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Investigation of physicochemical parameter, heavy metal in Turag river water and adjacent industrial effluent in Bangladesh

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ABSTRACT

Industrial effluent (IE) is one of the major concerns in environmental issues due to its hazardous and chemical nature that is require on-site treatment and systematic management before discharge into sewage system. Therefore, the aim of this study was to investigate in order to determine the present pollution status and their alteration trends with the seasonal change of discharge amount. Water samples have been collected from Turag River adjacent to Konabari industrial area and analyzed for various water quality parameters during both dry and wet seasons. Physicochemical analyses revealed that, most of the water quality parameters exceeded the recommended levels set by the Department of Environment (DoE), Bangladesh. The dry season had significantly higher contamination loads, which were decreased during the wet season, as the river was found to be highly turbid in wet season. Furthermore, all of the dissolved metals in the water samples were also found to be significantly higher in concentrations during dry season, but still remain under the limit of recommended standards of DoE, Bangladesh, except the concentration of Cadmium in dry season. To conclude, the variation in river water flow during different seasons and the anthropogenic activities were the main reasons for this water pollution of Turag River.

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I. Introduction

Industrial effluent is one of the major concerns in environmental issues due to its hazardous and chemical nature that is require on-site treatment and systematic management before discharge into sewage system (Emongor et al., 2005). Due to rapid expansion of industry and increase its pollutant the soil and environment are under tremendous pressure. Very few are conscious regarding this globally raised issue and especially the Bangladesh is now in a vulnerable position (Nuruzzaman et al., 1998). As a developing country, Bangladesh is being confronted with many serious environmental problems especially in water aspect, resulting from rapid industrialization and urbanization, stubborn customs, low economic conditions and lack of awareness and technology of the country (Sarker, 2005). In Bangladesh, the environmental condition and economic growth are highly influenced by water situations, such as its regional and seasonal availability and the quality. In terms of quality, the surface water of country is unprotected from untreated industrial effluents and municipal wastewater, run off pollution from chemical fertilizers and pesticides (Tapp et al., 1996). The water quality also depends on effluents types and discharge quantity from different types of industries types of agrochemicals used in agriculture and seasonal water flow and dilution capability of the river system (DHV, 1998). Rapid industrialization of Bangladesh in last two decades resulted in 30,000 large and small industries which is destructing the river system with their effluents. The pollution from industrial and urban waste effluents and from agrochemicals in some water bodies and river has reached alarming levels (Ahmed and Reazuddin, 2000). Dhaka is the capital city of Bangladesh which is located in the middle of the country. There are five peripheral rivers, including Buriganga, Dhaleswari, Turag, Balu, Sitalakhya and Tongi Khal that are accepting large quantities of municipal sewage and industrial wastewater from Dhaka city (Paul and Huq, 2010). There are 300 outfalls of domestic and industrial effluents, along with the river bank. The rivers are further polluted by indiscriminate throwing of household, clinical, pathological and commercial wastes and discharge of spent fuel and human excreta (Rahman and Hadiuzzaman, 2005). The industrial units such as chemicals, fertilizer, pesticides, textile, oil, power station, ship repairing dock, cement and tannery are located in and around the Dhaka city (DOE, 1993). In general, the quality of river water around Dhaka is vulnerable due to pollution from untreated industrial effluents and municipal wastewater, runoff from chemical fertilizers and pesticides, and oil and lube spillage in and around the operation of river ports (Alam et al., 2006). In recent years, environmental pollution has been increasing rapidly with increasing industrial development in Bangladesh. The Konabari of Gazipur district, which is the largest industrial belt in Bangladesh, has many more local and foreign industries. The industries of Konabari area generate a large amount of effluents every day, which are being directly discharged into the surrounding land, agricultural fields, irrigation channel and surface water and finally enter into the Turag River. More seriously, contaminated water destroys aquatic life and reduces its reproductive ability. For this reason, in September 2009, the four rivers Buriganga, Sitalakhaya, Turag and Balu have been declared by the Department of Environment as Ecologically Critical Areas (ECA), for improving the condition of ecosystems. The Ecologically Critical Areas (ECA) is ecologically defined areas or ecosystems affected adversely by the changes brought through human activities. These include four rivers around Dhaka city emphasizing the impacts of rapid urbanization and industrialization around the capital (DOE, 2015). Eventually, it is hazardous to human health. For this reason, the environment of this area is now being threatened. The toxicity of freshwater of Turag River, adjacent to Konabari industrial area is fluctuated season to season due to different anthropogenic causes. When water contains high concentrated heavy metals then more people will die from the water borne disease including diarrhea, cholera, jaundice, hepatitis, dysentery, skin disease, etc. In addition, polluted water has other health, economic, and natural consequences (Karn and Harada, 2001). On the other hand, the fish resources have drastically decreased due to metal contamination of the river. The excessive concentration of heavy metals causing the unnatural deaths of water flora and fauna, the ecosystem and making living condition worst for the people of adjoining areas. Trace heavy metal such as Cu, Fe, Pb, Cd, Co, Mn, Zn, etc., which are present in water trace in amount but have significant effect on water environment and human survival (IWM, 2006). Industrial pollution is an area of growing environmental concern in Bangladesh. The country still has a relatively small industrial base contributing about 20% of GDP. The manufacturing sub-sector accounts for about half of this contribution and it grew at a rate of 5.04% between 1982 and 1992. With the growth of the ready-made garments sector, the textile sector is also growing at a high rate in recent years (WB, 2006).

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Table 01. Estimated BOD load by industries in and around Dhaka city

Type of Industry	Public enterprise [No.]	Private enterprise [No.]	Wastewater Discharge (m3/s)	BOD Load (ton/day)
Leather	1	195	15,800	17.6
Textile	20	482	40,000	26.0
Pulp and Paper	4	1	228,000	40.0
Fertilizers	7	1	-	21.0
Chemical	1	99	1448	1.4
Pharmaceuticals	2	100	3500	0.7
Sugar	12	4	30000	4.0
Food and fish	0	193	5400	61.0
Rubber	-	25	-	17.7
Plastics	-	30	-	-
Pesticides	1	3	200	-
Distilleries	-	4	1600	5.7
Metal	17	67	13800	-
Cement	1	1	-	-

Source: JICA (2015).

Table 02. Industrial areas in and around Dhaka City

Cluster Name	Type of Industry	Number of Industries	Total Wastewater discharge (m3/day)	Total BOD load (kg/day)	Discharge recipient river
Hazaribagh	Leather	136	15800	17600	Turag
Tongi BSCIC	Textiles	13	4300	4400	Tongi Khal
Fatulla	Textiles	6	3400	3850	Buriganga
Kanchpur	Textiles	9	4300	3480	Lakhya
Tejgaon	Textiles, Chemical	16 27	3350 535	1960 475	Begunbari Khal
Tarabo	Textiles	14	1150	1475	Lakhya
Total		**221**	**32835**	**33240**	

Source: JICA (2015).

In Bangladesh, industrial plants are mostly situated along the banks of the rivers in the vicinity of the cities of Dhaka, Chittagong, Khulna and Bogra districts. The Department of Environment has listed 1,176 industries that cause pollution that have been categorized into 9 types, such as Chemical including pharmaceuticals, Paper and pulp, Sugar, Food and tobacco, Leather, Industrial dyes, Petroleum, Metals and Power generation. Most of the effluents produced by these industries are dumped directly or indirectly into the rivers. In case of industries located in Dhaka, they are discharged into Buriganga and Turag rivers badly polluting them. Some 300 mills and factories created in and around Khulna city currently discharge huge amounts of liquids waste into the Bhairab River causing a severe pollution. In Chittagong, the main polluters are the pulp and paper, fertilizer and petroleum industries located on the banks of the Karnafuli River and Kaptai Lake. Operation of ships, mechanized boats and ports cause marine oil pollution. Tables 01 and 02 indicate that most of the rivers are highly populated by the effluents discharged into these rivers without treatment. The dissolved oxygen in these rivers is very low and some are already polluted beyond toxic point. The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizers, chemicals and refineries where a large volume of water is involved in their production process thus producing equal volume of effluents which when discharged into rivers, streams and other water bodies become a major source of pollution. According the zoning of Bangladesh by regions for industrial purpose, the North Central (NC) region comprises about 49% of the total industrial establishment. About 33% of industries in NC region are textile apparels and tanneries of which Dhaka district accounts for almost half of it while Narayanganj accounting for another 32%. About 65% of the total chemicals, plastics and petroleum industries are also located in the NC region concentrated in and around Dhaka, Narayanganj and Gazipur districts (JICA, 2015).

Table 03. Industries by types in and around Dhaka

Type of Industry	Number
Paper, Pulp, Wood, etc.	171
Dyeing, Painting, Printing, etc.	241
Electrical, Electronics, Computers, etc.	129
Metal, Iron, Aluminum, Steel, etc.	289
Plastic, Polythene, Glass, Cosmetics, Jewelry, etc.	142
Food, Confectionery, Hotels, etc.	140
Dairy, Poultry, Fishery, etc.	28
Tannery, Shoe, etc.	75
Pharmaceutical, Hospital, Soap, etc.	61
Chemicals, etc.	95
Ceramics, etc.	5
Building construction related, etc.	49
Handicrafts, etc.	16
Total	**2179**

Source: JICA (2015).

The main industrial clusters and effluent “hotspots” include the tanneries at Hazaribagh which pollute the Buriganga River, the Tejgaon Industrial Area which drains to the Balu River, the Tongi Industrial Area which pollutes Tongi Khal, the Sayampur and Fatullah industrial clusters in Dhaka South and Narayanganj which discharge to the Buriganga River, and the developing heavy industrial strip along the Sitalakhya River. Dhaka city is surrounded by Sitalakhya, Buriganga, Turag and Balu rivers and different lakes (Begunbari Khal, Norai Khal, Tongi Khal), carrying wastewater from different parts of the city including the North-eastern flood plain. Therefore, this study has designed to find the pollution level of Turag river’s water in terms of physicochemical parameters and heavy metal contents, as heavy metal is one of the most concerning pollutants around the world. The variation of water quality of the Turag River throughout a year was also investigated and compare it with the standards, which are recommended by the Department of Environment (DoE), Ministry of Environment and Forest, Bangladesh (DoE, 1997). The impact of industrial activities on water quality of the Turag River was also investigated throughout this research. Furthermore, the preventive measures were also recommended for the identified water contamination of Turag River.

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II. Materials and Methods

Study area consists of Turag River at Konabari in Gazipur district beside the industrial area of Bangladesh. It is the main industrial area of Gazipur, Bangladesh. The Gazipur district is bounded by Mymensingh and Kishoreganj districts on the north, Dhaka, Narayanganj and Narshindi districts on the south, Narshindi on the east, Dhaka and Tangail districts on the west, with an area of 1741.53 sq km. Furthermore, the Gazipur district is located at 23°8'230.48" N and 90°65'900.39′0" E, whereas the Gazipur Sadar is located at 24°00000" N and 90°42500" E (Islam and Jamal, 2012). Annual average temperature ranges from 36°C to 12.7°C. Annual average rainfall is 2376 mm. The Konabari industrial area of Bangladesh is characterized by densely populated residential area, unregulated growth of commercial and industrial installations and scattered slums with poor quality service facilities. Konabari is mainly important for the establishment of different types of production and process industries. The Turag River, one of the most prominent rivers in the flood plain region of Bangladesh which generates from Banshi River at Kaliakoir and meets Buriganga at Kholamora of Keraniganj. The Turag River drawn into the Jamuna river system by the invasion of the Lohajang River, alongside of Tangail district in Bangladesh. The Turag remains active, although it has only a small flow in the dry season. It joins the Buriganga near Mirpur (Dhaka) and is tidal in its lower reaches. It is navigable by country boats throughout the year. The whole of the Turag valley south of the Mymensingh Trunk road is notable for Boro rice cultivation. The GPS co-ordinate of selected four points along Turag River is shown in table 04.

Table 04. Global Positioning System (GPS) data of sample collection stations in Turag River of Bangladesh

Station No.	Name of Location(s) near by	Longitude	Latitude
St.-1	Ashulia Bridge	90°21'37.29"E	23°53'33.74"N
St.-2	Kamarpara	90°23'22.94"E	23°53'29.03"N
St.-3	Abdullahpur	90°24'20.35"E	23°52'54.69"N
St.-4	Kamarpara Petrol Pump	90°22'28.17"E	23°53'45.93"N

Figure 01. Sample collection point, using a satellite image. Turag river, 2016.

Sample collecting stations has selected on the basis of common point of river, maximum polluted point, near the outlet of point sources, intake of water treatment plant, easy to access to collect samples and water available all the year around. Water samples represent the water of this particular river. Four random sample collecting stations have selected for the study (Figure 01). Water samples collected from each station. The effluent samples were collected from four stations from each point such as St.-1, St.-2, St.-3 and St.-4 of the Turag River adjacent to Konabari Industrial area. Collection and analysis of all samples were performed in both dry season (January, 2015) and wet season (July, 2015). The water samples were collected in 500 mL plastic bottles. Before sampling, the bottles were cleaned and washed with detergent solution and rinsed again three times to avoid contamination.

Table 05. Different sampling stations of the study area

Sampling Stations (St.)	Distance from the discharge point (m)
St. – 1	0
St. – 4	300
St. – 2	600
St. – 3	900

After sampling, alkaline potassium iodide solution was added to protect water samples from any fungal and other pathogenic attack. Hydrochloric acid was also used as preservative in these bottles. Sampling bottles were sealed immediately to avoid exposure to air and placed into safe place. The bottles were screwed carefully and marked with the respective identification number. Necessary information for each sample such as date of sample collection, time of sample collection, location etc. were recorded in the note book.

Various physicochemical, heavy metals, biological parameters used in this study for determining and comparing the surface water quality. Physicochemical parameter includes Temperature, pH, Electrical conductivity (EC), Dissolved Oxygen (DO), Total dissolved Solid (TDS) and Biochemical Oxygen Demand (BOD). Heavy metal contents include, Lead (Pb), Cadmium (Cd), Copper (Cu) and Iron (Fe). Two types of test were performed. These are, (i) In-situ physical test mostly in the sampling spot by different potable meters, and (ii) Chemical parameter tests were performed in the laboratory. The study was conducted through experimental method. The samples were analyzed through experiment with the independent variable. Temperature was measured in the time of sample collection by Celsius thermometer (◦C scale). Sample was taken in a plastic container and recorded its temperature immediately by dipping the thermometer for about one minute. Dissolved Oxygen content of sample water determined by using the DO meter. The sample bottle was completely filled with water to avoid existence of air and DO was measured just after the sample collection. pH was measured by a single electrode pH meter (Model: pH Scan WP 1, 2, Malaysia). At first pH meter was calibrated with buffer solutions. Then it was ringed thoroughly using distilled water and wiped by using tissue paper. Then the electrode was dipped into the sample water and was kept until the stable reading was observed. The final reading was recorded. Electrical conductivity of the samples was measured by an EC meter (Model: HM digital, Germany). During the procedure firstly, conductivity electrode was washed out by distilled water. Then, the cell constant of the conductivity meter was checked. Twenty ml sample was taken in 50 mL measuring cylinder and immersed the electrode and waited for at least 10 seconds. Then readings of Electrical Conductivity (EC) were collected from this meter and wrote down in the notebook.

Biochemical Oxygen Demand (BOD): The rate removal (i.e. consumption) of oxygen by microorganisms in aerobic degradation of the dissolved or even particulate organic matter in water is called Biochemical Oxygen Demand (BOD). At first the collected water sample was taken in a suitable sample bottle. The DO content of the water (D1) was measured by using DO meter before incubation. Then the bottle was sealed and incubated in the dark chamber for 5 days at 20°C. After incubation, the dissolved oxygen (DO) of water (D2) was measured by using DO meter. The following formula was used to calculate the Biochemical Oxygen Demand (BOD) of the water,

$$BOD_{5\ mg/L} = D1 - D2$$

Where, D1 = The Dissolved Oxygen (DO) content of the water before incubation,
D2 = The Dissolved Oxygen (DO) content of the water after incubation.

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Total Dissolved Solid (TDS): Total dissolved Solid (TDS) of the sample is measured by a TDS meter. Firstly, TDS meter electrode was washed out by distilled water. Then, the cell constant of the conductivity meter was checked. Twenty ml sample was taken in 50 mL measuring cylinder and immersed the electrode and waited for at least 10 seconds. Total Dissolved Solid (TDS) readings were collected from this meter and wrote down in the notebook.

Determination of heavy metal content: All elements namely copper (Cu), iron (Fe), cadmium (Cd) and lead (Pb) were determined with the help of Atomic Absorption Spectrophotometer (Shimadzu, AA6800) in laboratory. Materials and reagents were sample bottle, Pipette, Distilled water Nitric Acid (HNO_3). At first, pipette and sample bottle were washed by distilled water. Some sample water was collected from mother/source sample by pipette and it was washed by this sample bottle. After that about 100 ml sample was collected by pipette from source sample and it was poured in to sample bottle. About 2 mL HNO_3 was taken by Graduated pipette and it was poured into sample bottle, the bottle was slightly shaken for mixing the sample water and HNO_3. These steps were conducted for each of the sample. After that this volumetric flask (Sample of Lead and Cadmium) was taken in to the Atomic Absorption Spectrophotometer in Graphite tube atomizer and the results were showed in computer. Then the results were written in notebook. Following procedures were taken for the test of the Calcium, Lead, and Cadmium.

Personal interview and questionnaire was arranged to collect the information. The method of collecting information through personal interview is usually carried out in a structural way. Besides questionnaires are free from the bias of the interviewer, answer is in respondent's own word. Questionnaires survey was conducted to know the impact of industrial effluent on the surrounding environment of Turag River. Questionnaire surveys were conducted randomly on people living around the Turag River at Konabari. Total 30 respondents were attained in the survey work. These sampling stations had quite similar environment that is why same field survey was performed. However**,** collected raw data was processed & analyzed through, MS Excel 2013. Statistical analysis was performed by various statistical tools such as average, standard deviation, confidence interval. Statistical analysis of the data out of the chemical analysis of water samples were done with the help of scientific calculator following the standard procedure.

III. Results and Discussion

Water quality assessment

The ranges and means of various physicochemical parameters as well as heavy metal contents of Turag River's water are compared with the standard values of Bangladesh. The water quality of Turag River adjacent to Konabari industrial area, revealed a high level of water pollution in different aspects, when these are compared with the standard values of Bangladesh, which are shown in Table 06. Standard temperature range provided by Department of Environment (DoE) of Bangladesh are 20-30°C for drinking water and 40°C for both inland surface water and irrigated land, whereas the present study shows that the temperature of investigated areas is in the suitable range in both seasons, as the temperatures of all water samples collected from four locations were with an average value of 28.25°C in dry season, whereas 30.5°C in wet season. Therefore, it can be concluded that, the temperature of surface water at Turag River are still under control considering the each and every aspect of usage. On the other hand, the present study shows that, the color of Turag River water was deep black in dry season, whereas brown in wet season and very noxious odor emits, which means the water is polluted and dangerous for aquatic ecosystem and human health. Furthermore, the average value of pH was in 6.51 dry season, whereas 9.31 in wet season. Comparing with the standard limit (6.5 to 8.5 for drinking water and 6 – 9 for both inland surface water and irrigated land), it revealed that the river water is permissible during dry season and suitable for aquatic organisms as well as irrigation. The values of DO at different sampling points of the Turag River water in both seasons were within the range of 3.94 to 5.58 mg/L, indicating little bit higher DO value from standard level (4.5 to 8 mg/L for both inland surface water and irrigated land, and 6 mg/L for drinking), which is not suitable for aquatic body. Furthermore, the BOD values were within the average value of 1.08 mg/L in wet season, whereas 3.10

mg/L in dry season, indicating higher value compared to standard value (0.2 mg/L for drinking, 50 mg/L for inland surface water and 100 mg/L for irrigation). Meanwhile, the average values of TDS were 2872.5 mg/L in wet season, whereas 3715 mg/L in dry season, which also indicates higher TDS value, considering the standard values. The average EC values recorded at different sampling points of the Turag River water were 728.75 µS/cm in wet season and 1980 µS/cm in dry season, which is low in wet season and very high in dry season compared to standard value (800 µS/cm for drinking and 1200 µS/cm for both inland surface water as well as irrigation). On the other hand, in wet season, the average values of Pb, Cd, Cu and Fe from four sampling points were 0.021 mg/L, 0.0033 mg/L, 0.2 mg/L and 0.47 mg/L, whereas in dry season 0.056 mg/L, 0.0068 mg/L, 0.47 mg/L and 1.04 mg/L, accordingly. Pb, Cd and Fe concentrations were lower or within the range in wet season and higher in dry season, comparing with the standard values of 0.05 mg/L, 0.005 mg/L and 0.3-1.0 mg/L for drinking water, respectively. Moreover, the Cu concentration was lower both in wet and dry seasons, comparing with the standard values of 1.0 mg/L for drinking purpose, whereas all the investigated heavy metal contents (Pb, Cd, Cu and Fe) are under the limit of standards of Bangladesh, regarding the aspect of inland surface water and irrigation land. Pollution level of Turag River gradually increasing considering all the parameters, when compared with the mean values of historical reports, which are shown in Table 07. However, it may be concluded from the above results that, the water quality of the Turag River is beyond acceptable limit that is unfavorable for all aquatic lives and human beings due to discharging of untreated industrial effluents directly to the water.

Table 06. General water quality of Turag river during wet and dry seasons

Parameter	Season	Present study		Standards of Bangladesh*		
		Range	Mean	Inland surface water	Irrigated land	Drinking water
Temperature (°C)	Dry	26 - 30	28.25	40	40	20 - 30
	Wet	29 - 32	30.5			
DO (mg/L)	Dry	3.75 – 4.10	3.94	4.5 - 8.0	4.5 - 8.0	6
	Wet	5.20 – 6.10	5.58			
pH	Dry	6.35 – 6.75	6.51	6 - 9	6 - 9	6.5 – 8.5
	Wet	8.35 – 9.75	9.31			
EC (µS/cm)	Dry	1850 – 2120	1980	1200	1200	800
	Wet	640 – 780	728.75			
BOD (mg/L)	Dry	2.9 – 3.3	3.10	50	100	0.2
	Wet	0.9 – 1.2	1.08			
TDS (mg/L)	Dry	3460 – 4145	3715	2100	2100	1000
	Wet	2680 – 3020	2872.5			
Pb (mg/L)	Dry	0.052 – 0.062	0.056	0.1	0.1	0.05
	Wet	0.017 – 0.025	0.021			
Cd (mg/L)	Dry	0.0062 – 0.0075	0.0068	0.5	0.05	0.005
	Wet	0.0028 – 0.0039	0.0033			
Cu (mg/L)	Dry	0.38 – 0.56	0.47	0.5	3	1
	Wet	0.17 – 0.25	0.20			
Fe (mg/L)	Dry	0.95 – 1.12	1.04	2	2	0.3 - 1
	Wet	0.32 – 0.58	0.47			

*DoE: Department of Environment, Ministry of Environment and Forest, Bangladesh. DoE (1997).

Table 07. Variation of water quality parameters in Turag river

Parameter	Season	Year		
		2012[a]	2015[b]	Present study
Temperature (°C)	Dry	17.75	NI*	28.25
	Wet	32.36	NI*	30.5
DO (mg/L)	Dry	1.12	3.49	3.94
	Wet	5.75	5.2	5.58
pH	Dry	5.69	5.86	6.51
	Wet	6.94	7.28	9.31
EC (µS/cm)	Dry	736.3	477.2	1980
	Wet	193.1	354.5	728.75
BOD (mg/L)	Dry	4.38	55.92	3.10
	Wet	2.65	42.34	1.08
TDS (mg/L)	Dry	398.9	196.7	3715
	Wet	93.1	126.41	2872.5
Pb (mg/L)	Dry	NI*	0.080	0.056
	Wet	NI*	0.033	0.021
Cd (mg/L)	Dry	0.11	NI*	0.0068
	Wet	-0.03	NI*	0.0033
Cu (mg/L)	Dry	0.02	1.341	0.47
	Wet	-0.24	0.143	0.20
Fe (mg/L)	Dry	NI*	2.52	1.04
	Wet	NI*	2.1	0.47

* NI = Not Investigated; a (Meghla et al., 2013); b (Islam and Azam, 2015).

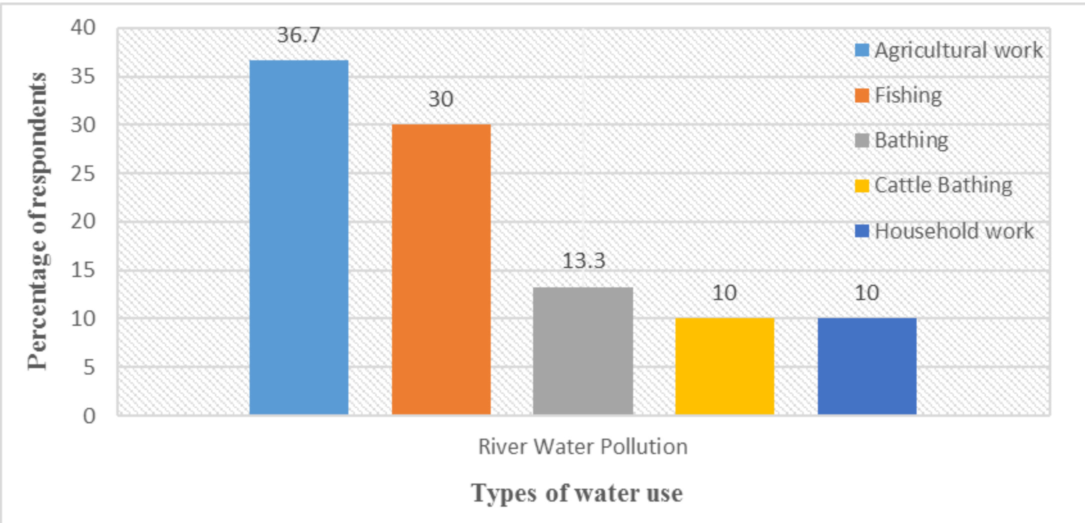

Figure 02. Different types of usage of Turag river water.

Measurements of water pollution control in Turag river

Bangladesh being a riverine country, the requirement of dredging, as a tool for developing and maintaining its navigation channels. Bangladesh Inland Water Transport Authority (BIWTA) has a future plan to remove garbage's from the Turag River and to decontaminate the water. The sediments and garbage's will be dumped into a new location. So, the ultimate success of cleaning the river depends on disposal of dredged materials in suitable place and control of industrial and other pollution. Now, it is the high time to take appropriate measures to stop environmental degradation. There are only few previous works done based on this river and it is important to know the current situation of this river, so that this investigation will be helpful for future river management or pollution control. People use Turag river water in many purposes. According to the survey analysis around the river area, most of the people used the river water for agricultural work (36.7%) and fishing (30.0%) purpose. Besides that, the human bathing (13.3%), cattle bathing (10.0%) and household work (10.0%) (e.g. cooking, dish wash, cloth wash, etc.) were performed (Figure 02). So, the people near the river area were found to be highly dependent on river water for their daily needs. This may be considered as one of the main causes of water pollution of Turag River. To prevent such kind of pollutions, a conventional method can be applied for the irrigation purpose, such as developing the irrigation systems or using the organic fertilizers to the farming system. Another pollutant (such as bacteria, fungi, etc.), which are came from bathing and household works or wastage; those can be controlled by creating awareness trough different campaigns overtime. According to China's State Environmental Protection Administration (SEPA) in 2006, 60% of the country's rivers suffer from pollution to such an extent that they cannot be safely used as drinking water sources (Water 11, 2007). China grades its water quality in six levels, from Grade I to Grade VI, with Grade VI being the most polluted. By 2020, the quality of over 70 percent of the water in seven key river basins, such as the Yangtze River and Yellow River, will reach level III or above, and the amount of foul water in urban built-up areas will be controlled (Xiangcong, 2007). On the basis of interviewing the surrounding living dwellers and the survey data analysis, several causes were found that were responsible for the pollution of Turag River, such as industrial effluents, unplanned brick fields, agrochemicals from farming sites, illegal encroachment, household and municipal wastes etc. According to the respondents, the major causes for river water pollution were brick fields (23.3%), industrial effluents (46.7%), agrochemicals (13.3%), illegal encroachment (6.70%) and household waste (10.0%). Different causes of Turag river water pollution are presented in Figure 03.

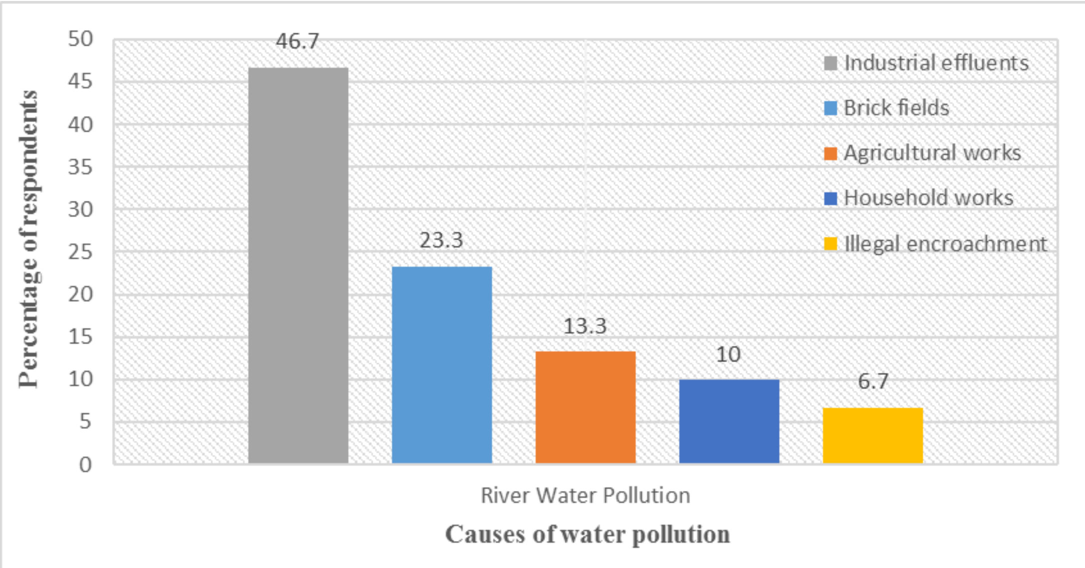

Figure 03. Causes of water pollution.

Implementation of proper law enforcement for the industries, those are throwing effluents directly to the river water, without proper treatment, can mitigate this problem in some extent. In China, large-scale water transfers have long been advocated by Chinese planners as a solution to the country's water woes. The South-North Water Transfer Project is being developed primarily to divert water from the Yangtze River to the Yellow River and Beijing. In 2007 Ma Xiancong, a researcher at the Chinese Academy of Social Sciences Institute of Law identified the following areas where the government failed to act, or tacitly consented, approved or actively took part and so created a worse situation: land appropriation, pollution, excessive mining and the failure to carry out environmental impact assessments. An example of this emerged in 2006, when the State Environmental Protection Administration revealed over a dozen hydroelectric projects that had broken the Environmental Impact Assessment Law (Xiangcong, 2007). In 2005 experts warned that, China must use Integrated Water Resources Management in order to achieve sustainable development (China Daily, 2005). To find out the particular causes of Turag River pollution on that specific area, an extended questionnaire survey was also conducted on the following time. Because, different types of waste were thrown into the Turag river. According to the respondent's information analysis, most of the industries discharge their untreated industrial effluents (63.3%) directly into the Turag River. Besides, the household waste

(26.7%), urban waste (10%) also thrown into the river water (Figure 04). Household waste included the organic and solid waste from kitchen, bath and cloth washing sewages, toilet waste etc.

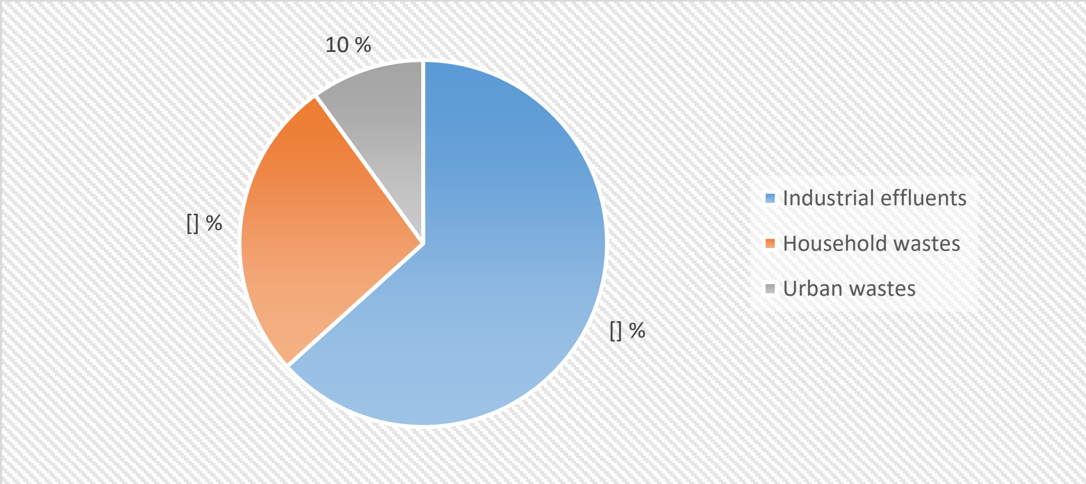

Figure 04. Major types of waste thrown into the Turag river.

About 48.6 % slum dwellers polluted river water by throwing household wastes. The discharges from plastic product industry, cement industry and garments were also responsible for river water pollution. Various types of toxic chemicals can be measured by applying analytical techniques before discharged into the river water or stream. Due to such kind of massive water pollution, the aquatic ecosystem as well as fish culture are also hampered gradually. According to the field survey, most of the respondents (56.7%) commentated that, the amount of fishes degraded day by day. Some species of fish were distinct and other aquatic animals also in endangered. Furthermore, from the water quality analysis results, it was found that the DO value was below than 5 mg/L during dry season, which means that, it is not a favorable condition for fish culture and also for the survival aquatic animals on that investigated areas of Turag River. Polluted water may also create disease of many fish species. In Figure 05, the effects of polluted water of Turag River on fisheries are presented.

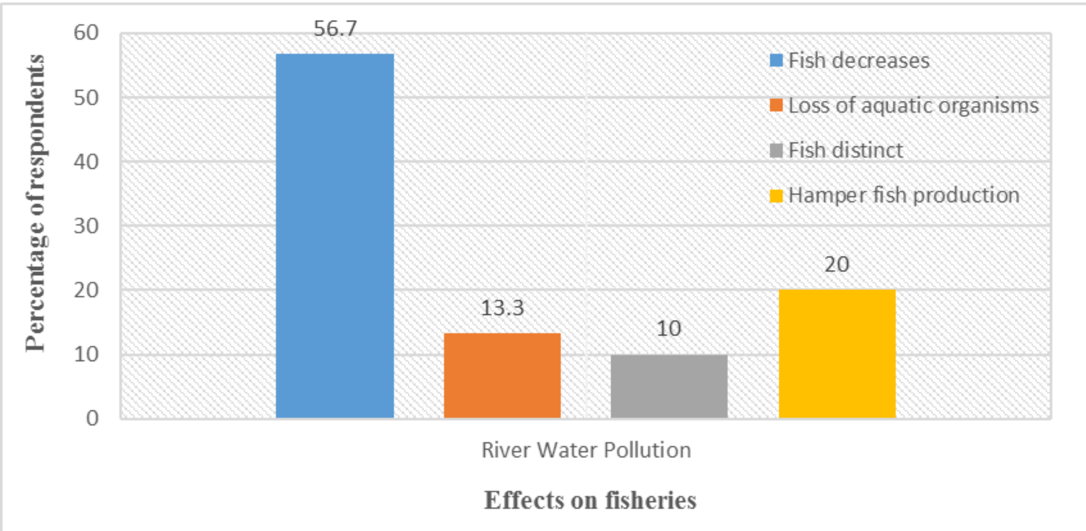

Figure 05. Effects of water pollution on fisheries.

Research and Development of waste water treatment, biomass and energy production should be undertaken in the country. In 2010, the water quality monitoring found almost all rivers with high levels of BOD. The worst pollution, in decreasing order, were found in river Markanda (490 mg/L BOD), followed by river Kali (364 mg/L BOD), river Amlakhadi (353 mg/L BOD), Yamuna canal (247 mg/L BOD), river Yamuna at the Delhi (70 mg/L BOD) and river Betwa (58 mg/L BOD). Since 2005, Indian wastewater treatment plant market has been growing annually at the rate of 10 to 12 percent. At this rate of expansion, and assuming the government of India continues on its path of reform, major investments in sewage treatment plants and electricity infrastructure development, India will nearly triple its water treatment capacity by 2015, and treatment capacity supply will match India's daily sewage water treatment requirements by about 2020 (CPCB, 2009). More or less, the people living around the Turag River, used river water for bath, cloth wash, kitchen work. They use this polluted water every day for performing their daily activities. They also built up open toilets that had gradually degraded the water quality and caused pollution. By exposing polluted water, the people suffered with various diseases and illness. The most remarkable health problems found at this station were Diarrhea and Dysentery, Skin disease, respiratory disease, eye irritation, Typhoid, etc. Effects of polluted water on human health are presented in Figure 06.

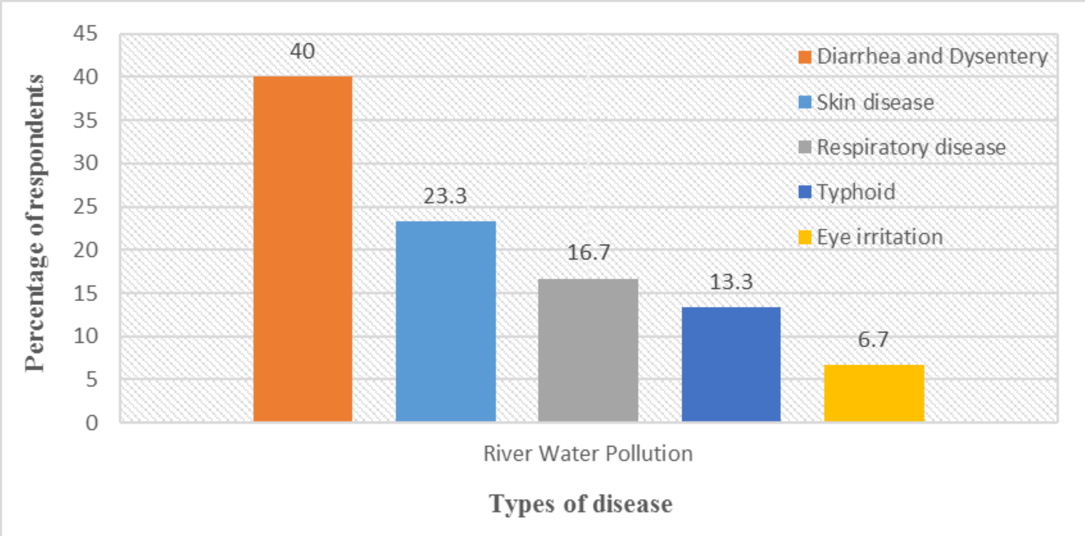

Figure 06. Effects of water pollution on human health.

To eradicate such kind of problems, Government of Bangladesh should establish such types of rules and regulation which obligate the owners of industries to establish Effluent Treatment Plant (ETP). Furthermore, it should be mandatory that industries construct and then regularly operate their Effluent Treatment Plant (ETP) to monitor their effluents to keep them within the standards set by law. On the other hand, Department of Environment (DoE) of Bangladesh and other environmental regulatory bodies should be more aggressive and effective in environmental monitoring, assessment and enforcement of laws and regulations regarding water polluting. A new Water Framework Directive adopted in 2000, setting the objectives for water protection for the future Europe. The Urban Waste Water Treatment Directive, providing for secondary (biological) waste water treatment, and even more stringent treatment where necessary. The Nitrates Directive, addressing water pollution by nitrates from agriculture throughout the European countries (EU Water framework, 2016).

IV. Conclusion and Recommendation

Pollutants enter into the river system by direct discharges or surface runoff from the waste of many industrial, municipal and agricultural sources. Results of the present study show that the overall levels of pollution in Turag River are beyond the threshold limits in terms of physicochemical properties. The data show that the water is certainly unfit for drinking purposes without any form of treatment, but for various other surface water usage purposes, it still could be considered quite acceptable. On the other hand, the temperature, DO, pH and BOD values were within the DoE recommended values in case of other purpose usages, while EC and TDS were above the standard. Concentrations of all metals were found to be within the recommended values, except Cd (0.0068 mg/L) exceed little bit higher than the standard in dry season. Furthermore, the pollution levels showed a seasonal pattern of change. Values of almost all the parameters remained high during the dry season with a lower river flow as compared to the wet season. Alternatively, during the rainy season the concentration was diluted from the higher water flow. Therefore, river pollution is largely dependent on the upstream river flow. However, the examined physicochemical parameters and heavy metal contamination indicate that the water quality of Turag river is unsuitable for aquatic lives and human consumption. These parameters help us in

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selecting the right options to manage water resources and also assess water quality of Turag River properly.

Future research an assessment of heavy metal contamination in water samples can be carried out and correlation of heavy metal contamination between sediment and water samples can be prepared. Other heavy metals (Ni, Al, As, Hg, etc.) and other parameters such as organic content, total organic carbon, sediment oxygen demand and moisture content may be considered for further analysis and in-depth research. Furthermore, GIS and remote sensing based maps on both water and sediment contamination can be prepared. Contamination can be shown for aggregation, data transmission and visualization using GIS and Remote Sensing, including the full GIS capabilities of overlaying data, DBMS (Database Management Systems) and modeling. These tools would be helpful for decision making processes and management involving natural resources.

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Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration with all authors. Md. Hafizur Rahman conceived the survey and developed the model. Furthermore, Md. Rumainul Islam conducted analyzes, model runs and wrote the paper. Meanwhile, Md. Nuralam Hossain has written the manuscript and critically reviewed before submission. Lastly, all authors read and approved the final manuscript.

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APA (American Psychological Association)

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