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Heavy Metal Contents in Sediments of an Urban Industrialized Area—A Case Study of Tongi Canal, Bangladesh

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Abstract: A study was conducted to investigate heavy metal content in sediments collected from the whole area of Tongi canal, close to Dhaka city of Bangladesh. Total concentration of metals in aquous extract of sediments was determined by Atomic Absorption Spectrophotometer (AAS) and the range of Cu, Zn, Pb and Fe varied from 18.34 to 101.27, 92.80 to 1111.15, 18.42 to 38.11 and 12327.5 to 47112.5 µg g^{-1}, respectively while there was trace amounts of Cd. The study results showed that the mean concentrations of Cu, Zn and Pb in sediments of Tongi canal were higher compared to geochemical standard and other Bangladeshi rivers. The average concentrations of Cu, Zn and Pb in the carbonate fraction were 7.07, 40.13 and 2.06 µg g^{-1}, respectively which can be released to the sediment pore water in acidic conditions. The calculated geoaccumulation index (I_{geo}) for Zn in 85% sampling sites exhibited I_{geo} class 1-3, indicating moderately to strongly polluted sediment quality. But in most cases, I_{geo} values for Cu and Pb exhibited I_{geo} class 1, indicating moderately polluted sediment quality. Similarly, the calculated enrichment factors (EFc) for 100 and 88% sampling sites had values >5.0 for Zn and Pb, respectively indicating anthropogenic pollution load for these metals. As regards to risk assessment code (RAC), Zn and Cu come under the medium risk category, while Pb comes under low risk category. The study concluded that the degree of contamination due to Zn, Pb and Cu in the study area was comparatively high, so it is desirable to take necessary initiative to minimize the pollution level as well as to monitor their concentrations in water and sediments routinely in future.

Key words: Urban and industrialized, heavy metals, Tongi canal, Bangladesh.

Introduction

Different kinds of industrial activities and urbanization over the last few decades in Bangladesh have greatly increased the heavy metal burdens to water, soil and sediments. The list of sites contaminated with various metals increases every year in the country, presenting a serious problem for human health and formidable danger to the environment (Zakir et al., 2012; Zakir et al., 2013; Bakali et al., 2014; Zakir et al., 2014; Zakir et al., 2015). Usually, the concentrations of different heavy metals in water, soils and sediments are very low, but higher concentrations are found from naturally mineralized areas, where heavy metals have become dispersed as a result of different anthropogenic activities such as industrialization, urbanization, underground deposition of waste, discharge of effluent without treatment and others (Zakir and Shikazono, 2008; Shikazono et al., 2008; Zakir and Shikazono; 2011, Shikazono et al., 2012).

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Major industrial areas in Bangladesh are situated very close or inside the cities and are frequently located adjacent to rivers, canals or other water bodies that facilitates disposal of effluents. Satter and Islam (2005) reported that presently 10% of wastewater generated from different industrial sources is being treated and the rest is discharged into the nearest water bodies, which contaminates surface water and sediments (Ahmad and Goni, 2010; Zakir et al., 2012; Zakir et al., 2013; Bakali et al., 2014), and the scenario is increasing in all the urbanized and industrialized areas of Bangladesh. Toxic metals present in wastewater and sewage sludge easily bind to the sediments, which may bioaccumulate in aquatic organisms and their terrestrial predators, because sediments can act as a sink and secondary source of these metals in water and aquatic biota (Varol and Sen, 2012).

Tongi canal is situated in a most urbanized and industrialized area of Bangladesh and its location is in between the northern border of the mega city Dhaka and Tongi industrial area of Gazipur, Bangladesh. Hundreds of industries are situated at both sides of the canal, including garments, chemicals, paper and pulps, polythene, aluminium, pharmaceuticals, oil and food processing, soaps, plastic and packaging, recycling etc. The canal is a stream of about 15 km in length, which is connected to the Turag river to the west and the Balu river to the east and located at an elevation of four metres above sea level. Its coordinates are 23°51'25" N and 90°28'33" E (Khan, 2012). This canal plays an important role by providing drainage system, water for different usage, different kinds of fishes and also waterways for travelling to the surrounding areas. From both sides of the canal, contamination of water and sediments by various metallic and non-metallic chemicals, untreated effluents, different toxic waste and sewerages of more than hundred factories are very common. People living at the surrounding area are always complaining against offensive odour from this canal. As a result, environmental hazards are occurring with different health hazards. Considering the above facts, the present research study was planned to assess metal pollution levels in sediments of Tongi canal, Bangladesh.

Materials and Methodology

Collection and Preparation of Samples

Total 26 sediment samples were collected from the whole area (15 km in length) of the Tongi canal, Bangladesh as shown in Figure 1. The sampling distance from one station to another was at least about 250 m.

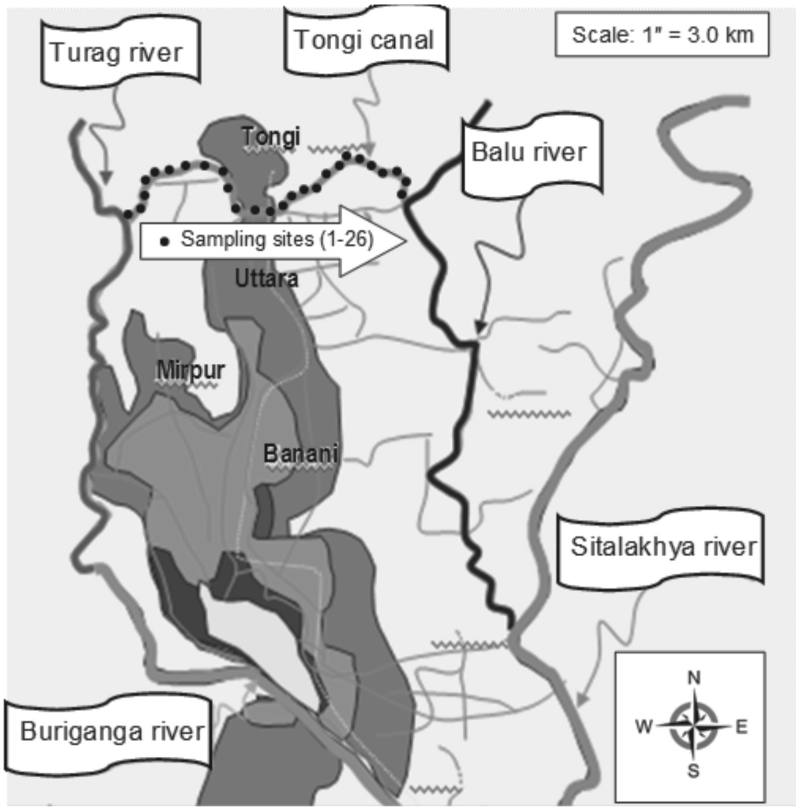

Figure 1: Location of sediment sample sites of Tongi canal, Dhaka, Bangladesh.

The surface sediment samples were taken from 0-10 cm depth and quickly packed in airtight polythene bags. Three (03) samples from each location were collected and mixed together to get a composite sample, and finally the sample mass was reduced to 500 g for further processing. Sub-samples of the material were oven dried at 50°C for 24 hrs and sieved (aperture 125 µm). The lower particle size fraction was homogenized by grinding in an agate mortar and stored in glass bottles for chemical analyses.

Determination of Physicochemical Properties of Sediments

The pH was measured in 1:2.5 sediment to water ratio by using a Jenway-3505 pH meter. The suspension was allowed to stand overnight prior to pH determination. The electrical conductivity (EC) was measured in the saturated extract of the sediments, using a sensION + EC5 portable conductivity meter. The organic carbon (OC) was measured by the wet oxidation method of Walkley and Black (1934).

Determination of Heavy Metals Concentration in Sediment Samples

Total concentrations of Cu, Zn, Pb, Cd and Fe in sediment samples were determined by using an atomic absorption spectrophotometer (AAS) (Shimadzo, AA7000, Japan), equipped with single elements hollow-cathode lamps at the wavelengths of 324.8, 213.9, 283.3, 228.8 and 248.3 nm, respectively. The instrument was operated at maximum sensitivity with an air-acetylene flame. Lamp intensity and bandpass were used according to the manufacturer's recommendations. For the determination of total heavy metal concentration, exactly 1.00 g of powdered sediment sample was digested with aqua regia (HNO_3:HCl = 1:3). On the other hand, for the determination of heavy metals in the carbonate bound fraction, exactly 1.00 g of powdered sediment sample was taken into 200 mL conical flask followed by the addition of 20 mL of 0.11M acetic acid. Then the content was stirred for 16 hours at room temperature (Rauret et al., 1999). All chemicals and reagents were of analytical reagent grade quality (Merck, Germany). Before use, all glass and plastic ware were soaked in 14% HNO_3 for 24 hrs. The washing was completed with distilled water rinse.

Assessment of Sediment Quality

Determination of Geoaccumulation Index (I_{geo})

The geoaccumulation index (I_{geo}) values were calculated for Cu, Zn, Pb, Cd and Fe as introduced by Muller (1969) as follows:

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

where C_n is measured concentration of metal in the sediment and B_n is the geochemical background for the same element which is either directly measured in precivilization sediments of the area or taken from the literature (average shale value described by Turekian and Wedepohl, 1961). The factor 1.5 is introduced to include possible variations of the background values that are due to lithologic variations. According to Muller (1969), there are seven grades or classes of the geoaccumulation index. Class 0 (practically uncontaminated/unpolluted): $I_{geo} < 0$; Class 1 (Uncontaminated to moderately contaminated): $0 < I_{geo} < 1$; Class 2 (moderately contaminated): $1 < I_{geo} < 2$; Class 3 (moderately to strongly contaminated): $2 < I_{geo} < 3$; Class 4 (strongly contaminated): $3 < I_{geo} < 4$; Class 5 (strongly to extremely contaminated): $4 < I_{geo} < 5$; Class 6 (extremely contaminated): $I_{geo} > 5$, which is an open class and comprises all values of the index higher than Class 5.

Determination of Enrichment Factor (EFc)

To evaluate the magnitude of contaminants in the environment, the enrichment factors were computed relative to the abundance of species in source material to that found in the Earth's crust (Huheey, 1983; Loska et al., 1997; Atgin et al., 2000). Atgin et al. (2000) reported that crustal enrichment factors (EFc) of elements are frequently used to determine the degree of modification in soil composition. The following equation was used to calculate the EFc:

$$\text{EFc} = (C_M/C_{Fe})_{sample}/(C_M/C_{Fe})_{\text{Earth's crust}}$$

where $(C_M/C_{Fe})_{sample}$ is the ratio of concentration of metal (C_M) to that of Fe (C_{Fe}) in the soil sample, and $(C_M/C_{Al})_{\text{Earth's crust}}$ is the same reference ratio in the Earth's crust. The average abundance of metals in the reference Earth's crust were taken from Huheey (1983), and Fe was selected as the reference element, due to its crustal dominance and its high immobility.

Risk Assessment Code (RAC)

The metals in the sediments are bound with different strengths to the different fractions. The risk assessment code (RAC) as proposed by Perin et al. (1985), is the sum of exchangeable and carbonate bound fractions of total metals in sediments. If a sediment sample can release less than 1% of the total metal in these fractions, then it will be considered safe for the environment;

1-10% low risk; 11-30% medium risk; 31-50% high risk and more than 50% of the total metal is considered very high risk/dangerous and can easily enter into the food chain.

Results and Discussion

Physicochemical Properties of Sediment

The pH values of sediment samples ranged from 6.17 to 8.00 with a mean value of 7.05 at 0-10 cm depth (Table 1). Wastes, effluents, chemicals and salts discharged from different industries, municipalities and others into the Tongi canal might be responsible for this pH variations. Sediment pH has been identified as the key factor governing the concentration of soluble metals, which tend to increase at lower pH and decrease at higher pH (Wang and Qin, 2006). Thus the acid nature of sediment of this study area may enhance heavy metal availability to the aquatic environment. The EC values of sediment samples ranged from 121 to 2022 μScm^{-1} with a mean value of 766.38 μScm^{-1} (Table 1). Higher EC values were obtained from the sites where municipal and industrial wastes from Tongi area are discharged frequently without any sort of treatments.

Table 1: Some physicochemical properties of sediments collected from Tongi canal, Bangladesh

Sample ID	*pH*	*EC ($\mu S\ cm^{-1}$)*	*OC (%)*	*OM (%)*
1	7.26	210	0.48	0.83
2	6.71	200	0.19	0.33
3	6.71	204	0.09	0.16
4	7.32	347	0.28	0.48
5	7.33	779	0.28	0.48
6	7.11	168	0.31	0.53
7	6.88	203	0.35	0.60
8	6.55	121	0.52	0.89
9	6.22	237	0.52	0.89
10	7.09	258	0.57	0.99
11	8.00	166	0.80	1.38
12	7.51	725	0.74	1.28
13	6.66	166	0.66	1.14
14	7.40	730	0.17	0.29
15	6.17	146	0.41	0.71
16	7.88	1386	0.15	0.26
17	6.69	877	0.51	0.88
18	7.81	2022	0.32	0.55
19	6.46	820	0.29	0.50
20	6.57	2012	0.39	0.68
21	7.06	712	0.72	1.25
22	7.26	1862	0.77	1.34
23	7.43	1763	0.36	0.63
24	7.49	1537	0.25	0.43
25	7.01	1172	0.61	1.05
26	6.68	1103	0.52	0.89
Range	6.17-8.00	121-2022	0.09-0.80	0.16-1.38
Mean	7.05	766.38	0.43	0.75

According to Costa et al. (2001), high EC value in soil might be due to huge quantities of salt, solid wastes and effluents of tannery and other industries. Other studies have revealed that contaminated sediments contained relatively more organic matter than uncontaminated one due to deposition of large quantities of industrial wastes, sewage sludge and other organic substances (Zakir et al., 2014). Present study revealed that Tongi canal contained comparatively lower amount of organic matter (range is 0.16-1.38%). Organic matter along with clay contents of the sediments had a significant influence on metal accumulation (Wang and Qin, 2006; Zakir et al., 2006) and retention which could have implications on metal mobility and bioavailability (Manta et al., 2002). Furthermore, the variations of organic matter content might be due to temperature, rainfall, topography, textural class, pH and soil profile.

Content of Metals in Sediments

Total concentration of Cu in sediments ranged between 18.34 and 101.27 $\mu g\ g^{-1}$, having an average value of 49.23 $\mu g\ g^{-1}$ and total concentration of Pb varied from 18.42 to 38.11 $\mu g\ g^{-1}$ with a mean value of 29.59 $\mu g\ g^{-1}$ (Table 2). The results of the present study are almost similar to those obtained in the earlier study for Turag river sediment (Zakir et al., 2006) but Cu content was more than twice compared to the sediments of Korotoa river (Zakir et al., 2013). Total concentration of Zn in sediments ranged from 92.80 to 1111.15 $\mu g\ g^{-1}$, having a mean value of 397.72 $\mu g\ g^{-1}$. The concentrations of Zn were also higher compared to those reported earlier for Turag and Korotoa rivers (Zakir et al., 2006; Zakir et al., 2013) but lower than the Buriganga river (Mohiuddin et al., 2011) (Table 3). The present study revealed that the average Cu, Pb and Zn levels in sediments of Tongi canal were higher compared with several other Bangladeshi rivers as well as geochemical background (Table 3). Similarly, the mean concentration of Cu and Zn in sediments of Tongi canal was almost thrice the toxicity reference value as reported by US EPA (Table 3).

Table 2: Concentration of heavy metals in sediment samples collected from Tongi canal, Bangladesh

Sample ID	*Upto carbonate bound metals (μg g^{-1})*				*Total metal (μg g^{-1})*				
	Cd	*Zn*	*Cu*	*Pb*	*Cd*	*Fe*	*Zn*	*Cu*	*Pb*
1	Trace	13.84	0.24	1.07	Trace	28404.5	838.50	40.40	23.09
2	Trace	15.56	Trace	Trace	Trace	20724.5	864.25	38.03	23.34
3	Trace	14.62	Trace	Trace	Trace	14440.0	155.35	30.42	18.42
4	Trace	17.38	Trace	Trace	Trace	13700.0	130.20	27.76	19.40
5	Trace	69.77	1.09	Trace	Trace	18625.0	1111.15	49.03	29.00
6	Trace	18.37	Trace	Trace	Trace	25953.0	679.85	35.81	29.49
7	Trace	21.95	1.03	Trace	Trace	22578.0	615.00	36.23	30.23
8	Trace	9.97	0.79	Trace	Trace	17682.0	655.40	29.98	29.00
9	Trace	24.69	4.43	Trace	Trace	29321.0	836.80	33.72	32.20
10	Trace	29.18	2.01	Trace	Trace	47112.5	527.00	35.52	32.69
11	Trace	9.53	0.69	Trace	Trace	14825.5	124.00	19.49	24.32
12	Trace	91.14	3.65	Trace	Trace	18665.0	526.55	86.75	37.37
13	Trace	18.88	5.31	Trace	Trace	12845.0	242.50	23.88	31.95
14	Trace	79.11	4.53	Trace	Trace	12814.0	92.80	29.98	24.32
15	Trace	6.58	0.69	Trace	Trace	15940.5	364.20	18.34	23.59
16	Trace	68.11	9.53	0.23	Trace	21189.5	335.95	98.97	33.92
17	Trace	9.13	9.50	0.47	Trace	18021.0	282.30	48.81	33.68
18	Trace	77.33	15.60	0.84	Trace	13932.5	328.75	101.27	28.26
19	Trace	64.21	19.20	1.21	Trace	17888.0	171.10	86.25	36.14
20	Trace	85.99	6.20	2.07	Trace	14793.5	171.25	75.54	22.85
21	Trace	39.44	6.98	2.81	Trace	13423.5	251.70	35.30	37.37
22	Trace	39.11	14.40	2.56	Trace	13476.5	233.95	45.65	28.02
23	Trace	70.11	14.74	2.81	Trace	14194.0	178.10	72.59	31.95
24	Trace	57.34	9.77	3.30	Trace	14933.5	116.95	60.38	38.11
25	Trace	51.18	20.12	3.55	Trace	20313.0	219.9	80.21	37.61
26	Trace	40.83	5.01	3.79	Trace	12327.5	287.30	39.61	32.94
Range	Trace	6.58-91.14	Trace -20.12	Trace -6.32	Trace	12327.5-47112.5	92.80-1111.15	18.34-101.27	18.42-38.11
Mean	-	40.13	7.07	2.06	-	18773.94	397.72	49.23	29.59

Table 3: A comparison of different metal concentration (μg g^{-1}) in sediment of Tongi *khal* with reference values and those in some other rivers in Bangladesh

Metals	*Reference values*			*Other Bangladeshi rivers*							*Present study*
	ASV[a]	*CCA*[b]	*TRV*[c]	*Turag*[d]	*Padma*[e]	*Jamuna*[e]	*Burigonga*[f]	*Meghna*[c]	*Brahmaputra*[g]	*Karatoa*[h]	
Fe	47200	56300	nm	41706	38000	42200	nm	46500	29000	nm	18773.94
Zn	95	70	110	111	71	83	835.5	110	78.26	82.3	397.72
Cu	45	55	16	49.40	23	28	231.5	32	nm	20.5	49.23
Pb	20	12.5	31	24.30	15	19	476.5	22	9.61	69.5	29.59
Cd	0.30	0.20	0.60	nm	nm	nm	5.30	nm	0.47	10.85	Trace

Note: [a]ASV - Average Shale Value; [b]CCA - Continental Crustal Average; [c]TRV - Toxicity Reference Value
[a]Turkian and Wedepohl (1961); [b]Taylor (1964); [c]US EPA (1999); [d]Zakir et al. (2006); [e]Datta and Subramanian (1998); [f]Mohiuddin et al. (2011); [g]Ramesh et al. (2000); [h]Zakir et al. (2013); nm = not measured.

Reasons behind such higher concentration of these metals are: discharge of untreated wastewater/effluents, dispose of different noxious substances and sewerages of different factories and residential areas which are very common into the canal. This is the general scenario of the study area as both sides of the canal have hundreds of industries, markets and residential units. On the other hand, the present study also revealed that for most cases the average Fe concentration in sediments collected from different areas of Tongi canal were smaller compared with all other Bangladeshi rivers and geochemical background values (Table 3). According to Hossain et al. (2009), total Fe contents in some benchmark soil of the Ganges river floodplain of Bangladesh ranged from 3.06 to 9.09% and no definite sequence in the distribution of Fe with depth was noticeable probably due to young nature of these alluvial soils.

It is well recognized that metals associated with the carbonate bound fraction may be weakly sorbed to other non-carbonate phases. But it is clear that metals recovered within this fraction, whether truly associated with carbonates or not, are not strongly bound to the sediment solids, and can be released to the sediment pore water in acidic conditions (pH < 5), which may endanger to the aquatic flora and fauna. Mean concentrations of Cu, Zn and Pb into this fraction were 7.07, 40.13 and 2.06 µg g^{-1}, respectively (Table 2), which can easily be released to the sediment pore water in acidic conditions and may deteriorate the surrounding aquatic environment. But Cd concentrations in both the total and carbonate bound fractions were in trace amount in all the sediment samples of Tongi canal. It can be inferred from the results that there was no anthropogenic pollution load due to Cd in sediments of Tongi canal (Table 2). Although sediments of several other rivers of Bangladesh had Cd greater than the geochemical background values (Table 3).

Assessment of Sediment Pollution Level

Index of Geoaccumulation (I_{geo})

The geoaccumulation index, I_{geo} introduced by Muller (1969) was used to assess metals pollution in sediments of Tongi canal, Bangladesh. In the present study the I_{geo} index values are calculated for different elements with respect to standard shale composition as mentioned by Turekian and Wedepohl (1961). The calculated I_{geo} for metals of sediments collected from different areas of Tongi canal, and their corresponding contamination intensity are illustrated in Figure 2. While considering the I_{geo} the values for Zn at 22 sites of Tongi canal, among those seven sites correspond to I_{geo} class 3 ($2.0 < I_{geo} < 3.0$), indicating moderately to strongly polluted sediment quality and all of those sites are situated at the upstream of the canal. Similarly, five sites exhibited I_{geo} class 2 ($1.0 < I_{geo} < 2.0$), indicating moderately polluted sediment quality and all of those sites are situated at the midstream of the canal. It is also evident from Figure 2 that the rest ten sites correspond to I_{geo} class 1 ($0 < I_{geo} < 1.0$), indicating unpolluted to moderately polluted sediment quality and most of those sites are situated at the downstream of the canal. This indicates that upstream industrial and municipal wastewater/effluents and sewerages discharges along the canal bank are major sources of Zn pollution. In case of Pb, 50% of the sample sites of Tongi canal exhibited I_{geo} class 1 ($0.011 < I_{geo} < 0.343$), indicating unpolluted/moderately polluted sediment quality. On the other hand, only seven sites of Tongi canal exhibited positive values (0.104 to 0.582) for Cu, which also exhibited I_{geo} class 1, indicating unpolluted/moderately polluted sediment quality. But all the sample sites of Tongi canal exhibited negative values for Fe indicating unpolluted sediment quality. In case of Turag river sediment quality, a similar observation was reported by Zakir et al. (2006) for Zn, Cu and Pb.

Enrichment Factor (EFc)

To evaluate the magnitude of contaminants in the environment, the enrichment factors were computed relative to the abundance of metal species in source material to that found in the Earth's crust (Huheey, 1983; Loska et al., 1997; Atgin et al., 2000). If the EFc value of an element is greater than unity, this indicates that the metal is more abundant in the sample relative to that found in the Earth's crust. Although EFc value <5 may not be considered significant, they are indicative of metal accumulation, because such small enrichments may arise from differences in the composition of local sample material with respect to the reference Earth's crust ratio values used in the EFc calculations (Atgin et al., 2000). If the EFc values are >5, samples are considered contaminated. Figure 3 represents the EFc values of all the heavy metals measured in the sediment samples collected from Tongi canal. It is evident from Figure 3 that all the sampling sites had EFc values >5.0 for Zn and the range of EFc values was 5.79 to 47.73, indicating more anthropogenic pollution load for Zn. Similarly, 23 sites had EFc values >5.0 for Pb. On the other hand, in case of Cu, only three locations had EFc values >5.0 (Figure 3). It is presumed that

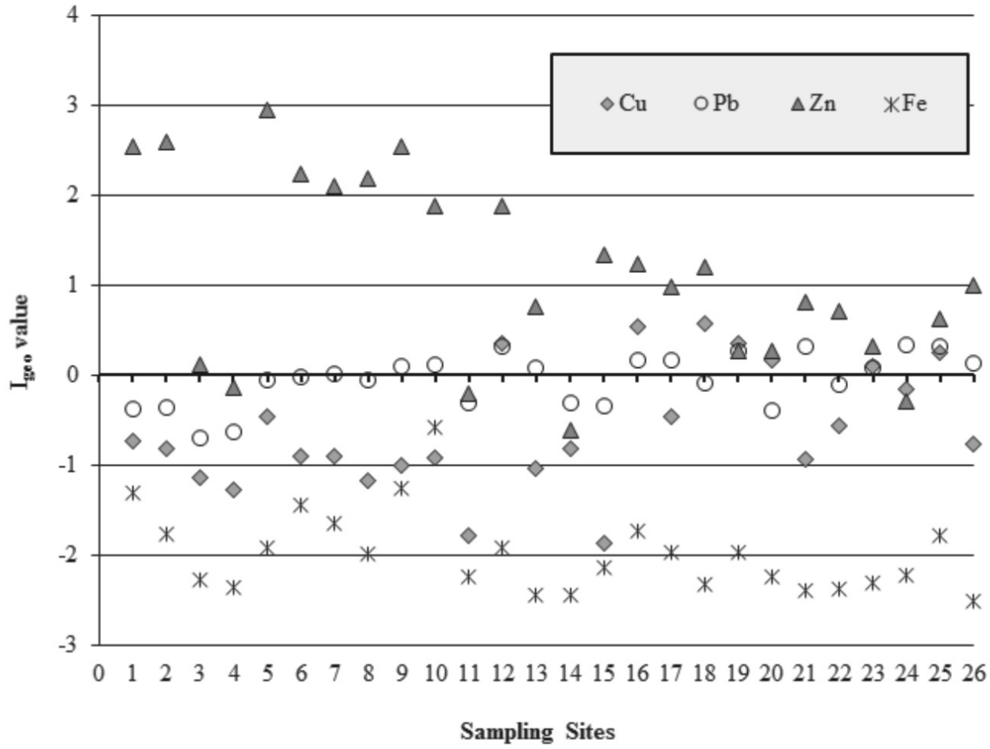

Figure 2: Geoaccumulation index of metals in sediment samples collected from different sites of Tongi canal, Bangladesh.

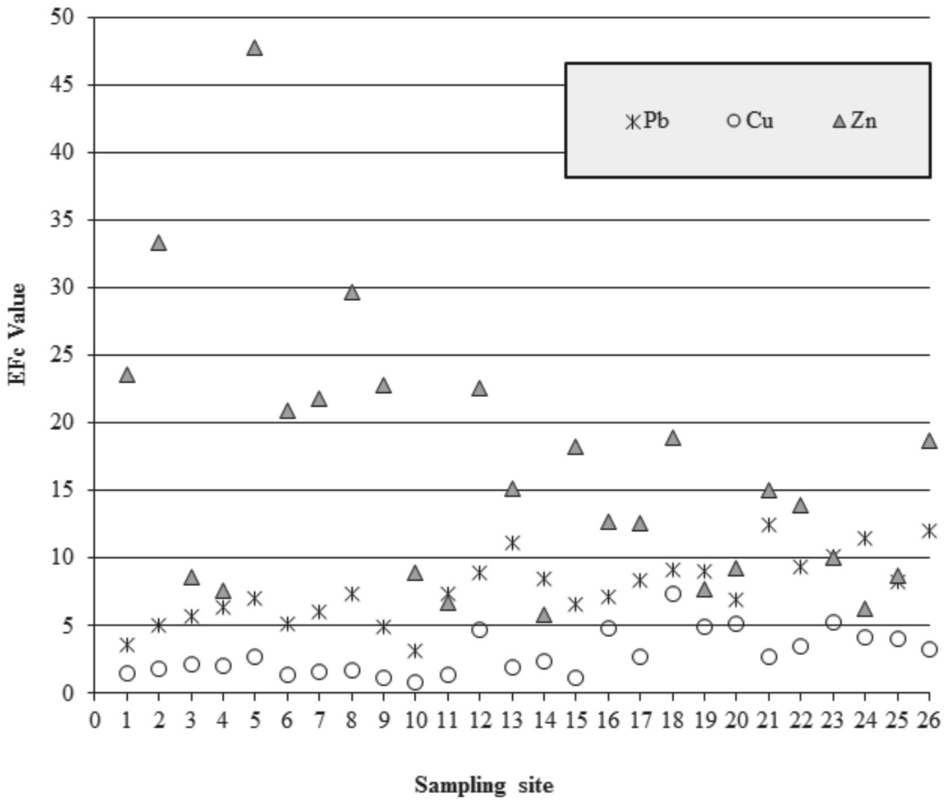

Figure 3: Enrichment factors of metals in sediment samples collected from different sites of Tongi canal, Bangladesh.

high EFc values indicate an anthropogenic source of metals, mainly from activities such as industrialization, urbanization, deposition of industrial wastes and others. Since, the bioavailability and toxicity of any metal in soil and sediments depend upon the chemical form and concentration of the metals (Kwon et al., 2001), it can be inferred that metals in soil and sediment samples with the highest EFc values have a potential for mobility and bioavailability on the aquatic ecosystems.

Risk Assessment Code (RAC)

The code as applied to the present study revealed that 1.5-85.2% (average value 17.76%) of total Zn of the study sites either is adsorbed, exchangeable or carbonate bound and therefore comes under the medium risk category and can easily enter into the food chain (Table 4). Similarly, an average value 10.63% of total Cu of the study sites is bound to the carbonate fraction and therefore comes under the medium risk category. Because of the toxicity and availability of Zn and Cu, it can pose serious problem to the ecosystem and can be remobilized by changes in environmental conditions such as pH, redox potential, salinity and others. On the other hand, only 0-11.5% of total Pb was found in the same fraction with an average value of 2.97% and pose a low risk category indicating lower availability from which Pb cannot be easily leached out for the aquatic environment (Table 4). So, the potential hazard of Zn and Cu are larger than those of Pb which occurred mostly in the inert residual fraction.

Conclusions

Tongi canal locally known as Tongi *khal* flowing between Dhaka and Gazipur districts of Bangladesh is highly susceptible to environmental pollution due to high population density, rapid industrialization and urbanization. The study revealed that the mean concentrations of Cu, Zn and Pb in sediments of Tongi canal were higher compared to geochemical standard and other Bangladeshi rivers. The calculated I_{geo} values for Zn exhibited I_{geo} class 1-3, indicating moderately to strongly polluted sediment quality. In case of Pb and Cu, most sampling sites exhibited I_{geo} class 1, indicating unpolluted/moderately polluted sediment quality. Similarly, the calculated enrichment factors (EFc) for 100 and 88% sampling sites had values >5.0 for Zn and Pb, respectively. It is presumed that high EFc values indicate an anthropogenic source of metals, mainly from activities such as industrialization, urbanization and deposition of industrial wastes. Risk assessment code (RAC) applied to the present study revealed that the mean value 17.76% of total Zn and 10.63% of total Cu of the study sites either is adsorbed, exchangeable or carbonate bound and therefore comes under the medium risk category and can easily enter into the food chain. Finally, the I_{geo}, EFc and RAC calculations of sediment samples revealed the potential hazard of Zn, Pb and Cu at the study sites and these metals in sediment samples have a great potential for mobility and bioavailability on the aquatic ecosystems. So it is desirable that necessary initiative should be taken to minimize the pollution level and monitor their concentrations in water and sediments routinely in future. In this regard, to minimize water and sediments pollution in the canal some recommendations can be drawn as: (i) The government of Bangladesh or municipal authority should compel industrialists to establish effluent treatment plant (ETP) and frequently monitor its operation, (ii) Initiative to implement existing rules and regulations strictly, and (iii) Finally, awareness should be created among the people and industrialists about the pollution problem and their legal as well as social responsibility to prevent it.

Table 4: Average metal percentage in carbonate bound fraction of sediments collected from different sites of Tongi canal and risk assessment code (RAC)

Metal	*Average percentage of metal in up to carbonate bound fraction*		*Level of risk on the basis of RAC*
	Range	*Mean*	
Copper (Cu)	0-31.5	10.63	Medium risk
Zinc (Zn)	1.5-85.2	17.76	Medium risk
Lead (Pb)	0-11.5	2.97	Low risk
Cadmium (Cd)	0	0	No risk

References

Ahmad, J.U. and M.A. Goni (2010). Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. *Environmental Monitoring and Assessment*, **166:** 347-357.

Atgin, R.S., El-Agha, O., Zararsiz, A., Kocatas, A., Parlak, H. and G. Tuncel (2000). Investigation of the sediment pollution in Izmir Bay: Trace elements. *Spectrochimica Acta - Part B*, **55(7):** 1151-1164.

Bakali, B., Md. Younus Mia and H.M. Zakir (2014). Water quality evaluation of tongi area in bangladesh: An impact of industrialization. *Journal of Chemical Biological and Physical Sciences*, **4(2)D:** 1735-1752.

Costa, C.N., Castilhos, D.D., Castilhos, R.M.V., Konrad, E.E., Passianoto, C.C. and C.G. Rodrigues (2001). Tannery sludge effects on soil chemical properties, matter yield and nutrients uptake by soybean. *Revista Brasileira de Agrociencia*, **7(3):** 189-191.

Datta, D.K. and V. Subramanian (1998). Distribution and fractionation of heavy metals in the surface sediments of the Ganges-Brahmaputra-Meghna river system in the Bengal basin. *Environmental Geology*, **36(1-2):** 93-100.

Hossain, M.M., Khan, Z.H. and M.S. Hussain (2009). Nutrient elements in some benchmark soil pedons from the Ganges river floodplain of Bangladesh. *Bangladesh Journal of Scientific and Industrial Research*, **44(3):** 359-366.

Huheey, J.E. (1983). Inorganic Chemistry: Principles of Structure and Reactivity. Harper and Row Publishers, New York.

Khan, A.S. (2012). Augmentation of Buriganga dry season flows. Proceedings of the 15th International River Symposium. Rivers in a Rapidly Urbanizing World, 8-11 October, 2012, Melbourne, Australia.

Kwon, Y.-T., Lee, C.-W. and B-Y. Ahn (2001). Sedimentation pattern and sediments bioavailability in a wastewater discharging area by sequential metal analysis. *Microchemical Journal*, **68:** 135-141.

Loska, K., Cebula, J., Pelczar, J., Wiechula, D. and J. Kwapulinski (1997). Use of enrichment and contamination factors together with geoaccumulation indexes to evaluate the content of Cd, Cu and Ni in the Rybnik water reservoir in Poland. *Water Air and Soil Pollution*, **93:** 347-365.

Manta, D.S., Angelone, M., Bellanca, A., Neri, R. and M. Sprovieri (2002). Heavy metals in urban soils: A case study from the city of Palermo (Sicily), Italy. *Science of the Total Environment*, **300:** 229-243.

Mohiuddin, K.M., Ogawa, Y., Zakir, H.M., Otomo, K. and N. Shikazono (2011). Heavy metal contamination in water and sediments of polluted urban rivers in developing countries. *International Journal of Environmental Science and Technology*, **8(4):** 723-736.

Muller, G. (1969). Index of Geoaccumulation in sediments of the Rhine river. *Geojournal*, **2(3):** 108-118.

Perin, G., Craboledda., L., Lucchese, M., Cirillo, R., Dotta, L. et al. (1985). Heavy Metal Speciation in the Sediments of Northern Adriatic Sea. A New Approach for Environmental Toxicity Determination. *In:* Heavy Metals in the Environment. Lakkas, T.D. (Ed.). CEP Consultants, Edinburg.

Ramesh, R., Ramanathan, AL., Ramesh, S., Purvaja, R. and V. Subramanian (2000). Distribution of rare earth elements and heavy metals in the surficial sediments of the Himalayan river system. *Geochemical Journal*, **34:** 295-319.

Rauret, G., Lopez-Sanchez, J.F., Sahuquillo, A., Rubio, R., Davidson, C., Ure, A. and Ph. Quevauviller (1999). Improvement of the BCR three-step sequential extraction procedure prior to the certification of new sediment and soil reference materials. *Journal of Environmental Monitoring*, **1:** 57-61.

Shikazono, N., Zakir, H.M. and Y. Sudo (2008). Zinc contamination in river water and sediments at Taisyu Zn-Pb mine area, Tsushima Island, Japan. *Journal of Geochemical Exploration*, **98:** 80-88.

Shikazono, N., Tatewaki, K., Mohiuddin, K.M., Nakano, T. and H.M. Zakir (2012). Sources, spatial variation and speciation of heavy metals in sediments of the Tamagawa river in Central Japan. *Environmental Geochemistry and Health*, **34:** 13-26.

Taylor, S.R. (1964). Abundance of chemical elements in the continental crust: A new table. *Geaochimica et Cosmochimica Acta,* **28:** 1273-1285.

Turekian, K.K. and K.H. Wedepohl (1961). Distribution of the elements in some major units of the earth's crust. *Geological Society of America Bulletin*, **72:** 175-192.

US EPA (U.S. Environmental Protection Agency) (1999). Screening level ecological risk assessment protocol for hazardous waste combustion facilities. Vol. 3, Appendix E: Toxicity Reference Values, EPA530-D99-001C.

Varol, M. and B. Sen (2012). Assessment of nutrient and heavy metal contamination in surface water and sediments of the upper Tigris River, Turkey. *Catena*, **92:** 1-10.

Walkley, A. and I.A. Black (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* **38:** 29-37.

Wang, X.S. and Y. Qin (2006). Spatial distribution of metals in urban topsoils of Xuzhou (China): Controlling factors and environmental implications. *Environmental Geology*, **49:** 905-914.

Zakir, H.M. and N. Shikazono (2008). Metal fractionation in sediments: A comparative assessment of four sequential extraction schemes. *Journal of Environmental Science for Sustainable Society*, **2:** 01-12.

Zakir, H.M. and N. Shikazono (2011). Environmental mobility and geochemical partitioning of Fe, Mn, Co, Ni and Mo in sediments of an urban river. *Journal of Environmetal Chemistry and Ecotoxicology*, **3(5):** 116-126.

Zakir, H.M., Moshfiqur Rahman, M., Rahman, A., Ahmed, I. and M.A. Hossain (2012). Heavy metals and major ionic pollution assessment in waters of midstream of the river Karatoa in Bangladesh. *Journal of Environmental Science and Natural Resources*, **5(2):** 149-160.

Zakir, H.M., Nazmul Hasan, M., Quadir, Q.F., Sharmin, S. and Istiaq Ahmed (2013). Cadmium and lead pollution in sediments of midstream of the river Karatoa in Bangladesh. *International Journal of Engineering Sciences*, **2(2):** 34-42.

Zakir, H.M., Sattar, M.A. and Q.F. Quadir (2015). Cadmium pollution and irrigation water quality assessment of an urban river: A case study of the Mayur river, Khulna, Bangladesh. *Journal of Chemical Biological and Physical Sciences*, **5(2)D:** 2133-2149.

Zakir, H.M., Nahid Sultana and Mousumi Akter (2014). Heavy metal contamination in roadside soils and grasses: A case study from Dhaka city, Bangladesh. *Journal of Chemical Biological and Physical Sciences*, **4(2)D:** 1661-1673.

Zakir, H.M., Sharmin, S. and N. Shikazono (2006). Heavy metal pollution assessment in water and sediments of Turag River at Tongi area in Bangladesh. *International Journal of Lakes and Rivers*, **1(1):** 85-96.