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Status of heavy metal in sediments of the Turag river in Bangladesh

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Abstract

The experiment was conducted to appraise the level of Cr, Pb, Cd, Ni, Zn, Cu, Fe and Mn contamination in 15 sediment samples of upstream of Turag river, at the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh. The concentrations of Cr, Pb, Cd, Ni, Zn, Cu, Fe and Mn were 178.0, 18.3, 0.8, 155.4, 194.1, 54.8, 13679 and 5501.6 µg g^{-1} and the pH and EC ranged from 2.01-7.85 and 391-3910µS cm^{-1}, respectively. Heavy metal concentrations were compared with geochemical background and standard values of previous report on the Turag and other rivers in Bangladesh. The average concentrations of Cr, Zn and Ni in sediments of the Turag are almost twice of the geochemical background *i.e.* average worldwide shale standard and continental upper crust. Cadmium is about three times higher than the geochemical background values. Chromium and Ni concentration exceeded the severe effect level (SEL), where as Cd, Zn and Cu exceeded toxicity reference values (TRV). The average Enrichment Factors (EFc) for Mn, Cd, Cr and Ni reflected moderate to extremely contaminated pollution. The pollution load index (PLI) varied from 1.65 to 3.21. The geoaccumulation index (I_{geo}) for Mn of 11 locations and Cd for a single location were greater than 2.0, and exhibited moderately to strongly polluted sediment quality. The I_{geo} for Zn in two locations and Ni in one location were greater than 1.0, indicated moderately polluted sediment quality. Sediment pollution load signaled alarming condition for city dwellers and aquatic ecosystem of the Turag river. Pollution sources to be sealed immediately and continuous monitoring on pollution prevention and cleanup operation is suggested.

Key words: Heavy metal, sediments, pollution load, Turag river

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Introduction

Heavy metal pollution of aquatic system is growing at an alarming rate worldwide due to anthropogenic activity (Malik *et al.,* 2010). Metals like Cr, Pb, Cd, As *etc.* exhibit extreme toxicity even at trace levels. Rivers are a dominant pathway for metals transport (Miller *et al.,* 2003) and become significant pollutants of many riverine systems (Dassenakis *et al.,* 1998). Industrial growth has led to increase the deposition of toxic materials into the air, water and soil. The problems occur in specific locations and regions but they are in fact global problems in their frequency, magnitude, and potential effects. The major pollution sources of Turag river water are various industries (soap and detergent), garments, pharmaceuticals, dyeing, aluminum, carbide, match and ink manufacturing, textile, paint, paper pulp and iron bar factories, frozen food and steel workshop *etc.* (Rahman *et al.,* 2012).

Turag river is the upper tributary of the Buriganga, a major river in Bangladesh. The river originates from the Bangshi river, the latter is an important tributary of the Dhaleshwari river, flows through Gazipur and joins the Buriganga at Mirpur and the Tongi Khal links the Turag with the Balu river. Both organic and inorganic waste effluents that are discharged into the Turag river which adversely interacting with the river system and deteriorating the water quality. The river water is pitch-black with the foul smell and cannot be used for any purpose. For this reason, water causes the adverse effect of surrounding land and aquatic ecosystem as well as subsequent impact on the livelihood of the local community (Meghla *et al.,* 2013; Rahman *et al.,* 2012). Chromium, Cu, Zn belongs to moderately to highly polluted, Pb and Cd belongs to not polluted for Turag river (Banu *et al.,* 2013).The study was carried out to determine the levels of some heavy metals Cr, Pb, Cd, Ni, Zn, Cu, Fe and Mn in Turag river sediments.

Materials and Methods

Sampling

Surface sediment samples were collected and processed from 15 sites (Table 1 and Figure 1) of the upstream of the Turag river in January 2014 following standard protocol (US EPA, 2001). The sample mass collected in each case was about 500 g. Sub-samples of the material were oven dried at 45^{o}C for 48 hrs and homogenized by grounding and sieving and stored carefully for subsequent chemical analyses.

Table 1. Name of the locations of different sampling sites of theTurag river

Sample No.	*Location*
1	Tongi Bazar Boat Mooring
2	Tongi Highway Bridge
3	Sluice Gate Area
4	Kamar Para Bridge
5	Noyanichala Bailey Bridge
6	AsuliaAnnotex Group
7	Rustampur
8	Asulia Highway Bridge
9	Water Dev Board Office
10	Uttara Sector 16
11	Mirpur Road
12	Sinnirtak
13	Golartak
14	Gabtoli
15	Aminbazar

Analysis of sediment samples

The pH of sediments was measured in 1:2.5 sediment to water ratio. The EC was measured in saturation extract of sediments using EC meter. For the determination of total heavy metals, the extraction was carried out in Teflon containers provided with screw stoppers, using strong acid mixtures, as described by Baker and Amacher (1982). Brief description of this method was as follows: 1 g sediment sample was transferred to a Teflon beaker and 15mL of distilled water and 2mL of concentrated HNO_3 were added and allowed to dryness. This was followed by the addition of three drops of concentrated H_2SO_4 and 10mL of HF. The sample was then placed on a sand bath while the temperature slowly rose to 200°C and was allowed to evaporate to dryness. This was followed by the addition of 15mL conc. HNO_3, 2mL H_2SO_4 and 3mL $HClO_4$. Heating was continued until strong fumes of SO_3 were produced. The Teflon beaker was cooled and the solution was transferred to a 50mL volumetric flask by adding distilled water. Concentrations of Cr, Pb, Cd, Ni, Zn, Cu, Fe and Mn in the extract were determined by Shimadzu Atomic Absorption Spectrophotometer (AA7000).

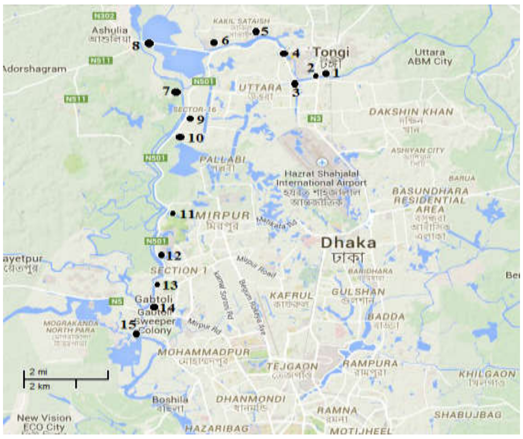

Figure 1. Location of different sampling sites of the Turag River, Dhaka, Bangladesh

Enrichment factors (EFc)

Enrichment factors (EF_c) is considered as an effective tool to evaluate the magnitude of contaminants in the environment (Franco-Uria *et* *al.,* 2009). The following equation was used to calculate the EFc:

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

Where, $(C_M/C_{Fe})_{sample}$ is the ratio of concentration of heavy metal (C_M) to that of iron (C_{Fe}) in the sediment sample, and $(C_M/C_{Fe})_{Earth's\ crust}$ is the same reference ratio in the Earth's crust. Average shale values taken from Turekian and Wedepohl (1961).

Pollution load index (PLI)

The pollution load index (PLI) proposed by Tomlinson *et al*., (1980) provides the idea about the quantity of a component in the environment. The PLI of a single site is the *n*th root of *n* number of multiplied together contamination factor (CF) values. The CF is the ratio obtained by dividing the concentration of each metal in the sediment by the baseline or background value.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdots \times CF_n)^{1/n}$$

Site indices can be treated in exactly the same way to give a zone or area index. Therefore, PLI for a zone is the *n*th root of *n* number of multiplied together PLI values. A PLI value of zero indicates perfection, a value of one indicates the presence of only baseline levels of pollutants, and values above one would indicate progressive deterioration of the site and estuarine quality (Tomlinson *et al*., 1980).

Index of geoaccumulation (I_{geo})

The geoaccumulation index (I_{geo}) values were calculated after Muller (1969), which is

$$I_{geo} = \log_2 [Cn/(1{:}5 \times Bn)]$$

Where, C_n is the measured concentration of element n in the sediment and B_n is the geochemical background for the element n 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). Based on EF and I_{geo}, sediments can be categorized into seven classes (Table 2) (Legorburu *et al.* 2013).

Table 2. Classification of sediments on the basis of EF and I_{geo} (Legorburu, 2013)

Class	I_{geo}	*EF*	*Pollution Level*
0	<0	<1.5	Unpolluted
1	0~1	1.5~3	Unpolluted to moderately polluted
2	1~2	3~6	Moderately polluted
3	2~3	6~12	Moderately to strongly polluted
4	3~4	12~24	Strongly polluted
5	4~5	24~48	Strongly to extremely polluted
6	>5	>48	Extremely polluted

Results and Discussion

Physicochemical properties of sediments of the Turag river in Bangladesh

The pH of sediment ranged from 2.01 to 7.85 (Table 3). The maximum pH 7.85 was recorded in sediment of Kamar Para Bridge (sample no. 04). The lowest pH value was observed 2.01 at Aminbazar (sample no. 15). Various wastes, effluents, chemicals, salts etc. discharged from different industries might be responsible for such pH variation. Sediment pH has been identified as the key factor governing the concentration of soluble metals, which tends to increase at lower pH and decrease at higher pH (Wang and Qin, 2006). The EC of sediments ranged from 391 to 3910 µS cm^{-1} (Table 3). The highest EC 3910 µS cm^{-1} was obtained in sediments collected at Amin bazar (sample no. 15) and lower at Uttara Sector 16 (sample no. 10). High EC in sediment, might be due to huge quantities of salt, solid wastes and effluents of tannery and other industries. In general, EC of sediments varied markedly with sediment salinity. The high salt affected soils of contaminated sites account for the higher EC. The low EC of uncontaminated sediment is related to comparatively low salinity hazards (Costa *et al.* 2001).

Table 3. pH and EC of sediment samples of different sites of the Turag river

Sample No.	pH	EC (µS cm^{-1})
1	7.57	394
2	6.98	397
3	7.15	356
4	7.85	485
5	7.18	666
6	7.60	684
7	2.55	1509
8	6.24	661
9	6.92	529
10	6.70	391
11	3.21	692
12	2.87	858
13	5.18	520
14	2.50	1446
15	2.01	3910
Range	2.01-7.85	391-3910
Mean	5.50	899.87

Concentrations of heavy metals in sediments

Metal concentrations in river bed sediments are shown in Table 4. The concentration of Cr ranged from 109.1 to 231.7µg g^{-1} with a mean value of 178µg g^{-1}. Maximum concentration of Cr was found in sample No. 15 at Amin bazar. Chromium concentration is high in other sites of the Turag river. Chromium compounds are used as pigments, mordents and dyes in the textiles and as the tanning agent in leather. Anthropogenic sources of emission of Cr in the surface waters are from municipal wastes, laundry chemicals, paints, leather, road run off due to tire wear, brake wires, radiators (Dixit and Tiwari, 2008). The status of Pb in sediments ranged from 13.1 to 24.6µg g^{-1}, having an average value of 18.3µg g^{-1}. The permissible limit for Pb according to Dutch Standards is 85µg g^{-1}. The maximum acceptable concentration of Pd is 50µg g^{-1} for crop production (Kabata and Pendias, 1992) but the status of Cd in present study ranged from 0.2 to 3.6µg g^{-1}, having an average value of 0.8µg g^{-1}. The highest Cd was found at sample no. 14 and lowest at sample no. 15. The concentration of Cd in the Turag River water was ranged from 0.09 to 0.13 and 0.15 to 0.20µg g^{-1} during post-monsoon and pre-monsoon season (Meghla *et al.,* 2013). The sediment concentration of Ni was found in the range of 108-221.6µg g^{-1}, with a mean value of 155.4µg g^{-1}. The highest sediment concentration of Ni was found at sample no. 7 and the lowest was found at sample no. 13.

The concentration of Cu in sediments ranged from 30.6 to 72.3µg g^{-1}, having an average of 54.8µg g^{-1}. All the 15 sediment samples, had less than the maximum acceptable concentration (100µg g^{-1}) for crop production (Kabata and Pendias, 1992). But the results of the present study showed that maximum samples were higher than those obtained in the earlier study of Domingo and Kyuma (1983) who reported that the Cu status of selected Bangladesh paddy soils ranged from 6.0 to 48.0µg g^{-1}. A study conducted by Zakir *et al.* (2006) reported that the concentration of Cu ranged from 31.9 to 69.1µg g^{-1} with the mean value of 51.8 µg g^{-1} in the Turag river sediment and is at par with the present study. The total concentration of Zn in sediments ranged from 119.4 to 548.9µg g^{-1}, having an average value of 194.1µg g^{-1}. Iron comes into water from natural geological sources, industrial wastes, domestic discharge and also from by-products. The concentration of Fe in sediments ranged from 10413 to 14455µg g^{-1}, having an average value of 13679µg g^{-1} is not at par with that of Zakir *et al.* (2006) where the sediments contained Fe from 38204 to 47505µg g^{-1} with a mean value of 43246µg g^{-1}. The concentration of Mn in sediments samples ranged from 2512 to 7964µg g^{-1}, with a mean value of 5501.6µg g^{-1}. Out of 15 samples 08 samples exceed the mean value. Maximum Mn concentration was found in sample no. 01 which was located at Tongi bazar boat mooring. The Mn concentration is also very high in other sites of the Turag river.

Comparative analysis with geochemical background and standard values, previous report on the Turag river and other rivers in Bangladesh

The available data for a comparative analysis with geochemical background and standard values, previous report on the Turag river and Other rivers in Bangladesh, along with average values obtained

Table 4. Concentration of heavy metals in sediment samples of the Turag river

Sample No.	Heavy metal concentration (µg g^{-1})							
	Cr	Pb	Cd	Ni	Zn	Cu	Fe	Mn
1	156.7	16.2	0.8	129.5	119.4	70.3	14455	7964
2	109.1	13.1	0.7	127.0	216.1	36.2	10413	2512
3	166.9	14.7	0.8	142.0	332.4	72.3	14179	4813
4	177.1	13.6	0.6	153.4	140.7	55.9	13997	5383
5	181.2	13.1	0.3	181.8	140.4	57.5	14091	5808
6	181.1	17.3	0.5	113.6	158.4	59.3	14242	5973
7	187.6	14.7	0.7	221.6	149.5	57.8	14204	6458
8	168.1	18.3	0.7	153.4	137.4	47.0	13987	6258
9	190.8	18.8	0.7	193.2	147.7	61.7	14265	6533
10	175.9	20.9	0.5	130.7	129.0	50.2	14073	6098
11	180.5	20.4	0.6	119.3	142.0	59.7	13502	4238
12	195.4	20.9	0.9	181.8	191.0	60.4	14157	6918
13	175.3	24.6	0.3	108.0	548.9	30.6	12184	2972
14	192.1	23.5	3.6	181.8	178.7	41.5	13500	5128
15	231.7	24.6	0.2	193.2	180.5	62.2	13942	5468
Mean	178.0	18.3	0.8	155.4	194.1	54.8	13679	5501.6
Range	109.1-231.7	13.1-24.6	0.2-3.6	108-221.6	119.4-548.9	30.6-72.3	10413-14455	2512-7964

for trace metals of the Turag river sediments are summarized in Table 5. It is evident that the average concentration of Cr, Cd, Zn, Cu and Ni in sediments of the Turag river exceeded the geochemical background *i.e.* average worldwide shale standard and upper continental crust value, but the average concentration of Pb is very close to the geochemical standard values as well as upper continental crust value. The mean concentrations of Cr and Ni in sediments of the Turag river were higher than those of the other river sediments like Buriganga, Padma and Korotoa river.

Assessments pollution in sediments

Enrichment factors (EFc)

The high EFc values indicate an anthropogenic source of trace metals, mainly from activities such as industrialization, urbanization, deposition of industrial wastes and others. Since, the bioavailability and toxicity of any trace metals in sediments depend upon the chemical form and concentration of the metals (Kwon *et al*., 2001). Figure 2 represents the EFc values of all the toxic metals measured in the sediment of the river Turag. It is evident from the Figure 2 that all the sampling site had EFc values > 12 for Mn indicating strongly polluted. Whereas at least half of the sampling sites had EFc values > 6.0 for Cr, Cd and Ni indicating moderately to extremely polluted. Most of the sample of Zinc and Cu also lies between moderately polluted (Figure 2). On the other hand, Pb in all the 15 locations 9 exhibit as unpolluted to moderately polluted (1.5-3.0) and 6 exhibit as moderately polluted (Figure 2). The average EFc for Zn, Mn Cu Cd and Ni reflects extremely polluted pollution level which implies that these metals originated from point source of pollution and very severely enriched in river sediments.

Pollution load index (PLI)

The pollution load index (PLI) values of sediments of the studied region varied from site to site which ranged from 1.65-3.21 (Figure 3). Figure 3 reflects the highest PLI values at Gabtoli area of the Turag River. Second PLI value was found at Sinnirtak. The area load is also higher (ALI 2.48). Chromium, Cd, Pb, Zn, and Cu were the major pollutants contributing towards the higher PLI for the Turag river. The PLI values for summer and winter samples of the Burigaga river ranged from 4.9-24.2 and 5.2-27.4, respectively (Mohiuddin *et al.*,2011).

Table 5. Comparison of heavy metal concentrations (μg g^{-1}) in the Turag River sediments with different standard values and Bangladeshi Rivers

Heavy metals	This study (average)	Geochemical background and Standard values				Report on Other Bangladeshi Rivers			
		ASV[a]	CUC[b]	TRV[c]	SEL[d]	Buriganga[e]	Turag[f]	Padma[g]	Korotoa[g]
Cr	178.0	90	92	26	110	173.4	97	97	109
Pb	18.3	20	17	31	250	31.4	24	17	58
Cd	0.8	0.30	0.09	0.60	10	1.5	-	-	1.2
Zn	194.1	95	67	110	820	481.8	111	76	-
Cu	54.8	45	28	16	110	344.2	49	25	76
Ni	155.4	68	47	16	75	153.3	42	28	95

ASV= Average Shale value; CUC=Continental upper crust; TRV= Toxicity reference value; SEL= Severe effect level. [a]Turekian and Wedepohl (1961), [b]Rudnick and Gao (2003), [c]US EPA (1999), [d]Persuad*et al*., (1993) [e]Mohiuddin*et al.* (2015), [f]Zakir*et al.,* (2006) and [g]Datta and Subramanian (1998).

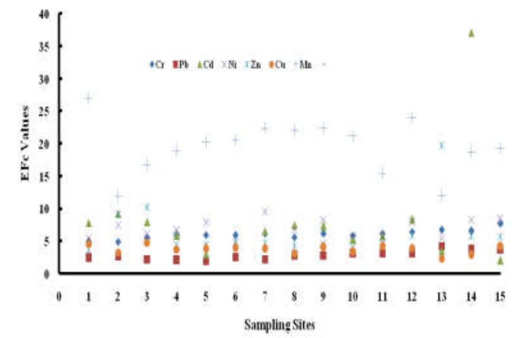

Fig. 2: Enrichment Factor (EFc) values of different sampling sites of the Turag River

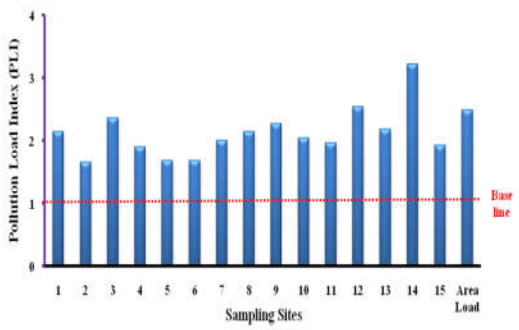

Fig. 3: Pollution Load Index (PLI) values of different sampling sites of the Turag River

Index of geoaccumulation (I_{geo})

The geoaccumulation index, I_{geo} introduced by Muller (1969) was used to assess toxic metals pollution in sediments of the Turag river. The geoaccumuation index, includes seven grades (Table 2). The calculated I_{geo} for toxic metals of sediments collected from different areas of the Turag river, and their corresponding contamination intensity are illustrated in Figure 4. While considering the I_{geo} the values for Pb and Cu river exhibited negative values (I_{geo}<0) in most sampling locations, that means I_{geo} class: 0, indicating unpolluted sediment quality. On the other hand, the I_{geo} values for Cr (14 location out of 15) Ni for all locations and Cd (12 location out of 15) were positive but the (I_{geo}>0), which also exhibited I_{geo} class: 1, indicating Unpolluted to moderately polluted sediment quality (Fig. 4). The geoaccumuation index values for Mn of 11locations were >2.0, and the (I_{geo}>2) which also exhibited I_{geo} class: 3, indicating moderately to strongly polluted sediment quality (Figure 4).

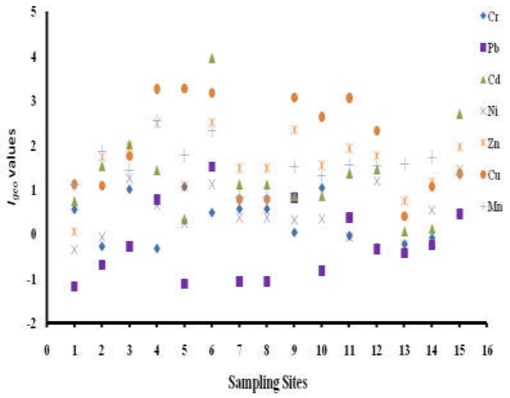

Fig. 4: Geoaccumulation Index (I_{geo}) values of different sampling sites of Turag River

Conclusion

All the sampling sites of the Turag river had EFc values > 12 for Mn and at least half of the sampling sites had EFc values > 6.0 for Cr, Cd and Ni indicating moderately to extremely polluted. Zinc and Cu also lies between moderately polluted. The average EFc value implies that heavy metals in the Turag river sediments is severely enriched and mostly originated from the point source of pollution. The PLI values of all the sediment samples of the studied region also exceed the base line. Chromium, Cd, Pb, Zn, and Cu were the major pollutants contributing towards the higher PLI for the Turag river. It is therefore recommended that the industrial establishments should follow establish efficient waste treatment and disposal system.

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