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Spatial Differences in the Physicochemical Characteristics and Heavy Metal Pollution of the Turag River's Water and Sediment in Gazipur

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Abstract

A study was carried out to look at the Turag River's water quality and the degree of toxicity in the sediment and water. Five sites namely Kathaldiya, Korir Bagan, Rosodiya, Tungi Bridge, and Bishwa Ijtema Field were randomly selected for the collection of water and sediment samples, taking into account the 500 m separation between each station. Water and sediment samples were taken on December, 2019 following standard sampling procedures. Upon arriving at the Bangladesh Agricultural Research Institute (BARI), Gazipur, the chemical analyses of the water and sediment (pH, EC, and heavy metals: Cu, Zn, Pb, Fe, Cd, Cr, and Ni) were completed as soon as possible. To determine the degree of toxicity in water and sediment, the pollution load index (PLI) and the geo-accumulation index (Igeo) were computed. pH ranged from 7.6-8.2, EC ranged from 516-1221 $\mu S\ cm^{-1}$, and Cu, Zn, Ni, Pb, Cr, Cd, and Fe concentrations in water ranged from 0.005-0.009, 0.24-0.47, 0.30-0.36, 0.001-0.0012, 0.30-0.36, 0.52-0.75, 0.0011-0.0012, and 0.23-0.45 ppm, respectively. In sediments, Cd was above the average shale value and toxicity value, Ni exceeded the toxicity reference value, and Cr was nearly four times higher than the standard limit and near the severe effect level. For sediment samples, the mean PLI value was 0.48, with a range of 0.002-1.58. With the exception of Fe, all sampling sites were moderately polluted (Igeo class 1), with Igeo values ranging from 0.01 to 0.74. Sediment sample’s PLI readings revealed concerning conditions for both city inhabitants and the Turag River's aquatic ecology.

Keywords: Heavy metal’s toxicity, Sediments, Turag River, Water

Introduction

The Turag River is a significant river that separates Dhaka's Gazipur District from the city's northern side. On the Turag River (Tongi), there was a rapid industrial expansion, and people dumped their rubbish into the river. The Tongi area is home to numerous tanneries, chemical factories, clothing, jute, textile, spinning, pharmaceutical, and food manufacturing companies, among other types of industries. The majority of industries pollute the surface water by releasing their untreated wastewater into the Turag River either directly or indirectly. Furthermore, the Turag River is being contaminated by a variety of solid, liquid, and chemical wastes that are dumped into several sewers and municipal sewage drainage systems (Rahman et al., 2012). The water quality of the river is deteriorated by the discharge of both organic and inorganic waste effluents, which interact negatively with the river system. Water hence has a negative impact on the aquatic ecology and the surrounding land, which in turn affects the local community's standard of living. In September 2009, the Department of Environment designated the Turag River as an environmentally important area (ECA) (Meghla et al., 2013). The Turag River became more polluted due to a variety of man-made and natural factors, including industrial, municipal, water vehicle, and land runoff from agricultural fields, including fertilizer and pesticides.
According to Rashed (2011), sediments are crucial sinks for a variety of pollutants, including pesticides and heavy metals. They also have a major impact on the remobilization of contaminants in aquatic systems. One of the main problems in many rapidly expanding cities is heavy metal poisoning of rivers, as sanitation and water quality facilities have not kept up with population and urbanization growth, particularly in developing nations (Ahmed et al., 2010). The study was meant to ascertain the current state of sediment and water quality and to evaluate the degree of toxicity in Turag River waters and sediments, taking into account the pollution load in the vicinity of the river.

Materials and Methods

Water and sediment sampling

Water and sediment samples were taken at random from five locations maintaining 500 meters’ distance among the locations of Turag River, Bangladesh (**Table 1**) on December 2019. Using the procedure outlined by APHA (2005). 500 mL water samples were taken from each location and placed in plastic bottles. Concentrated nitric acid was used to filter and acidify every water sample. 500–600g of sediment samples was taken from each site at the depth of 0 and 10 cm just below 2 to 4 meters’ depth of water using the procedures of Sincero and Sincero (2004). As soon as the samples arrived at the Bangladesh Agricultural Research Institute (BARI), Gazipur, they underwent chemical testing.

Table 1. List of sampling sites with possible sources of pollution

Sam.No.	Location	Source of Pollution
S1	Kathaldiya	Alta washing Industries
S2	KorirBagan	SKF Factory
S3	Rosodiya	Normal Water
S4	Tungi Bridge	Alympriya Factory

S5	BishwaIjtema Field	Shoe and Soap Factory, IUBAT

Assessing the physical-chemical characteristics of sediments and water

As stated by Singh et al. (1999), measurements were made of the pH and electrical conductivity (EC) of water samples. The pH, EC and organic carbon of the sediment were measured using Jackson's (1962) methodology. By multiplying the organic carbon content by the Van Bemmelen factor, 1.73, the amount of organic matter in sediment samples was determined (Piper, 1950). The approach described by Kjeldahl (1983), Black (1965), and Ghosh et al. (1983) was used to determine the available N, P, K and S contents. In the Laboratory of the Department of Soil Science, Bangladesh Agricultural Research Institute, Gazipur, the levels of heavy metals (Cu, Fe, Zn, Pb, Cd, Cr, and Ni) in sediment and water samples were measured. An atomic absorption spectrophotometer (AAS) (Shimadzo, AA7000, Japan) was used to identify the various metals present in water and sediment samples.

Pollution load index evaluation (PLI)

The PLI put forth by Tomlinson et al. (1980) gives the local populace some insight into the amount of a component in the environment. A single site's PLI is equal to the nth root of the total number of multiplied Contamination Factor (CF) values. The concentration of each metal in the sediment divided by the baseline or background value yields the CF.

$$PLI = (CF1 \times CF2 \times CF3 \times \cdots \times CFn)^{1/n}$$

Consequently, the PLI for a zone is equal to the nth root of the n multiplied PLI values. According to Tomlinson et al. (1980), a PLI value of zero denotes perfection; a value of one means that only baseline amounts of pollutants are present, and values greater than one would suggest that the site and estuarine quality are gradually declining.

Geoaccumulation index measurement (Igeo)

Muller (1969) introduced the index of geoaccumulation (Igeo), a quantitative indicator of metal contamination based on the correlation between the background and the element's concentration in the sediment. The following is a definition of the geoaccumulation index values:

$$I_{geo} = \log_2 (C_n/1.5 \times B_n)$$

where, Bn is the geochemical background for the same element, which can be obtained from the literature (average shale value described by Turekian and Wedepohl, 1961) and Cn is the measured concentration of heavy metal in the sediment. In order to account for any differences in the background values caused by lithologic variances, the factor 1.5 is included. Muller (1969) created seven Igeo classes according to the index's numerical value (**Table 2**).

Table 2. Metal pollution in sediment based on the I_{geo} values

I_{geo} range	I_{geo} Class	Sediment quality
10- 5	6	Extremely polluted
4 - 5	5	Strongly/ extremely polluted
3- 4	4	Strongly polluted
2- 3	3	Moderately/ strongly polluted
1-2	2	Moderately polluted
0-1	1	Uncontaminated/mod. polluted
0	0	Unpolluted

Physicochemical properties of water

pH

All of the water samples had pH values between 7.6 and 8.20 (**Fig. 1a**). Rosodiya, Tungi Bridge, and Bishwa Ijtema Field had the greatest pH content (8.20), while Korir Bagan had the lowest (7.60). The pH in Kathaldiya was 8.15. According to proposed Bangladesh Standards, FAO standards and Bangladesh Environment Conservation Rule (ECR), 6.5 to 8.5 (DoE, 2005; EPA, 2001; ECR, 1997) and 6.0 to 8.5 (ADB, 1994) are the permitted pH ranges for irrigation water. pH values between 6.5 and 8.0 (Meade, 1998; ADB, 1994) and 6.5 and 8.5 (Chowdhury, 2007; ECR, 1997) are suitable for fish production. Domestic water sources should have a pH between 6.0 and 8.5 and 6.0 and 9.0, according to the Indian Standard Institution (ISI) and the United States Public Health (USPH) (De, 2005). Drinking water should have a pH between 6.5 and 8.5, recreational water between 6.0 and 9.5, industrial water between 6.0 and 9.5, and cattle water between 5.5 and 9.0 (ADB, 1994). The investigated samples' pH values fell within the permissible range (**Fig. 1a**).

Electrical conductivity (EC)

The average EC of the water samples was 954 µS cm^{-1}, with a range of 516 to 1221 µS cm-1. Rosodiya had the greatest value at 1221 µS cm-1, while Bishwa Ijtema Field had the lowest value at 516 µS cm^{-1}. Nonetheless, the tested water samples were classified as acceptable for irrigation (EC = 750-2000 µS cm^{-1}) (Wilcox, 1955). 500 µS cm^{-1} is the permissible EC range for recreational water, 750 µS cm-1 for irrigation water, and 800 to 1000 µS cm^{-1} for fishing water (ADB, 1994). The water sample taken from the Bishwa Ijtema Field region fell within the permitted range for irrigation water quality based on measured EC. However, all of the water samples taken from the Tongi industrial area had measured ECs that were within the permissible range for irrigation, according to Bakali et al. (2014).

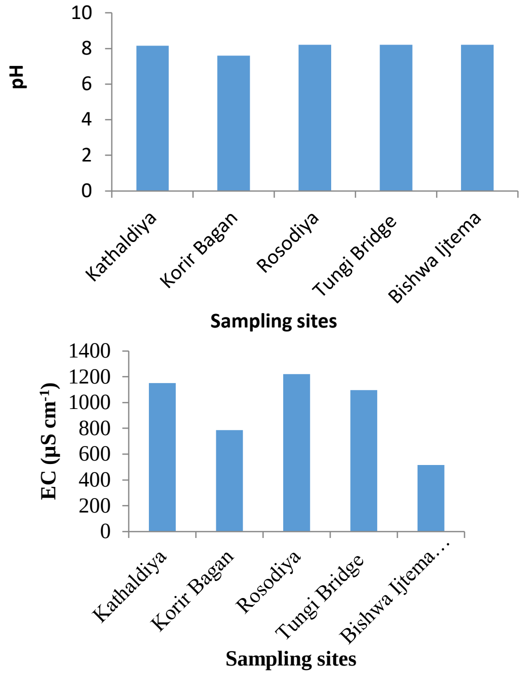


Fig. 1. Concentrations of (a) pH and (b) Electrical conductivity (EC) in water samples at different locations

Heavy metals in water samples

Iron (Fe)

The mean value of Fe was 0.36 ppm, with a range of 0.23 to 0.45 ppm. According to **Table 3**, the lowest value was 0.23 ppm in Kathaldiya while the highest was 0.45 ppm at Rosodiya. All of the samples' measured Fe concentrations were far below the irrigation-acceptable level of 5.00 ppm (Ayers and Westcot, 1985). According to Akter et al. (2016), the WHO recommends 0.30 ppm of iron for drinking water and 1.0 ppm for Bangladesh. Fish culture requires a Fe level of less than 0.10 ppm (Meade, 1998). All of the water samples in the study area had levels of Fe over this limit, which is considered typical, and were deemed unfit for fish culture.

Cadmium (Cd)

Traces of Cd were found in the water samples taken from several Turag River locations (**Table 3**). The lowest value was 0.0011 ppm at Tongi bridge, Bishwa Ijtema Field, while the highest value was 0.0012 ppm at Korir Bagan, Rosodiya and Kathaldiya. According to the ADB (1994), the standard levels of Cd in drinking, irrigation, and livestock water are 0.005, 0.01 and 0.5 ppm, respectively. In this case, every observed value was below the typical threshold. The levels of Cd in surface water samples taken from the Tongi industrial area were low and appropriate for all uses, claim Bakali et al. (2014). According to research by Rahman et al. (2012), the Cd levels at Ashulia Point in the Turag River ranged from 0.000092 to 0.002 ppm.

Zinc (Zn)

Water samples taken from several locations along the Turag River had a mean Zn concentration of 0.35 ppm, ranging from 0.24 to 0.47 ppm (**Table 3**). Tongi Bridge had the lowest zinc concentration, whereas Korir Bagan had the highest. Ayers and Westcot (1985) stated that 2.00 ppm of zinc is the maximum amount that can be present in irrigation water. All samples were determined to be appropriate for irrigation when this limit was taken as the norm. According to USPH, the standard for zinc in household water supply is 5.5 ppm (De, 2005). 5.0 ppm of zinc is the criterion for drinking water (ADB, 1994). Zn contents in all samples fell within the appropriate range for all uses when these limits were taken into account (**Table 3**).

Copper (Cu)

Water samples from several Turag River sampling locations had Cu concentrations ranging from 0.005 to 0.009 ppm, with a mean of 0.007 ppm (**Table 3**). It was lowest in Kathaldiya and highest at Tongi Bridge. All five samples were determined to be within the Ayers and Westcot (1985) suggested irrigation limit of 0.20 ppm. Similarly, irrigation effluent water should not include more than 0.20 ppm Cu for continuous usage, according to the National Academy of Science's recommendation (Gibeault and Cockerham, 1985). Cu levels in drinking water and animal drinking water are typically limited to 1.0 ppm and 5.0 ppm, respectively (ADB, 1994). Cu concentrations in all water samples were found to be within the appropriate range when these limitations were taken into account.

Lead (Pb)

The mean Pb concentration in water samples was 0.0011 ppm, with a range of 0.0010 to 0.0012 ppm (**Table 3**). The lowest value was 0.0010 ppm at Korir Bagan, Rosodiya, and Bishwa Ijtema Field, while the highest value was 0.0012 ppm at Kathaldiya. Pb levels in home water sources should be less than 0.05 ppm, according to USPH, and 0.01 ppm, according to ISI (De, 2005). 0.05 ppm, 0.05 ppm, 0.01 ppm, 0.05 ppm, and 0.05 ppm are the Pb standards for drinking, fishing, industrial, irrigation water, and livestock, respectively (ADB, 1994). According to Ayers and Westcot (1976), the permissible limit of lead for bathing and public supplies is 0.10 ppm. DoE (2005) stated that irrigation water has a Pb concentration of 0.01 ppm. Pb concentrations in all water samples taken from the research region were determined to be appropriate in light of these limitations.

Chromium (Cr)

Water samples taken from the Turag River had a mean content of 0.63 ppm of Cr, with a range of 0.52 to 0.75 ppm (**Table 3**). It was at its lowest (0.52 ppm) in Rosodiya and at its greatest (0.75 ppm) in Kathaldiya. The USEPA has established a Maximum Contaminant Level (MCL) of 0.1 ppm for total Cr in drinking water. For total Cr, the World Health Organization (WHO) recommends 0.05 ppm. Chromium concentrations in all of the water samples that were gathered were found to be higher than the WHO-recommended allowable level. For surface water, 0.05 ppm of Cr is the standard value (EPA, 2001). All of the measured values in this case are greater than the typical level, indicating that the water samples under study have Cr pollution (**Table 3**).

Nickel (Ni)

The average Ni content in the water sample was 0.34 ppm, with a range of 0.30 to 0.36 ppm (**Table 3**). Three of the five samples namely Kathaldiya, Tungi Bridge, and Bishwa Ijtema Field had Ni contents that were higher than usual. Ni levels in drinking water must not exceed 0.02 ppm (WHO, 2003). The content of Ni in all of the water samples that were gathered was higher than the WHO recommended allowable level.

Table 3. Concentrations of heavy metals (ppm) in water samples at different sampling locations

Loc.	Fe	Cd	Zn	Cu	Pb	Cr	Ni
S1	0.23	0.0012	0.38	0.005	0.0012	0.75	0.36
S2	0.35	0.0012	0.47	0.008	0.001	0.55	0.30
S3	0.45	0.0012	0.28	0.007	0.001	0.52	0.33
S4	0.42	0.0011	0.24	0.009	0.0011	0.68	0.35
S5	0.36	0.0011	0.39	0.007	0.0011	0.66	0.35

Physicochemical properties of sediments

pH of sediments

At a depth of 0–10 cm, the mean pH of the sediment samples was 6.22, with a range of 4.6–7.2 (**Fig. 2a**). Three locations in Rosodiya, Kathaldiya, and Bishwa Ijtema Field have relatively higher pH values, measuring 6.7, 7.0, and 7.2, respectively. The sampling location Bishwa Ijtema Field had the highest sediment pH value, while Korir Bagan had the lowest. This large range of pH variation may be caused by a variety of materials (wastes, effluents, chemicals, salt etc.) that are released into the Turag River from various companies, towns, and other sources. According to Mohiuddin et al. (2016), the Turag River's pH ranged from 2.01 to 7.85, with a mean of 5.50.

Organic matter (OM)

Fig. 2b displays the amount of organic matter found in sediment samples taken from the Turag River. The sediment sample taken from the Korir Bagan site had the maximum amount of organic matter (3.13%), while the Kathaldiya site had the lowest amount (0.99%). Because less OM-containing pollutants were being dumped into the river by various enterprises, there were decreased levels of OM at all test locations. According to various researches, contaminated soil and sediments have a comparatively higher amount of organic matter than uncontaminated ones. Large-scale deposition of sewage sludge, industrial wastes, and other organic materials may be the cause of this (Sultana, 2010).

Total N

Sediment samples taken from the Turag River had an average total N concentration of 0.08%, falling between 0.05 and 0.2% (**Fig. 2c**). When compared to other locations, it was significantly higher at Korir Bagan. Because less industrial effluents containing the nutrient of total N were discharged, the N content was lower in all sample sites.

Available phosphorus (P)

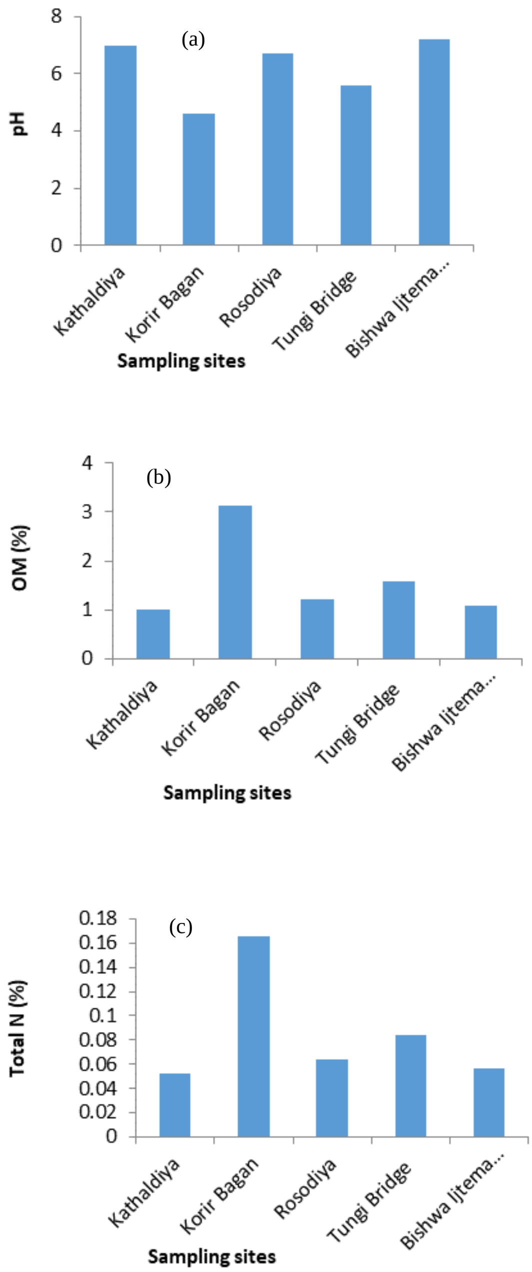
The sediment samples taken from the Turag River had an available P content ranging from 2 to 23 ppm (**Fig. 2d**). P levels were lower in Kathaldiya and Rosodiya and higher in Korir Bagan and Bishwa Ijtema Field. The sediment sample taken from the river next to the Bishwa Ijtema field had the highest P value (23.0 ppm), while the sample taken from the area around Rosodiya had the lowest (2 ppm). It is important to note that frequent discharges of industrial effluents into the Turag River may have a beneficial effect on the sediment sample's P level.

Exchangeable potassium (K)

The sediment sample taken from the river next to Rosodiya had the highest exchangeable K content (0.35 meq 100 ml^{-1}), whereas the sample taken from the area around Korir Bagan had the lowest (0.17 meq 100 ml^{-1}) (**Fig. 2e**). Because fewer potassium-containing pollutants were being dumped into the river by various enterprises, the K levels were lower at all sample locations.

Available sulphur (S)

Sediments taken from the area near Kathaldiya in the river had a higher concentration of accessible sulfur (353 ppm) than sediments taken from other locations, which ranged from 43.5 to 353 ppm (**Fig. 2f**).



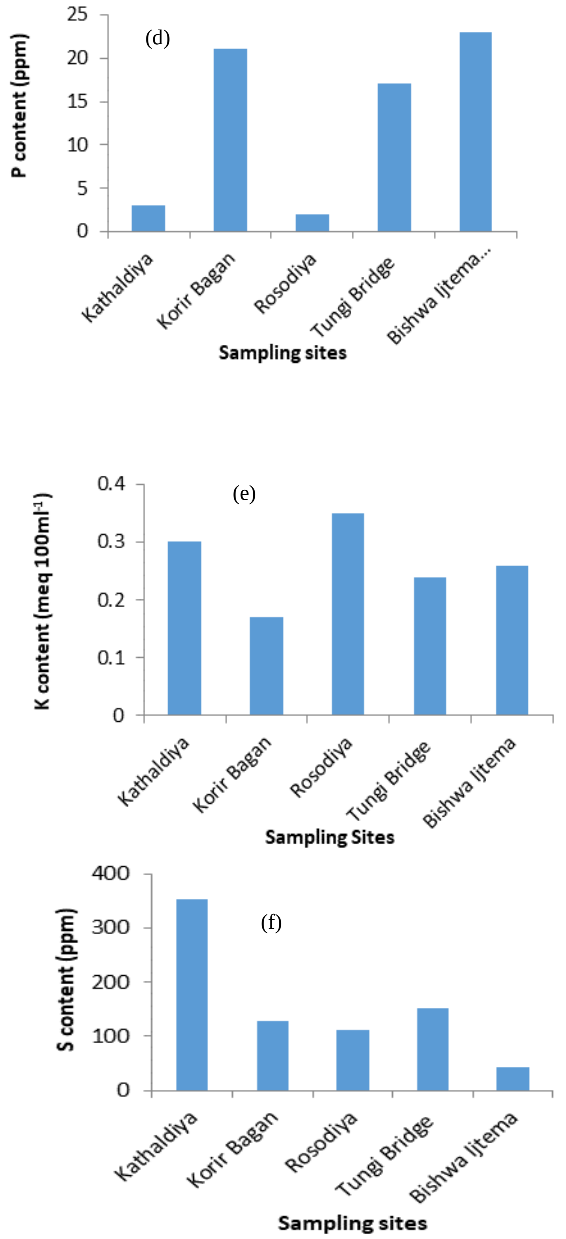


Fig. 2. Concentrations of (a) pH; (b) OM; (c) Total N; (d)Phosphorous (P); e) Potassium (K) and (f) Sulphur (S) in sediment samples at different sampling locations

Metals content in sediments

Copper (Cu)

The average concentration of Cu in sediments was 3.42 ppm, with a range of 3.1 to 3.8 ppm (**Table 4**). It was 3.8 ppm at its maximum in the Korir Bagan area and 3.1 ppm at its lowest in the Tungi Bridge area. According to the current study, the average Cu content in sediment taken from the Turag River was generally lower than that of several other rivers in Bangladesh and the geochemical background (average shale and continental crust) (**Table 7**). Similarly, according to the US EPA (2001), the mean concentration of Cu in the sediments of the Turag River was almost below the toxicity standard limit. According to Mohiuddin et al. (2016), the average concentration of copper in sediments upstream of the Turag River was 54.8 ppm, with a range of 30.6 to 72.3 ppm. Less than the maximum permissible concentration (100 ppm) for crop cultivation was present in all five sediment samples.

Chromium (Cr)

The average concentration of Cr in sediment samples was 80.86 ppm, with a range of 52.20 to 97.80 ppm (**Table 4**). About two of the five sampling sites—Kathaldiya and the area around Tungi Bridge—had Cr contents that were below the average. It may be concluded that the sediments of the analyzed area had several times more Cr if we compare the mean Cr concentration with various reference values. This suggests that the study area is contaminated by Cr. According to Mohiuddin et al. (2016), the average concentration of Cr in the sediments of the Turag River was 178 ppm, which was higher than the average concentration of other river sediments, which ranged from 109.1-231.7 ppm.

Zinc (Zn)

The average Zn concentration in sediments taken from the Turag River was 5.65 ppm, with a range of 4.08 to 7.60 ppm. Three of the five sampling locations—Korir Bagan, Tungi Bridge, and Bishwa Ijtema Field were found to have values higher than the mean (**Table 4**). Compared to the results of the previous study for the Turag River (Zakir et al., 2006; Sarkar et al., 2013), the Zn contents in the current study were lower. Compared to the geochemical background and toxicity reference values, as well as a number of other rivers in Bangladesh, the average zinc level in the sediments of the Turag River was extremely low.

Lead (Pb)

The average total Pb concentration in sediments was 16.42 ppm, with a range of 1.80 to 38.50 ppm (**Table 4**). Two samples (Korir Bagan and Rosodiya site) out of five sediment samples exhibited Pb contents higher than the average. It was lowest at Kathaldiya (1.80 ppm) and highest at Korir Bagan (38.50 ppm). The Pb content of the various sites varied significantly. According to Mohiuddin et al. (2016), the highest permissible Pd content for agricultural cultivation is 50 ppm. The readings in each sample were below the allowable limit for crop production. This is because fewer pollutants are leaking from various Pb-containing companies along the river's edge. The lead levels found in the sediments taken from the research region were lower than those found in the Buriganga and Korotoa rivers (Mohiuddin et al., 2011; Zakir et al., 2013), but they were nearly identical to those found in the Turag river sediment as reported by Zakir et al. (2006).

Cadmium (Cd)

Sediments taken from the Turag River had an average total Cd concentration of 0.62 ppm, with a range of 0.20 to 1.10 ppm (**Table 4**). It was lower in the Korir Bagan and Rosodiya area (0.20 ppm) and higher in Kathaldiya and Tungi Bridge (1.10 ppm). At all sampling sites, the Cd concentrations were below the severe effect value (10 ppm), however they were higher than the hazardous reference value (0.60 ppm) at Kathaldiya and Tungi Bridge. According to Mohiuddin et al. (2016), the average Cd level upstream of the Turag River was 0.8 ppm, with a range of 0.2 to 3.6 ppm.

Iron (Fe)

Sediments taken from several Turag River locations had an average total Fe concentration of 109 ppm, with a range of 77–137.5 ppm (**Table 4**). Korir Bagan had the highest value, while Kathaldiya had the lowest. According to the current study, the average concentration of iron in sediments taken from various Turag River locations was generally lower than that of all other rivers in Bangladesh and the geochemical background values. Fe concentrations in Turag River sediments ranged from 10413 to 14455 ppm, with an average of 13679 ppm (Mohiuddin et al. 2016).

Nickel (Ni)

The average total Ni concentration in sediments taken from the Turag River was 16.17 ppm, with a range of 10.44 to 19.56 ppm (**Table 4**). It was lower in the Kathaldiya area and higher in Korir Bagan. All sampling sites had Ni amounts that were lower than the severe effect value (75 ppm) but higher than the hazardous reference value (16 ppm) at Korir Bagan, Rosodiya, and Bishwa Ijtema Field (**Table 4**). Because there was less industrial effluent containing Ni, the Ni readings were low at all test sites. According to Mohiuddin et al. (2016), the average Ni level upstream of the Turag River was 155.4 ppm, with a range of 108–221.6 ppm. It was comparable to the current investigation.

Table 4. Concentrations of heavy metals (ppm) in sediment samples at different sampling locations

Loc.	Fe	Cd	Zn	Cu	Pb	Cr	Ni
S1	77.0	1.10	4.08	3.20	1.08	52.20	10.44
S2	137.0	0.20	7.60	3.80	38.50	97.80	19.56
S3	115.0	0.20	4.22	3.40	25.40	87.50	17.50
S4	94.0	1.10	6.19	3.10	5.90	76.00	15.20
S5	122.0	0.50	6.17	3.60	11.20	90.80	18.16

Table 5. EPA heavy metal guidelines for sediments (mg/kg)

Metals	Not Pol.	Mod. Pol.	Hea. Pol.	This study
Pb	‹40	40-60	›60	1.08-38.5
Cr	‹25	25-75	›75	52.2-97.8
Cd	-	‹6	›6	0.20-1.1
Cu	‹25	25-50	›50	3.1-3.8
Fe	ND	ND	ND	77-137
Zn	‹90	90-200	›200	4.08-7.6

Assessment of pollution level

Pollution load index (PLI)

The standard shale concentration for each heavy metal introduced by Turekian and Wedephol (1961) was taken into consideration as background concentration values for calculating the contamination factor (CF) for the pollution load index (PLI) of sediments of the study region. A basic problem with the creation of a PLI is the idea of a baseline (Tomlinson et al., 1980). According to Tomlinson et al. (1980), the index as it is currently provided offers a straightforward, comparable method of evaluating a site's quality: a value of zero denotes perfection, a value of one shows the presence of just baseline levels of pollutants, and values above one would indicate progressive site deterioration. Sediment samples taken from five places along the Turag River have PLI values ranging from 0.002-1.58 with an average of 0.48 (**Fig. 3**). For Cd, it was greatest, while for Fe, it was lowest. The site's ongoing deterioration was indicated by the highest PLI result for Cd (1.6). PLI values were also greater for Cr and Pd. PLI results for Cu, Zn, and Ni likewise showed that only baseline amounts of contaminants were present.

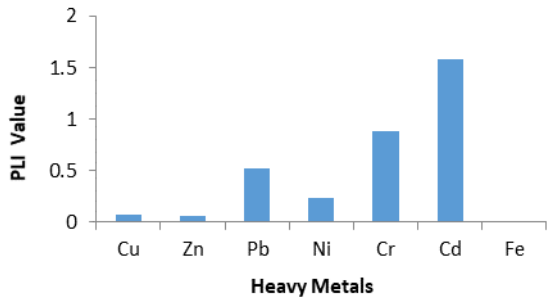


Fig. 3. PLI values in sediment samples at different sampling locations

Geo-accumulation Index (Igeo)

To compare the various heavy metals in sediments and measure the extent of anthropogenic pollution, a geo-accumulation indexing technique is employed (Forstner et al., 1980). Sediment samples taken from five different places along the Turag River have Igeo values ranging from 0.01 to 0.74 (**Table 6**). According to **Table 2**, every sampling location was in Igeo class 1 (Igeo value 0-1). Cd, Pb, and Cr showed greater Igeo values of Igeo class 1, but Fe had no Igeo value. At the majority of the sites, the Igeo indexes for all elements are much below grade zero, indicating that the sediment quality is uncontaminated. All sampling locations, with the exception of Fe, were moderately contaminated (Igeo class 1), as indicated by **Table 2**.

Table 6. Igeo values in sediment samples at different sampling locations

Loc.	Cu	Zn	Pb	Ni	Cr	Cd	Fe
S1	0.01	0.01	0.02	0.03	0.01	0.74	0.00
S2	0.01	0.02	0.39	0.06	0.22	0.13	0.00
S3	0.01	0.01	0.25	0.05	0.20	0.13	0.00
S4	0.01	0.01	0.06	0.04	0.17	0.74	0.00
S5	0.01	0.01	0.11	0.05	0.20	0.33	0.00

Relationships among heavy metals of water and sediments

Heavy metal relationships between sediment and water samples revealed a strong correlation value (**Table 7**). In the sediments, lead (Pb) had a negative significant connection with Zn (-0.419), Cu (-0.605), Pb (-0.903), Cr, and Ni (-0.874), and a high and moderate positive significant correlation with Cd (0.867). There was a moderately significant positive association between iron in the water and the sediments' Zn (0.175), Cu (0.039), Pb (0.375), Cr, and Ni (0.639). Additionally, there was a large and significant positive association between zinc in the water and the sediments' Fe (0.477), Cu (0.785), Pb (0.444), Cr, and Ni (0.250). However, **Table 7** also shows that, likely as a result of their redox sensitivity in oxidizing conditions in aquatic systems, Cr and Ni in the water exhibited a negative connection with metals in the sediments in the majority of cases.

Table 7. Correlation coefficient among heavy metals of water and sediments of Turag River

Sediments	Metals in Water						
	Fe	**Cd**	**Zn**	**Cu**	**Pb**	**Cr**	**Ni**
Fe	0.439	0.039**	0.477**	0.442**	-0.833	-0.788**	-0.815**
Cd	-0.436	-0.361	-0.383	-0.156*	0.867*	0.910	0.787
Zn	0.175**	-0.323**	0.453	0.698**	-0.419**	-0.255**	-0.594**
Cu	0.039**	0.223**	0.785**	0.106	-0.605**	-0.598**	-0.761**
Pb	0.375*	0.468*	0.444*	0.349*	-0.904	-0.903	-0.981
Cr	0.639**	-0.130**	0.250**	0.609**	-0.874**	-0.804	-0.743**
Ni	0.639**	-0.130**	0.250**	0.609**	-0.874**	-0.804**	-0.743

* and ** denotes significant at 5% and 1% levels, respectively.

Conclusions

The increased levels of heavy metals are seen in close proximity to industrial and urban regions, suggesting that human activity has had a significant impact on their concentrations. The distribution pattern of heavy metals in the Turag River, as determined by the Igeo Index, shows that the area of the river under study is not yet polluted; however, if this trend continues, the level of metal pollution in the river will rise to unacceptable levels, which could have a detrimental effect on the aquatic life there. Therefore, it is preferable that the required steps be made to reduce the pollution level and regularly check the concentrations of these pollutants in water and sediments in the future.

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