but also affect non-target plants and animals during their application. Most of the pesticides are persistent in the environment for years without degradation due to the chemical, biological or photolytic processes. The pesticide residues, after taken up by the target organisms or being degraded, may be transported to groundwater aquifer, may be transported to surface water bodies, volatilize to atmosphere depending on their physico-chemical properties (Bernardes et al., 2015). A small group of pesticide residues may however be trapped within the environmental system of the place of their application without causing potential harm to surrounding environment. Depending on their chemical properties they may enter the organism, bioaccumulate in food chains and consequently affect human health. In general, intensive pesticide application for agricultural use results in several negative effects on the environment that cannot be ignored.

Being dependent on an agro-based economy, Bangladesh uses varieties of pesticides to protect crops from different pests and consequently to increase crop yield. The widely cultivated and high-yielding

plant varieties of Bangladesh (rice, wheat, jute, potato, sugarcane, vegetables and tea) are highly vulnerable to pests and diseases. Therefore, the use of pesticides has been taken as an obvious and preferable option to the pest control strategies in the agricultural sector of Bangladesh since the demand for agricultural products continually increased to meet the demands of huge population of Bangladesh. However, a very small quantity of pesticides was typically used for agricultural use in the country until 1970s. It is evident from recent research findings that there has been a dramatic increase of pesticide use in the country over the past four decades (Rahman, 2013; Rahman and Thapa, 1999).
A significant number of researches have been conducted on productivity and trend of pesticide use, occupational and environmental health hazard and risk assessment of using pesticide, including field surveys that dealt with assessing effects of pesticide use and widespread use of banned pesticides including incidences of pesticide poisoning (e.g., Dasgupta et al., 2005; Mahmoud and Shively, 2004; Rahman and Hossain, 2003). Few studies have been performed on assessing the leaching potential of pesticides or its residues in either surface water or groundwater, in the soil, and their adverse impacts on aquatic systems (Anwar and Anika 2010; Hasan et al., 2012; Chowdhury et al., 2012, 2013; Zaman et al., 2012; Sumon et al., 2016; Rahman ,2013). However, the study on the factors/properties of pesticides affecting their transport and leaching potential of harmful components of pesticides is still at the rudimentary level in Bangladesh.
In this backdrop, this paper presents a review on the effect of pesticide on environment, public health, environmental fate of pesticide after consumption and their pollution potential in the various components of environment. The discussion follows further on the assessment of the current status, trend and types of pesticide use in agriculture of Bangladesh during the period of 1993-2016 to forecast associated environmental risk potentials. A few suggestions are made at the end of the paper to supplement current practices of pesticide management in Bangladesh which might help minimize potential hazards to environment and human health due to improper use of pesticides for agricultural use in Bangladesh.

PESTICIDES IN AGRICULTURAL USE

Pesticides are divided into different categories such as insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides etc. depending on the target species. Nutritional value of food could be improved by pesticide, and therefore, its use is generally viewed as an economically feasible and efficient tool for pest management (Rahman, 2013; Damalas and Eleftherohorinos, 2011). The main use of pesticides in Bangladesh is for rice (70%) and the remaining 30% is on tea, sugarcane, potato, mango, banana and vegetables (Aziz, 2005). A synthetic group of insecticide named organophosphate (OP) has been introduced in the 1960s while carbamates introduced in 1970s, pyrethroids in 1980s and the introduction of herbicides and fungicides in the 1970s–1980s contributed greatly to pest control and agricultural output (Aktar et al. 2009). A typical pattern of pesticide usage in Bangladesh is presented in [Fig.1 (a)]. In Bangladesh insecticide usage rate (46% of total usage) is the highest (16985 metric ton in 2014) which is very close to overall global use, 44%. (Mathur, 1999). The use of fungicides in Bangladesh is almost similar to insecticide (16138 metric ton, 43% of total pesticide). Oraganochlorine (OC), a group of insecticides used successfully in controlling a number of diseases such as malaria and typhus, were banned or restricted after 1960s in most of the technologically advanced countries. DDT, one of the mostly used OC insecticides, is banned in Bangladesh since 1993 because of their very high toxic potential.
The pesticide consumption in Bangladesh during the period of 1984 -2014 is presented in [Fig. 1 (b)]. Pesticide poisoning is more widespread in developing countries like Bangladesh as compared to developed countries (Hou and Wu, 2010) which might be due to the lack of users' awareness and knowledge on selection or proper use of pesticide. A steady and sharp increase in pesticide use since 1980s, as shown in [Fig. 1(b)] might be due to government's preference to adopt chemical control measures to increase crop production as well as to prevent pre and post-harvest crop losses (Aziz, 2005; Matin, 2003; Rahman, 2013). However, it is also noteworthy from the figure that there is a decrease after the year 2008. The reduction in the usage may be ascribed to the people's increasing awareness about health or environmental hazards and government policies or regulations on limiting use of pesticide in agriculture.

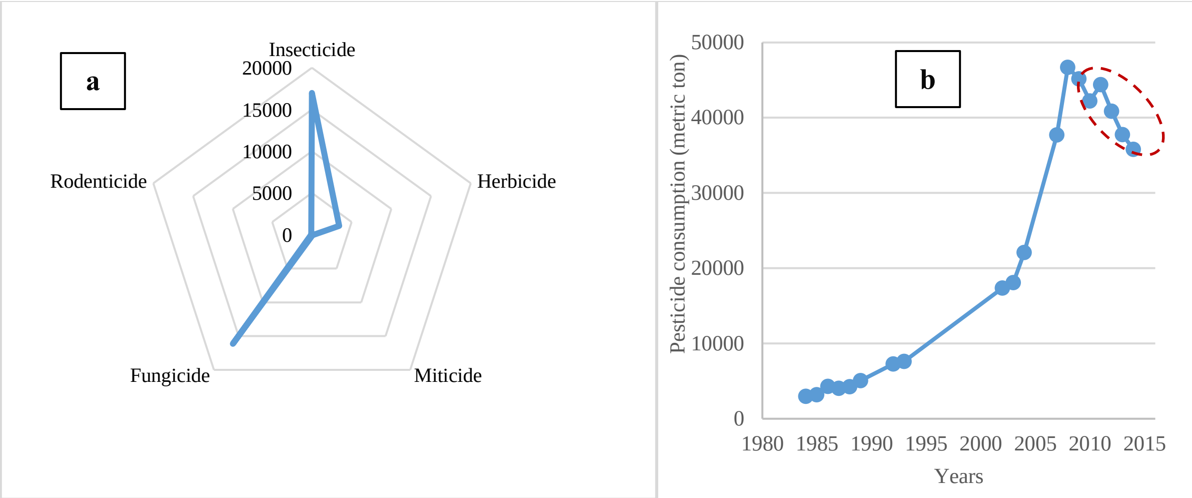

Fig1: (a)Typical pattern of pesticide consumption (metric ton) in Bangladesh in 2014 (Data Source: BCPA) (b) Pesticide consumption in Bangladesh (Data Source: BCPA; Aziz, 2005; Rahman and Alam 1997)

FATE OF PESTICIDES IN THE ENVIRONMENT

Pesticide enters into the environmental cycle through different pathways during its preparation and also during the period of its application or intended use in agriculture. Pesticides are taken up by target organisms, the residues degraded and leached through the soil and transported to the groundwater. They may reach surface water bodies by runoff during rainfall and may also volatilize to the atmosphere, or ingested by non-target organisms. The degradation potential of pesticides determines the behavior and fate of these compounds in the environment. In ideal conditions, they remain in the area of application long enough to achieve desired effects after which they are degraded into harmless products. The fate of pesticides in the environment is shown in [Fig. 3]. The three basic modes of degradation of pesticides in the environment are biological (breakdown by micro-organisms present in the soil), chemical (hydrolysis, redox reactions etc.) and photochemical (breakdown by ultraviolet or visible light) processes (USDA NRCS, 1998). The type and extent of transport from the point of application or degradation in the environment depends on its physicochemical properties (chemical formulation, persistency, water solubility, DT_{50}) of pesticides, soil types and formulation (texture, permeability, organic matter, plant uptake, sorption capacity, volatilization etc.), environmental conditions (e.g., frequency and timing of rainfall or irrigation and depth to ground water, temperature, moisture) etc. (Lourencetti et al., 2008; USDA NRCS 1998, Bernardes 2015).

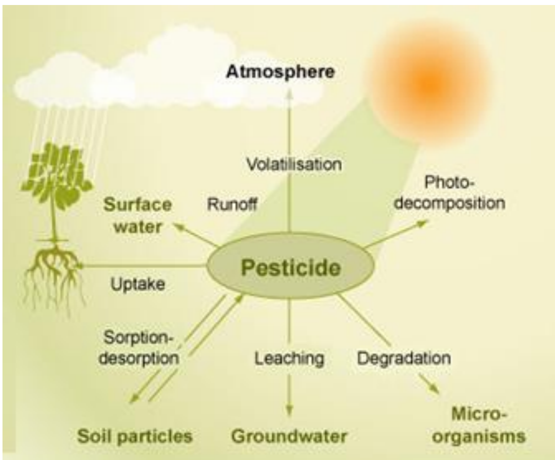

Fig. 3: Fate and degradation of pesticide in the environment (Source: Cromedia)

The solubility of pesticides mainly determines their transport in surface runoff and their leaching capacity to groundwater. The higher the solubility, the greater the carrying and leaching potential. Several researches have been performed to identify the factors contributing to pesticide leaching

(Anwar and Yunus, 2010; Gish et al., 1991; Truman and Leonard, 1991; Agertved et al., 1992). However, detailed study on factors influencing the fate of pesticide is still very limited. Meisener (2004) and Sumon et al. (2016) used the LD_{50} or DT_{50} value to quantify the risk associated with the use of extremely hazardous pesticides. Leaching potential of various of pesticides was studied in a shallow unconfined aquifer located in Northwest Bangladesh (Anwar and Yunus et al., 2010). There was no trace of known pesticide residues in the soil-water found in the study except for a few unknown peaks were detected in the analysis indicating illegal use of some unknown chemicals or some other organics coming from unknown area. The physico-chemical properties of different insecticides which are being used in Bangladesh has been summarized in Table 1.

Table 1: Physico-chemical properties of insecticides mostly used in Bangladesh

Chemical Class	Common Name of Products	Class (WHO, 2010)	LD_{50} (mg/kg) (WHO, 2010)	DT_{50} (days) (Chowdhury et al., 2012)	Water Solubility (mg/L) (Anwar and Yunis, 2010; Vogue et al., 1994)	$DT_{50\_wtaer\ hydrolysis}$ (days) (Sumon et. al., 2016)
Organo-phosphates	Diazinon	II	300	7-15	60	----
	Malathion	II	----	0.49-107	130	6.1
	Chlorpyrifos	II	135	16-72	0.4	25.5
	Cypermethrin	II	c250	----	0.004	179
	Fenitrothion	II	503	----	30	----
Carbamate	Carbofuran	Ib	8.0	13-14	351	37
	Carbaryl	II	c300	0.15-35	120	----
Organo-chlorine	Heptachlor	O	----	----	0.056	----
	Endosulfan	II	80	----	0.32	----

DT_{50}: degradation time for 50% of a compound; **LD_{50}**: lethal dose for 50% of the population $DT_{50\ water\ hydrolysis}$: Half-life in water at pH=7 and 20°C; WHO Classification of Active Pesticide Ingredients: Ib = Highly hazardous; II = Moderately hazardous; O = Obsolete as pesticide, not classified.

WATER POLLUTION DUE TO USE OF PESTICIDES IN AGRICULTURE

Many pesticides may contaminate soil, water, turf and other vegetation particularly due to their unrestricted use in agriculture. Besides killing harmful insects or weeds, pesticides can be toxic to a host of other organisms including birds, fishes, beneficial insects, and non-target plants. Insecticides are generally the most acutely toxic class of pesticides, but herbicides can also pose risks to non-target organisms (Aktar et al., 2009). As water is a vital element of the physical environment, and the quality of water is directly related with human wellbeing, the water pollution because of pesticide has been especially discussed in the paper.

Contamination of water by pesticides is widespread now-a-days, and some of the key-findings of recent researches regarding impact of pesticide on water and aquatic environment have been summarized in Table 2. It is reported in a study done in USA (Aktar et al, 2009) that at least 143 different pesticides and 21 transformation products have been found in groundwater, including pesticides from every major chemical class, and pesticides residues were found in all samples from major rivers with mixed agricultural and urban land uses (USGS, 1995). Different types of herbicides such as 2,4-D, diron and promenton, and insecticides chlorpyrifos and diazinon were detected most often in surface water and groundwater across USA (USGS, 1995). A few studies performed in Bangladesh were mainly aimed at identifying trace of pesticide residues in surrounding water source of an area of application of pesticides (Chowdhury et al., 2012, 2013; Zaman et al., 2012; Hasan et al., 2012; Uddin et al., 2013) and assessing their effects on the aquatic systems (Hasan et al., 2012; Sumon et al., 2016). Although DDT was banned in 1993, its concentration exceeding the guideline value of WHO was found in surface water in several districts of Bangladesh (Chowdhury et al., 2013). Organochlorine insecticide residues are typically found in surface water, irrigated water samples from several districts of Bangladesh. Water samples from from surface water in five locations (Feni, Nawabganj, Putia, Burichang and Chatak) were contaminated with DDT and the water from Natore, Sikderpara, Chatak and Rajoir were contaminated with heptachlor residues and the highest level detected was 5.24 mg/L, which is above the maximum contaminant level recommended by the World Health Organisation. Sumon et al. (2016) concluded in a risk assessment study that chlorpyrifos, cypermethrin, alpha-cypermethrin, and malathion may pose a high to moderate acute and chronic risks for invertebrates and fish in all evaluated spray drift scenarios and these may have severe consequences for the prawn production yields.

Table 2: Effects of pesticide in water and aquatic environment

Types of pesticides	Name of pesticides	Effect	References
Insecticides	Organophosphates	• toxic effect on aquatic organisms: reduces abundances of invertebrates in the pond	Shahjahan et al., 2016
	Pyrethroids	• Loss of ecological balance: causes death of fishes	Mondal et al., 2015
	Carbamate	• affect water temperature and alkalinity • affect fish size and increase mortality of fish	Altinok et al., 2007
	Chlorinated Hydrocarbon i.e. DDT	• Causes acute toxicity in plants; interferes with growth of oysters, higher residues cause declination of mollusks and shrimps	Goldberg et al.,1971
Herbicides	Bipyridyls	• toxic effect on vegetable seedlings	Mullison 1970
	Phenoxy Hormone	• affects fish, plankton and other water inhabitants	Mullison 1970
Fungicides	Benzimidazoles	• Exhibits toxic effect on aquatic organisms, causes ecological hazard	Wagil et al., 2015
	Dithiocarbamate	• affects breathing of fishes, and hypo- and hyperactive behavior of fishes • loss of ecological balance	Srivastava and Singh, 2014

CONCLUSIONS AND FUTURE OUTLOOK

The freshwater source in many districts of the country is already polluted by the pesticide residues. A comparative fact chart is presented in this paper highlighting consequential toxic effects of human, animal, aquatic lives, plant species and other living organisms. Realizing the fact of long-term adverse effects of using certain group of pesticides, the government of Bangladesh has already started some practices across the country e.g., integrated pest management options (IPM), farmers' awareness programs, formulating and adopt regulations and legislations on proper application of pesticides etc. However, more detailed study should be conducted in all different regions of the country to assess the pollution risk on different phases of environment through different pathways. The presence of few banned pesticides in different environmental components indicates weakness in regulatory practices. Therefore, a combined and focused approach to minimize the explosion in pesticide usage is a pressing demand. Raising countrywide community awareness, promoting organic farming and organic pest management wherever feasible, strict enforcement and monitoring of existing pesticide regulations and expansion of IPM are recommended to make the agricultural sector more sustainable and more protected against the harmful effects of pesticides.

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ASSESSMENT OF WATER QUALITY OF BAMUN SHAHI CANAL OF CHITTAGONG CITY

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ABSTRACT
The water quality of Bamunshahi Canal of Chittagong city, the busiest seaport in southern Bangladesh has been assessed in the study. The canal water is being used for irrigation, fishing, recreation etc. by the local community living alongside the river. However, the canal receives industrial toxic wastes as well as human sewage and carries these pollutants to the tidal river Karnaphully. Hence the physical, chemical and biological quality of the canal water has been analysed in the study. The values of pH, dissolved oxygen (DO), faecal coliform(FC), total hardness, alkalinity, phosphate are within the allowable limit of Bangladesh Standard (BDS). However, the values of biological oxygen demand (BOD_5), chemical oxygen demand (COD), turbidity, nitrate, color, total solid (TS), electrical conductivity(EC) exceed the standard limit prescribed for Bangladesh. The study indicates that the water is not suitable for irrigation or fishing purpose. Hence industrial effluent must be treated before discharging into the canal like any other natural water systems to sustain the ecological balance of the river and canal as well.

Keywords: Water quality; canal water; biological oxygen demand; chemical oxygen demand; dissolved oxygen

INTRODUCTION
Surface water, one of the major water sources used for all water-related purposes, is obviously highly susceptible to contamination, and it has historically been the most convenient sewer for industry and municipalities alike (Masters, 2004). The quality of surface water is being degraded day by day due to the unplanned urbanization and consequent speedy economic growth through intensified industrial activities in developing countries. Like other developing countries, the quality of surface water in Bangladesh is also at high risk, and the problems are acute especially in the urban areas. Chittagong, the busiest coastal seaport city in the southern Bangladesh, is located on the banks of the tidal river Karnaphuli, and the river has major contributions to the national economy through import-export activity, hydropower generation, drinking water supply for Chittagong city dwellers, navigation for waterways, employment of many fishermen, boatmen etc. and a significant prospect of tourism in its 88 kilometers of course in Bangladeshi border (Haider et al., 2014). However, the industrial effluents which may contain highly toxic substances from various industries situated throughout the city corporation area as well as a large amount of municipal waste are being discharged into the Karnafully river directly or through almost twenty tributary canals flowing across the city to dispose city's wastewater and stormwater. Although the pollution level of the river water may be minimized by its self-cleaning capacity and the diurnal tidal cycle of the river, its quality is being deteriorated day by day. A significant number of studies have found that the water quality of the river has been exceeded its tolerable limit such as for fisheries, irrigation etc. (Haider et al., 2014; Ahmed et al., 2010; Sarwar et al. 2010; Hossain et al., 2006). Many studies have been conducted to assess the water quality of the river of the city but the study on water quality assessment of its tributary canals are limited.
In this backdrop the study has been conducted to assess the water quality of Bamubshahi canal, one of the tributary canals of the Karnafully river, which receives pollutant both from point and non-point sources such as the industrial effluents from heavy industrial area of the city, as well as the municipal waste from the surrounding areas. Few suggestions are also made at the end of the study which might help minimize the potential risk from the disposal of untreated effluent to the environment.

METHODOLOGY

The study was conducted on a canal which is originated from Oxygen area, a heavy industrial area of Chittagong city, and ended up into the Karnafully river. The Shitaljharna Khal is flowing from Oxygen area to Dhalipara which is about 5 Km long, and the name of the canal has been changed as Bamun Shahi Khal from Dhalipara to the Karnafully confluence. Therefore, the two canals are named here as Bamunshahi Khal in later section of the paper for the convenience. The details of the 11 Km long study area and sampling locations are shown in Fig. 1. Water samples were collected from 21 locations along the length of Baminshahi Khal at approximately equal distances (500 m interval) to analyse its physical, chemical and biological parameters during the period of August 2014 - August 2015. Necessary precautions were taken during sample collection, and the samples were analysed in the environmental engineering laboratory of Chittagong University of Engineering and Technology following standard procedure of water analysis. Table 1 presents sample identification and sample location.

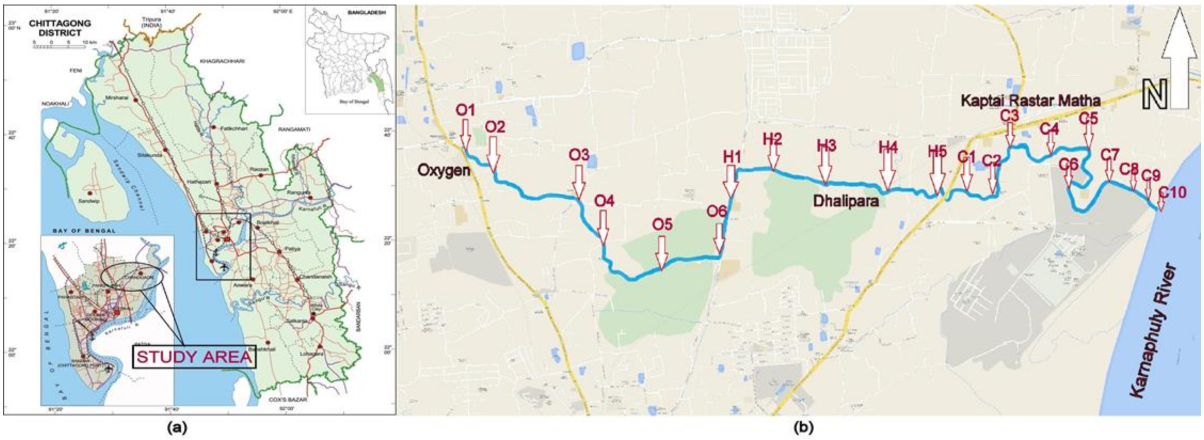

Fig. 1: (a) Map of the study area; (b) Sampling Location

RESULTS AND DISCUSSION

Physical, chemical and biological parameters of the water samples collected from the studied area were analysed to assess their quality for the intended uses. The obtained results were also compared with the Bangladesh Standards (BECR'1997) of water quality parameters for various water related purposes. The key findings of different parameters of water samples are discussed in the following sections.

Evaluation of Physical Properties of Water

The pH of the canal water was found between 6.4-7.9 which is within the allowable value suggested in the Bangladesh standard. Although there is no direct effect of pH on aquatic environment, there may be a gradual decrease in fish population with the decrease in pH. The toxicity of several common pollutants is markedly affected by pH changes, and increasing acidity or alkalinity may take those poisons more toxic (Russel et al, 1979). The temperature of water is a very important parameter because it has effects on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses. Optimum temperatures for bacterial activity are in the range 25- 35 ^{0}C, the temperature of the canal water was 26-29^{0}C. There is no standard value of color for fishing and agriculture but for drinking the BDS standard is 15PCU. The PCU value of the water was very high from Chandgaon to Raillarpore area and Mohra ward area which may be due to the colored wastewater discharges from various garments situated in the area. The water collected from all the locations were found very turbid and the turbidity values are higher (maximum 106 NTU) than those of the Bangladesh standard (10NTU) except Hazipara area. Turbid water interferes the recreational use, and turbid water can be dangerous for swimming, because of the possibility of unseen submerged hazards and the difficulty in locating swimmers in danger of drowning. (Russel et al, 1979). There is frequent dredging work found along the length of the canal which might be one of the reasons of being highly turbid water. The gradual increase in turbidity in 5 no. Mohra Ward is ascribed to the industrial disposal in the area .All the physical parameters of water samples analysed in the study are graphically presented in Fig. 1.

Table 1: Different sample location and their identification in the study at different distances

Sampling location	Sample ID	Distance from base point (Km)	Sampling location	Sample ID	Distance from base point (Km)
Oxygen moore*	O1	0	4 no Chandgaon ward	C1	6
Shahid nagar	O2	0.5	4 no Chandgaon ward	C2	6.5
Jomader pol	O3	1.5	4 no Chandgaon ward	C3	7
Hazipara	O4	2	5 no Mohra ward	C4	7.5
Chadgaon	O5	2.5	5 no Mohra ward	C5	8
Chadmia road	O6	3	5 no Mohra ward	C6	8.5
Hazirpul	H1	3.5	5 no Mohra ward	C7	9
Dhalipara	H2	4	5 no Mohra ward	C8	9.5
Dhalipara	H3	4.5	5 no Mohra ward	C9	10
Tekbazar	H4	5	Karnaphuly river	C10	10.5
Raillarpul	H5	5.5			

*considered as base point for convenience

Regarding the solid concentration of the canal water, the TS values was higher in the upstream of the canal which might be due to the channel scouring phenomena and having lower depth. However, a comparatively lower TS value was found at the confluence point of the canal and the Karnaphully river due to the dilution process., TS values decreased rapidly due to dilution of the canal water. Electrical conductivity indicates the presence of ions, salt within the water. The water contains higher conductivity (maximum 1685 μmhos/cm) than that of BDS (1200 μmhos/cm) for irrigation purpose and hence it can be concluded that the water is unsuitable for irrigation. Also according to Indian Standard, EC value ranges from 750-2250 micro mhos/cm at 25℃ which should not be used on soils with restricted drainage because it hampers crop yielding. Unrestricted and untreated disposal of industrial effluent contributes various ions in the water which may help to increase EC value of water.

Evaluation of chemical properties of water

The results found from the chemical analysis of water samples from different areas are shown in Fig. 2. The study shows that the canal water is alkaline having the alkalinity value of 20-55 mg/L but it is below the Bangladesh standard for the water to be used for drinking and fishing purposes. Hardness analysis of all the samples shows that the values of most of the samples are within the BD standard. A spatial variation in hardness value along the canal length has been observed in the study and have slight variation throughout the canal. As the water is soft the water may be used for irrigation.

The DO value is the most important parameter considered for a healthy aquatic life. Hence the level of DO value of the studied canal was determined, and the DO values of the tested samples are within limit (≥6mg/L) for most of the cases except 4 no. Chandgaon Ward, 5 no. Mohora Ward and the confluence point with Karnaphuly River. A comparatively DO value can adversely affect aquatic life and other animals which live on fish. However, many other invertebrates are less sensitive to a lower DO concentration and may be equally suitable for fish food. The water had a BOD_5 value of 10-50 mg/L. Excessive discharge of industrial and tannery waste to the canal and disposal of

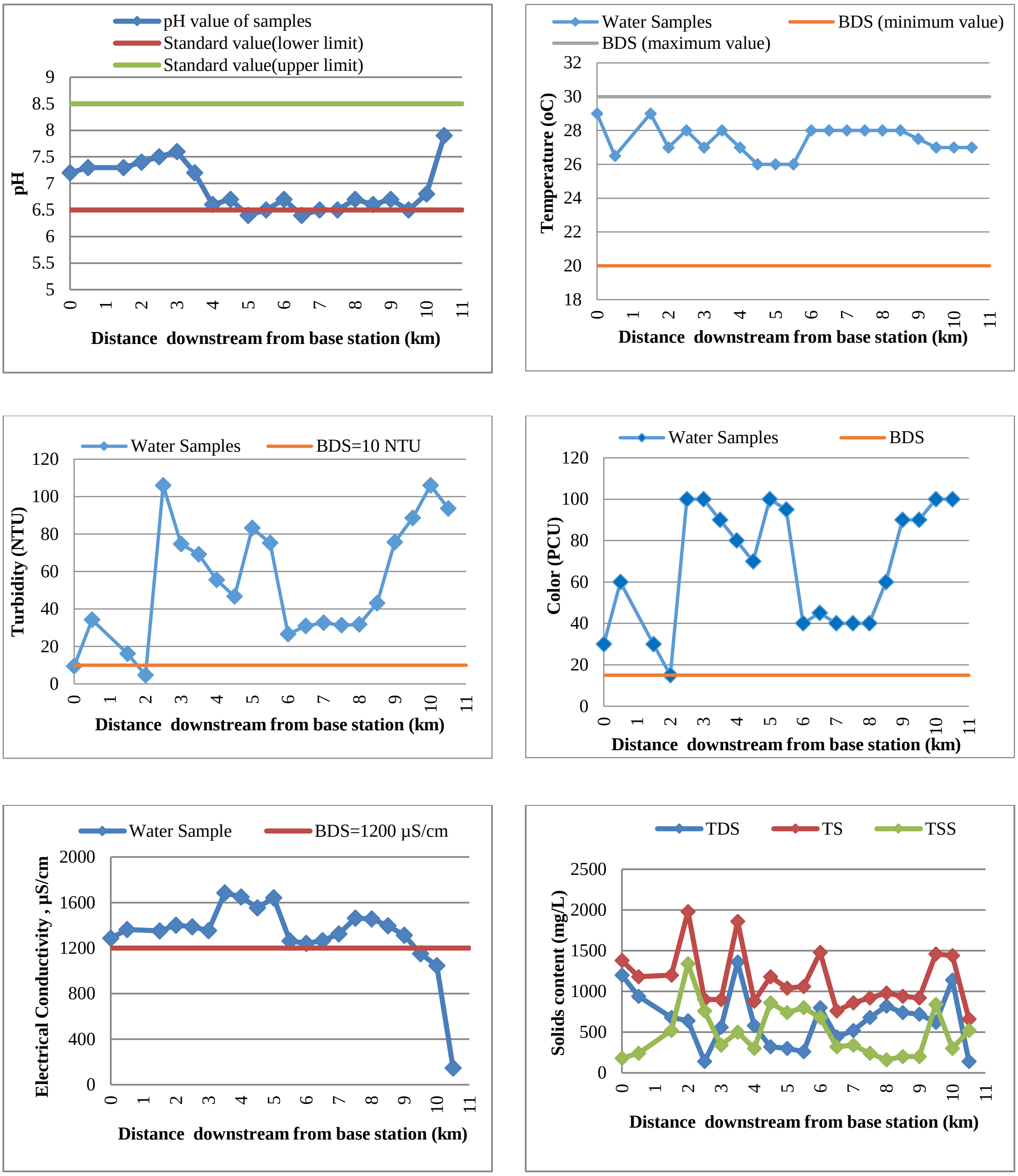

Fig. 2: Results of the physical quality analysis of water samples along the length of the canal

sanitary sewage as well as domestic waste are degrading the water quality and increasing the value of BOD_5. The water also contains COD concentration with an average value of 168 mg/L (maximum 400 mg/L and minimum 90 mg/L) which is much higher than that of Bangladesh standard for drinking water which may be due to the disposal of industrial effluent from various industries located along the length of the canal especially from the Nasirabad heavy industrial area. However, the results indicate that the water cannot be used for drinking purpose without proper treatment. The findings of the chemical analysis are summarized in Fig. 2. The water quality standards in Bangladesh for various purposes are presented in Table 3.

Table 3: Surface water quality standards for various purposes (BECR, 1997)

Parameters	Units	Bangladesh Standard			
		Irrigation	Drinking water	Recreation	Fishing
pH	-	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
DO	mg/L	5 or more	6	5 or more	5 or more
BOD_5	mg/L	<10	0.2	<3	<6
Turbidity	NTU	-	10	-	-
Total solid	mg/L	-	1000	-	-
Temperature	°C	-	-	-	-
TC	N/100 mL	<1000	0	<200	-
Nitrate	mg/L	-	10	-	-
Phosphate	mg/L	-	6	-	-
Alkalinity	mg/L		100		70-100
COD	mg/L	-	4.0	-	-
Color	PCU	-	15		-
Hardness	mg/L	-	250-500	-	80-120
E.C	µmhos/cm	1200	-	-	800-1000

Eutrophication is the process of algal bloom caused by excessive nutrient disposal into the natural systems. If any system gets eutrophied it will affect ultimately the DO value of water and hamper the ecological balance of the system. Hence the regulatory organizations of many countries worldwide put stringent rules and standards on nutrient disposal. Therefore, nutrient (nitrate and phosphate) content of water were analysed in the study. Nitrate values of the water samples were found 120 mg/L and the phosphate content of the water was 5 mg/ L. The nitrate content is much higher than the BDS (10 mg/L) while phosphate content is within the allowable limit (6mg/L).

Evaluation of Biological Parameters

It is noticed during the study that the water of the canal is being used for irrigation, fishing, recreation etc. and there are communities living alongside the canal. Hence there is the possibility of microbial pollution caused by human sewage or other animal's excreta along the length. Therefore. biological analysis (faecal coliform, FC) has been performed in the study to detect the level of microbial pollution. The analysis shows that the water does not contain any FC which comply with the BDS. Therefore, the water is safe to use for irrigation or even for drinking purpose regarding the microbial content of water.

CONCLUSION

The physical, chemical and biological water quality of Bamushahi Canal, one of the tributary canals of the Kranaphully river, of Chittagong city has been assessed in the study. The results of the water quality analysis indicate that the water is not suitable for irrigation, fishing and recreation. Although DO value of the water are considerably higher than that of Bangladesh standard for fishing, the very high BOD_5 COD content of the water indicates the presence of toxic organic wastes which may hamper the DO content and the ecological system of the canal. The study concludes that treatment of industrial effluent

Fig. 3: Results of the chemical quality analysis of water samples along the length of the canal

before discharging it into the canal should be done by the respective authority, and law enforcement and strict monitoring must be maintained on a regular basis to save the canal as well as the Karnaphully river.

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DISINFECTION BY-PRODUCTS (DBPS) IN DRINKING WATER AND THEIR ASSOCIATED HEALTH RISK: A REVIEW

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ABSTRACT

A variety of known and unknown byproducts are formed through the reaction between disinfectants and natural organic matter during the disinfection process of water treatment for drinking purpose. Since their discovery in 1974, numerous studies have been carried out covering their formation, occurrence and associated adverse effects. These disinfection by products (DBPs) may pose both the non-carcinogenic and carcinogenic risks to human health. Most developed countries have their own guidelines, standards and regulations for DBPs in drinking water. However, the research and knowledge regarding this critical problem is still at rudimentary level in Bangladesh like other developing countries. Hence this paper reviews the various issues of DBPs and its adverse effects on human health available in the scientific literature to disseminate awareness about the presence of DBPs in the drinking water and the associated human health risk.

Keywords: Disinfection; drinking water quality; disinfection by-products; risk

INTRODUCTION

Since the dawn of the 20th century, the disinfection process has been routinely carried out to eradicate and inactivate the pathogens from water used for drinking purpose (Krasner et al., 2006; Richardson et al., 2008). Disinfection for drinking water reduces the microbial risk but may pose chemical threat to human health due to disinfection residues and their by-products (DBPs) when the organic and inorganic precursors are present in water (Sadiq and Rodriguez, 2004). Covering DBPs formation, occurrence and health effects, a significant research have been carried out in the last decade. DBPs in drinking water have received considerable attention because of their association with cancer and potential adverse reproductive effects. (Xiaomao et al., 2014). Disinfection byproducts are suspected to cause liver and kidney and human fetus damage (WHO, 2008). The most studied DBPs are the trihalomethanes (THMs) and haloacetic acids (HAAs), two classes of compounds that are regulated by the USEPA (2013), and have guidelines in Canada, Australia, the European Union, and the World Health Organization (WHO).

Both the Dhaka and Chittagong Water Supply and Sewerage Authority (DWASA and CWASA) use chlorine as disinfectant in water treatment for drinking purpose. Any process that uses chlorine gas directly or chlorine liberating chemicals or where chlorine is produced in the process, there is the possibility of the formation of chloro-organo compounds if alkanes, alkenes etc. are available. These include but are not limited to trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles, haloketones, haloaldehydes, chloropicrin, cyanogen chloride, and chlorophenols (Sadiq and Rodriguez, 2004). The by-products issue however has attracted relatively less attention in Bangladesh and no intensive study has been carried out yet. The goal of this paper is to present a brief overview of the occurrence of DBPs in drinking water and related human concern available in the scientific literature aiming at disseminating awareness about the presence of DBPs in the drinking water and the risk associated with the consumption of water containing DBPs to the inhabitant of the country.

DISINFECTANTS: BASIC INFORMATION

Water-soluble oxidants, which are produced either on-site (e.g., ozone) or off-site (e.g., chlorine) are used as chemical disinfectant. Chlorine, ozone, chlorine dioxide and chloramine are the most widely used chemical disinfectants (WHO, 2000). Beside these ultraviolet radiation are also applied to a number of water supply systems (AWWA, 2000; MOE, 2006). These disinfectants are administered as a gas (e.g., ozone) or liquid (e.g. hypochlorite) at typical doses of several milligrams per litre, either alone or in combination (WHO Recommendations, 2008). Chowdhury et. al, (2009) summarizes the applications of various disinfectants, as well as their costs, disinfection efficiencies and stability in distribution systems which is given below (Table 1).

Table 1: Basic information of some widely used disinfectants (adapted from Chowdhury et. al, 2009)

Disinfectants	**Application**	**Cost**	**Disinfection efficiency**	**Oxidation**	**Stability**
Chlorine	Most common	Lowest	Excellent	Strong	Stable
Chloramine	Common	Moderate	Good	Weak	Stable
Chlorine dioxide	Occasional	High	Excellent	Selective	Unstable
Ozone	Common	High	Excellent	Strongest	Unstable
Ultraviolet Radiation	Emergency Use	Extremely high	Good	None	Unstable

Table 1 shows that in most cases, chlorine is relatively inexpensive and very effective disinfectant and has been widely used throughout the world as a chemical disinfectant, serving as the principal barrier to microbial contaminants in drinking-water (Clark et al, 1994; Sadiq and Rodriguez 2004; USEPA, 2013). Disinfectants have varying capacities to inactivate or kill pathogens. The environmental conditions such as temperature and pH as well as the types and nature of organisms, also affect the disinfection process. The efficiency of disinfection process can be characterized by dose and intensity and it is affected by different physico-chemical and biological factors (Gates, 1998). Table 2 shows a comparison of the disinfection efficiency of three disinfectants under varying environmental conditions. Disinfection efficiencies can be determined from the product of residual disinfectant concentration (C) and the contact time of the disinfectant in the water (t). Generally, inactivation of organisms' increases with increasing contact time (MWH, 2005). The pH has different effects on different disinfectants but in general chlorine is more effective against organisms in acidic conditions rather than in alkaline conditions (Sadiq and Rodriguez, 2004).

FORMATION OF DBPs IN DRINKING WATER

Upon the chemical reaction of organic and inorganic precursors present in water with chemical disinfectants, DBPs are formed. Natural organic matter (NOM) which is generally measured as total organic carbon (TOC) serves as the organic precursor, whereas bromide ion (Br^-) serves as the inorganic precursor (Rook, 1974). DBPs constitute a large family of compounds presenting various levels of toxicological effects: more than 600 DBPs have been detected, but few have been identified. Several hundred DBP species have been identified and new ones continued to emerge (Richardson, 2003).

Different water quality parameters such as pH, temperature, ammonia, carbonate alkalinity, TOC, bromide, and treatment conditions (e.g., disinfectant dose, contact time, removal of NOM before the point of disinfectant application, prior addition of disinfectant) influenced the formation of DBPs (WHO, 2000). Table 3 summarizes the DBPs identified as being formed from the use of chlorine, chlorine dioxide, chloramine and ozone. Trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles HANs, haloketones, chloropicrin and chloral hydrate are the identified major chlorination DBPs (AWWA, 2000)

Table 2. Disinfectant's efficiency at varying conditions (adapted from Sadiq and Rodriguez 2004)

Disinfectant	Dose (mg/l)	Organism (Group)	Contact Time (min)	pH	T(^{0}C)	Efficiency (%)
Chlorine	0.5	*Rota Virus* (V)	0.25	6.0	5	>99.99
	0.6-2.5	*Polio Virus* (V)	0.7-2.4		5	>99
	0.1	*C.jejuni* (B)	1	6.0	4	>99.99
	0.5	*Coliform* (B)	30	7.0	20	>99.99
	1.5	*G.lamblia* (P)	10	6-7	25	~ 99
	2.0	*MS2coliphage* (V)	10	6-7	25	~99.99
	2.0	*V. chloerae* (B)	30	7.0	20	>99.99
	1.1	*E. coli* (B)	2	7.0	5	>99.999
	0.61	*A. butzleri* (B)	1	7.1	5	>99.999
Monochloramin	10.0	*Rota virus* (V)	>360	8.5	5	~99
	1.0	*C.jejuni (B)*	15	8.0	5	>99
	80.0	*C.parvum* (P)	90		5	~99
	2.0	*MS2coliphage (V)*	1	7.0	5	~99
	2.0	*E.Intestinals*(P)	8-16			~99
Chlorinedioxide	0.5	*V.chloerae* (B)	< 1	6.0	5	>99

B: Bacteria, V: Viruses, P: Protozoa

Table 3: Disinfectants and their possible disinfectant by-products (WHO, 2000)

Chemical Class of DBPs	Types of Disinfectants			
	Chlorine/ hypochlorous acid	Chlorine dioxide	Chloramine	Ozone
Organo halogen compounds	THMs, HAAs, HANs, chloral hydrate, chloropicrin, chlorophenols, *N*-chloramines, halofuranones, bromohydrins	-------	HANs, cyanogen chloride, organic chloramines, chloramino acids, chloral hydrate	Bromoform, cyanogen bromide
Inorganic compounds	Chlorate (mostly from hypochlorite use)	Chlorite, chlorate	Nitrate, nitrite, chlorate, hydrazine	Chlorate, iodate, bromate, hydrogen peroxide, hypobromous acid, epoxides, ozonates
Non halogenated compounds	Aldehydes, cyanoalkanoic acids, alkanoic acids, benzene.	Unknown	Aldehydes**,** ketones	Aldehydes, ketoacids, ketones, carboxylic acids

ADVERSE EFFECTS OF DBPs

Carcinogenic and non-carcinogenic risks to human health may be posed due to chronic exposure to disinfection byproducts through the ingestion of drinking water, inhalation and dermal contact during regular indoor activities like showering, bathing, cooking (Xie YF, 2000). WHO recommendations (2008) report the adverse health effects through toxicological laboratory studies and adverse effects of some of the important DBPs. Linking chloroform to cancer in laboratory animals, the National Cancer Institute of USA published results in 1976. As a result, an important public health issue was born. Table 4 depicts significant adverse effects caused by various DBPs.

Table 4: Adverse effects of some important DBPs (adapted from Sadiq and Rodriguez, 2004)

By-product group	Compounds	Rating	Adverse effects
Trihalomethanes (THM)	Chloroform	Probable human carcinogen	Liver, kidney and reproductive effects and cancer
	Dibromochloromethane	Possible human carcinogen	Nervous system, liver, kidney and reproductive effects
	Bromodichloromethane	Probable human carcinogen sufficient laboratory evidence	Cancer, liver, kidney, and reproductive effects
	Bromoform	Probable human carcinogen sufficient laboratory evidence	Nervous system, Cancer, liver and kidney effects
Haloacetonitrile (HAN)	Trichloroacetonitrile	Possible human carcinogen	Cancer, mutagenic and clastogenic effects
Haloacetic acids (HAA)	Dichloroacetic acid	Probable human carcinogen sufficient laboratory evidence	Cancer, reproductive and developmental effects
Halogenated aldehydes and ketones	Formaldehyde	Probable human carcinogen	Mutagenic

OCCURANCE LEVEL AND GUIDELINES

Due to the potential health risks and widespread occurrence of DBPs in drinking water, many countries regulate DBPs in their drinking water. The common DBPs in drinking water are generally present at low-to-mid- $\mu g \cdot L^{-1}$ or sub-$\mu g \cdot L^{-1}$ levels in drinking water (Xie YF, 2000). Based on evidence of their adverse human health effects the DBPs regulation has been set, in particular cancer and reproductive disorders (Xiaomao *et al*., 2014). The US EPA (2013) has established the maximum allowable contaminant level of 0.08 mg/l for total THMs and of 0.06 mg/l for HAAs. However, in Bangladesh no drinking water quality guideline exists for DBPs, and awareness and monitoring of DBPs in drinking water is critically important for the country.

CONCLUDING REMARKS

Water disinfection has been used to improve the hygienic quality of drinking water by removing waterborne bacterial pathogens, and it is essential to understand better the chemistry, toxicology and epidemiology of chemical disinfectants and their associated DBPs. This will help create a balance between microbial and chemical risks and minimize the health risks associated with drinking-water. The research on DBPs in Bangladesh is still at rudimentary level, and hence standard set guidelines for DPBs is missing in the country to comply with. It is now a pressing demand to focus on the issues associated with DBP formation, health effects, regulatory compliance, including methods for DBPs analysis, occurrence levels, the mathematical models to estimate the formation and the fate of DBPs.

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