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Assessment and seasonal observation of the water quality of Turag, Buriganga and Shitalakshya rivers of Bangladesh

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ABSTRACT

Rivers near Bangladesh's major industrial areas and capital city have become highly polluted due to increased industrialization, urbanization and household garbage. The present investigation was carried out to assess and track the water quality at particular sampling locations, physico-chemical characteristics with levels of heavy metals and potentially toxic elements in the water and soil sediment samples. Water quality indicators such as pH, EC (µS/cm), heavy metals (mg L^{-1}*),* $NH4^{+}$ *(mg* L^{-1}*),* $NO3^{-}$ *(mg* L^{-1}*), organic carbon, total nitrogen (%N), etc. were measured in water and sediments from eleven different points at the Turag, Buriganga and Shitalakshya rivers close to Dhaka and Narayanganj's industrial and urban regions during pre-monsoon, monsoon and post-monsoon seasons. At several river water sampling areas, the measured levels of zinc (Zn) and lead (Pb) varied from 0.87 to 3.45 mg* L^{-1} *and 0.0052 to 0.0139 mg* L^{-1}*, respectively. Accordingly, the highest and lowest levels were observed at* S_1 *and* S_5 *points during the pre-monsoon and monsoon seasons. Cadmium (Cd) levels in analyzed water samples ranged between 0.0007 and 0.0040 mg* L^{-1}*. Sites* S_6 *and* S_2 *contained the lowest and highest amounts, respectively. The dry season (pre-monsoon and post-monsoon) had notably higher levels of contaminants and dissolved metals in water samples, which were reduced during the wet season (monsoon) when the river turned out to be extremely turbid.*

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I. Introduction

Water pollution is a serious worldwide issue. Numerous rivers become contaminated due to sewage disposal, municipal and agricultural waste, industrial effluents, and other sources. Water resources are essential for both the natural environment and human needs. Thus, this pollution issue has become a serious problem in all aspects.

Dhaka city is bounded by rivers and connected by different canals. The quality of surface water has been severely impacted in recent years by unchecked industrial growth, infrastructural development, rural-to-urban population migration, and insufficient enforcement of environmental laws, as demonstrated by today's Buriganga (Banu, 2013; Bhuiyan, 2015). Based on the research result, the Turag, Buriganga and Shitalakshya rivers are clearly under serious threat. This polluted situation affects the people and the flora and fauna, which could suffer greatly (Islam et al., 2015; Islam et al., 2020; Ferdousi et al., 2020; Rahman et al., 2020). About 10% of industries release treated wastewater into rivers or other bodies of water, whereas the remaining industries release wastewater into these bodies of water with little to no treatment (Satter and Islam, 2005). The wastewater from this industrial sector is directly dumped into the Begunbari and Narai canal, which then travels through the Balu river and empties into the Shitalakshya river (Zakir, 2012; Roy, 2013).

The majority of the industries were established along riverbanks. Thousands of waste products leak into river water daily (Hossain et al., 2010). Heavy metals are poisonous and accumulate in aquatic environments; the contamination of aquatic environments by these metals is a serious concern. Due to their inability to biodegrade, heavy metals are one type of chemical pollution that can concentrate along the food chain and produce hazardous effects far from their source (Rahman et al., 2016). The continuous flow of heavy metals into aquatic systems from anthropogenic and natural sources poses a severe danger due to their toxicity, bioaccumulation, lengthy persistence, and biomagnification in the food chain (Dey et al., 2015; Hasan, 2015; Gupta, 2017; Li, 2017;). Thus, river water has become poisonous for living biota. Additionally, agricultural areas along the contaminated river are seriously affected (Sakamoto et al., 2019). Farmers are utilizing this contaminated water for irrigation. Thus, the hazardous elements enter the food chain and eventually reach humans. Studies have shown that the crops cultivated near the polluted riverside are contaminated with heavy metals. Toxic metals are bioaccumulated in the crops, which could have a significant negative impact on human health (Islam et al., 2015).

Due to having no central ETP plants or lowering unit individual ETP plants, pollution concentration is increasing hazardously and environmental threats are increasing daily. Though some research was done previously on this study area by some researchers, regular monitoring of those parameters is necessary for estimating the up-to-date level of pollution so that we can be aware of the threats and the problems (Islam, 2012). So, the assessment of water quality of these rivers for identifying pollution sources and sinks is vital for taking steps for further mitigation studies. Therefore, the present investigation aims to examine and monitor the water quality of the selected locations and the levels of potentially harmful substances and compounds in the water and soil sediment.

II. Materials and Methods

Description of the study area

This investigation includes three major rivers in Bangladesh e.g., Turag, Buriganga and Shitalakshya. These rivers are adjacent to Dhaka, which is the capital city of Bangladesh. Untreated industrial effluents from nearby industrial belts, rural homes and municipal sewage are being disposed of in these rivers. A significant number of tanning factories, clothing, textile, paper and pulp factories, pesticide distilleries, as well as carbides and pharmaceuticals exist openly on the banks of the Turag, Buriganga and Shitalakshya rivers (The Daily Star, 2019; The Business Standard, 2019; Ahamad et al., 2020). The unscientifically disposed harmful materials are frequently contaminating these rivers. Therefore, it is essential to regularly check this region to enforce the proper actions of the environmental management system. Google Maps and GPS identified the locations to collect the samples (Figure 01).

Sampling

In 2022, the sampling was conducted during the pre-monsoon, monsoon and post-monsoon seasons. A total of eleven sampling locations were selected for sampling. Sampling sites and GPS are presented in Table 01. To examine the comparative seasonal fluctuations of heavy metal levels, 11 water and sediment samples were collected from the designated sites. River water and sediment samples were collected from 10-15 cm, 15-30 cm and 30-45 cm depths during pre-monsoon (March), monsoon (July) and post-monsoon (December). The samples were collected in 100 ml polypropylene bottles that had first been acid-washed. The polypropylene bottles were then treated with 1 ml of 99% nitric acid to attain a pH of approximately 0.1 (Cenci and Martin, 2004). Samples were collected using established guidelines (USEPA, 2001). All of these samples were stored at 4°C until analysis. These samples were promptly preserved and shipped in sealed poly bags to the laboratory.

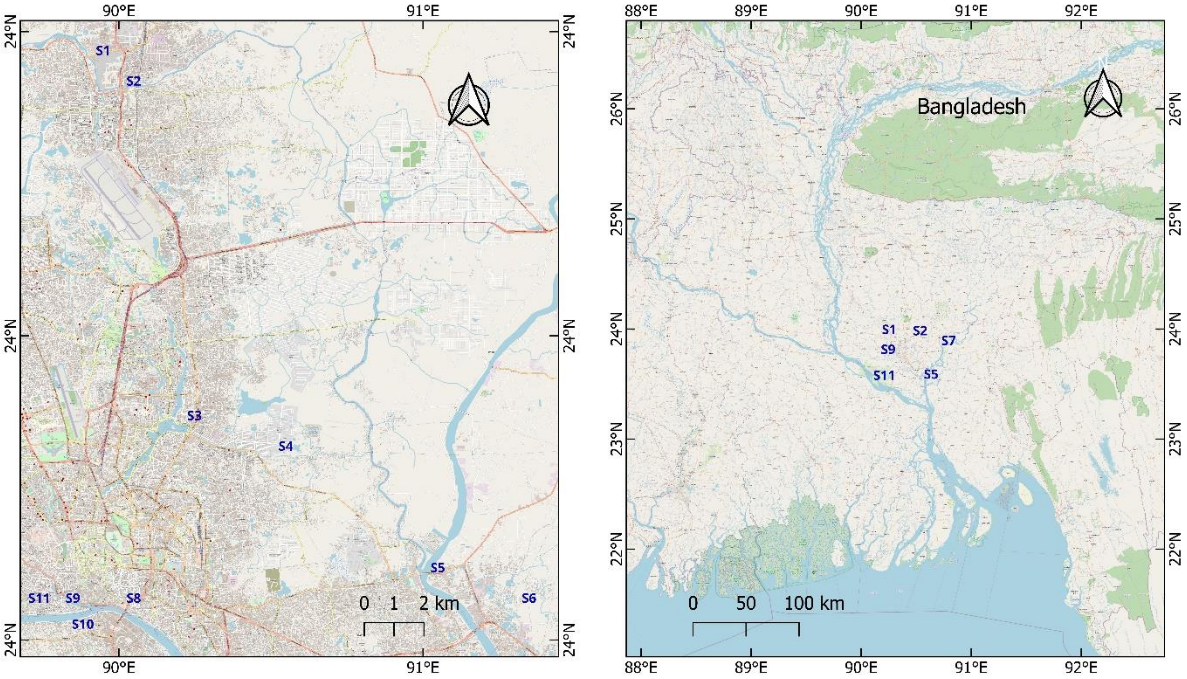

Figure 01. Locations of sampling points

Sample digestion and metal extraction

A beaker containing 100 milliliters of water was collected to analyze heavy metals. The beaker was filled with 2 milliliters of pure nitric acid, and the top exposed portion was covered with a watch glass. Subsequently, the beaker was gradually heated until the 100 ml sample was reduced to 60 ml. Heating was turned off and cooling was permitted. After that, the sample was filtered and mixed with double-distilled water to make 100 ml. Every chemical utilized was of analytical grade MERK Germany. Following digestion, the solution was filtered with Whatman filter paper 1. The filtrate was preserved in 50ml polypropylene containers.

Table 01. Locations and GPS value of the sampling locations

Sampling locations	Location	GPS
S_1	Turag Bridge	23.89°N, 90.39°E
S_2	Abdullahpur Bridge	23.88°N, 90.39°E
S_3	Rampura Bridge	23.77°N, 90.42°E
S_4	MeradiaGhat	23.76°N, 90.45°E
S_5	Demra Bridge	23.72°N, 90.49°E
S_6	PoschimgaonJame Masjid	23.71°N, 90.53°E
S_7	Dakkhinpara Masjid	23.78°N, 90.66°E
S_8	NolgolaGhat	23.72°N, 90.39°E
S_9	Killar Moor	23.71°N, 90.38°E
S_{10}	SoariGhat	23.71°N, 90.39°E
S_{11}	Kamrangichar Bridge	23.71°N, 90.38°E

Analytical procedures

The levels of heavy metals in digested samples were manually determined using atomic absorption spectrometry (Model-Thermo Scientific iCE 3500 AAS). The manufacturer's recommendations were followed when operating hollow cathode lamps (HCL) for specific heavy metals, typically as radiation sources for AAS. About 99.99% pure argon and acetylene gas are used to ignite the burner.

III. Results and Discussion

A general pollution scenario was observed around the locations. The watercolor of the sample sites varied from light to dark black with an acute bad odour. Poisonous smell refers to extreme pollution of river water. Different particulate matter floats on the surface and in most water. As a result, this river water no longer seems appropriate for agricultural and domestic uses. The pH value indicates hardness or softness of water and the pH of pure water is 7. The collected river water quality is neutral or slightly alkaline and the pH value ranges from 7.30 to 7.82 (Table 02). According to WHO (2011), the normal pH in surface water systems is 6.5 to 8.5. In a research study, the typical pH values of Buriganga, Balu, Tongi Khal and Turag river water samples were 7.75, 7.55, 7.51, and 7.35, respectively, with 7.85 being the highest average pH value. This was due to increased base saturations and less water during the dry season (Hasan et al., 2013).

The EC measures the concentration of ions in water. The concentrations of ions vary based on the environment, atmospheric movement, and water source. Conductivity is directly connected to total dissolved solids in water samples. The EC values of the samples ranged from 723 to 1148 µS/cm (Table 02). Higher EC values indicate that more pollution occurred in water. The EC ranged from 910 to 1082 µS/cm in Balu River, almost within the Bangladesh standard (ECR, 1997) (Sultana et al., 2019).

Table 02. pH and EC levels of the collected samples

Sampling points	Location	pH	EC (µS/cm)
S_1	Turag Bridge	7.71	862
S_2	Abdullahpur Bridge	7.50	1148
S_3	Rampura Bridge	7.33	723
S_4	MeradiaGhat	7.30	742
S_5	Demra Bridge	7.82	854
S_6	PoschimgaonJame Masjid	7.52	847
S_7	Dakkhinpara Masjid	7.43	905
S_8	NolgolaGhat	7.71	977
S_9	Killar Moor	7.70	901
S_{10}	SoariGhat	7.67	983
S_{11}	Kamrangichar Bridge	7.80	946
Mean		7.578	862
Range		7.33-7.82	723-1148
Permissible limit		6.5-8.5	1400

In the present study, heavy metal concentrations differed with the different seasons. The concentration of different heavy metals was found to be highest in pre-monsoon (March), followed by post-monsoon (December) and monsoon (July). Within the collected samples from different points of Turag, Buriganga and Shitalakshya rivers, Zn concentration in water samples ranged from 0.87 to 3.45 mg L^{-1} (Table 03). During the pre-monsoon season, Zn concentration showed the highest and lowest values in every sampling point during the monsoon season. Dissolved and particulate pollutants from industrial effluent cause increased levels of Zn. Seasonal changes in Zn concentrations were detected less in the current research locations. The concentrations of Zn were lower than the WHO standard (5 mg L^{-1}) and DoE standard (5 mg L^{-1}) for drinking water in all the seasons for all sampling points (Table 03) (WHO, 2011; DoE 1997). According to WHO (2006) and USEPA (2012), maximum allowable concentration of Zn in irrigation water is 2 mg L^{-1} (WHO, 2006; USEPA, 2012). According to the present study, the water of all points except S_1, S_5, S_6 and S_7 are unsuitable for irrigation purposes in pre-monsoon and post-monsoon seasons.

Lead (Pb) concentrations in the sampling sites ranged from 0.0052 to 0.0139 mg L^{-1}, with the highest and lowest values found at sites S_1 and S_5 during the pre-monsoon and monsoon seasons, respectively. (Table 03). This might occur due to the release of untreated industrial, oil, and municipal pollutants, among other reasons. According to WHO and the Department of Environment (DoE), the maximum permissible concentration of lead in water is 0.01 mg L^{-1} and 0.05 mg L^{-1}, respectively. (WHO, 2006; USEPA, 2012). Here, the concentration recorded in this study is lower than the DoE's recommended values in maximum points. But in pre-monsoon Pb concentration was higher than the WHO standard in points S_1, S_2, S_8, S_9, S_{10} and S_{11}. Similarly, in post-monsoon the Pb concentrations were higher than the WHO and DoE standard at S_1 and S_2 points, which might be hazardous to water quality which will be harmful for aquatic animals and crops grown near the points. According to (WHO, 2006; USEPA, 2012) maximum allowable concentration of Pb in irrigation water is 5 mg L^{-1} (WHO, 2006; USEPA, 2012). The study found that the water from all sampling points is suitable for irrigation purposes regarding Pb concentration.

Cadmium (Cd) levels in water specimens from different locations varied between 0.0007 and 0.0040 mg L^{-1}. The lowest and highest amounts were identified at sites S_6 and S_2, respectively (Table 03). The considerable amount of Cd in river water is primarily due to industrial waste dumping. The maximum permissible content is 0.003 mg L^{-1} and 0.005 mg L^{-1}, according to WHO and DoE. The Cd concentration in this study is lower than the maximum recommended value of WHO and DoE in most sites. But, in the pre-monsoon season, S_1 and S_2 points showed a greater Cd value than the WHO recommended value of Cd. The seasonal change in Cd concentrations was not greater in this study. According to (WHO, 2006; USEPA, 2012) maximum allowable concentration of Cd in irrigation water is 0.01 mg L^{-1} (WHO, 2006; USEPA, 2012). It is found from the study that, in pre monsoon and post-monsoon seasons, the water of all points except S_1, S_5, S_6 and S_7 are not suitable for irrigation purposes.

Table 03. Seasonal fluctuation of heavy metal levels (mg L^{-1}) in the sampling locations

Sampling points	Seasons	Seasons heavy metal concentration (mg L^{-1})		
		Zn	Pb	Cd
S_1	Pre-monsoon	1.78	0.0131	0.0032
	Monsoon	1.02	0.0087	0.0021
	Post-monsoon	1.52	0.0117	0.0023
S_2	Pre-monsoon	3.34	0.0139	0.0040
	Monsoon	1.59	0.0069	0.0015
	Post-monsoon	2.39	0.0126	0.0028
S_3	Pre-monsoon	3.17	0.0089	0.0017
	Monsoon	2.12	0.0061	0.0012
	Post-monsoon	3.10	0.0081	0.0016
S_4	Pre-monsoon	2.59	0.0097	0.0019
	Monsoon	1.76	0.0085	0.0010
	Post-monsoon	2.21	0.0065	0.0016
S_5	Pre-monsoon	1.89	0.0092	0.0018
	Monsoon	1.07	0.0053	0.0009
	Post-monsoon	1.34	0.0078	0.0012
S_6	Pre-monsoon	1.52	0.0073	0.0012
	Monsoon	1.11	0.0052	0.0009
	Post-monsoon	1.26	0.0061	0.0007
S_7	Pre-monsoon	1.11	0.0098	0.0015
	Monsoon	0.87	0.0071	0.0013
	Post-monsoon	0.91	0.0087	0.0011
S_8	Pre-monsoon	3.23	0.0121	0.0021
	Monsoon	2.18	0.0087	0.0014
	Post-monsoon	2.95	0.0092	0.0019
S_9	Pre-monsoon	2.87	0.0113	0.0025
	Monsoon	2.50	0.0099	0.0016
	Post-monsoon	2.72	0.0089	0.0019
S_{10}	Pre-monsoon	3.04	0.0102	0.0023
	Monsoon	2.65	0.0076	0.0011
	Post-monsoon	2.01	0.0083	0.0018
S_{11}	Pre-monsoon	3.45	0.0123	0.0021
	Monsoon	2.97	0.0069	0.0010
	Post-monsoon	3.60	0.0096	0.0017

The rising level of heavy metals in surface water caused by the combined effects of greater vaporizations and less precipitation during the pre-monsoon season. Again, during the period of rainfall, opposite events happened. This may be explained by the rainfall effect, which accelerated the lixiviation process and increased heavy metal dilution during the rainy season.

The primary three categories of nitrogen found in wastewater are total nitrogen, which comprises both organic as well as inorganic nitrogen, and total nitrogen, which includes ammonium and mineral forms such as nitrite, nitrate, and ammonium (Nourmohammadi et al., 2013). The total Kjeldahl nitrogen in wastewater is significant because it shows and measures the amount of organic pollutants existing in the water. Because organic nitrogen in waste water is constantly broken down throughout time by both aerobic and anaerobic microbial respiration. It is the source of current water pollution from ammonia, nitrite, methane, hydrogen sulfide and nitrous oxide (Mohammad et al., 2022).

Table 04. Concentration of NH_4^+ (Ammonium) and NO_3^- (Nitrate) in the collected river water

Sampling Points	NH_4^+ (ppm)	NO_3^- (ppm)
S_1	122	103
S_2	201	77
S_3	172	110
S_4	203	105
S_5	406	119
S_6	280	133
S_7	193	98
S_8	201	118
S_9	225	102
S_{10}	187	87
S_{11}	193	102

The concentration of ammonium (NH_4^+) was 122–406 mg L^{-1} in the case of Turag, Buriganga and Shitalakshya river water (Table 04). Again, the sampling points showed that the NO_3^- value ranged from 87 to 133 mg L^{-1}. It was reported that a high concentration of ammonia 270–420 mg L^{-1} and high nitrate concentration (107–157 mg L^{-1}) were found in the case of Buriganga river water (Aman et al., 2020). Under aerobic conditions in biologically polluted wastewater systems, nitrifying bacteria consume oxygen by converting ammonia to nitrite (NO_2^-). Nitrobacter then converts nitrite into nitrate ions (NO_3). Point sources such as livestock farming, sewage disposal sites, industrial waste, and excessive fertilizer application in agricultural areas can also deliver nitrate ions into groundwater (Schmidt et al., 2002). As a result, it may be said that the chosen rivers are vulnerable due to rising acute concentrations of nitrate and ammonia.

Table 05. Concentration of Total N (%) and OC (%) in the collected river sediment

Sampling Points	Total N (%)	OC (%)
S_1	0.146	1.33
S_2	0.124	0.60
S_3	0.230	2.42
S_4	0.181	2.58
S_5	0.129	1.81
S_6	0.052	0.16
S_7	0.241	2.18
S_8	0.213	2.22
S_9	0.231	2.16
S_{10}	0.216	2.14
S_{11}	0.192	2.09

The collected sediment samples during pre-monsoon from the different point's %N and %OC ranged from 0.052 to 0.231 and 0.16 to 2.58 in the soil sediments (Table 05). Highest %N and %OC were reported at S_3 and S_4, respectively. A positive correlation was found between the total nitrogen and organic carbon (Figure 02). The increased percentage of total nitrogen and organic carbon is possibly due to municipal and industrial wastewater, sewage treatment plants, animal feedlot discharges, animal wastes, runoff from fertilized crop fields and so on (Hamad and Omran, 2016). Carbon-containing substances with varying degrees of toxicity have been found in industrial waste effluents. When these wastewaters are combined with river water through an outlet channel, they are transformed into sources of water carbon. The range of organic carbon levels was 0.18-3.3% in the winter and 0.59-1.8% in the summer (Islam et al., 2017).

IV. Conclusion

The results demonstrated that there are considerable differences in the amounts of heavy metals (Zn, Pb & Cd), total N (%), OC (%), NH_4^+ and NO_3^- in sediment and water samples found from various sampling sites. The selected sampling areas of the three rivers have become poorly polluted due to the release of hazardous heavy metals and pesticides from point and non-point sources. Due to their inability to disintegrate, these harmful substances can bio-accumulate in the food chain, which can pose long-term dangers by staying in the environment for an extended period. Using contaminated river water for irrigation in agricultural fields is an alarming activity.

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