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Pollution and ecological risk assessment for the environmentally impacted Turag River, Bangladesh

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Abstract
The water quality parameters such as temperature, pH, salinity, conductivity, EC, TDS, TSS, DO, COD, BOD and *E. coli* were observed in the surface water and Cr, Cu, Zn, Pb, Ni, Cd, Mn, Hg, Fe and As were observed for surface water and sediment in dry and wet seasons for the Turag River. The mean value of observed parameters for surface water shows that the Turag River is highly polluted by pH (8.85), EC (1117.17 µS), DO (0.98 mg/L), COD (288.33 mg/L), BOD (157.67 mg/L), *E. coli* (<18000 cfu/100 mL), Cr (0.056 mg/L), Pb (0.015 mg/L) Mn, (0.7 mg/L) and Zn (0.30 mg/L) and for surface sediment is highly polluted by Cr (127.1 mg/kg), Cu (223.9 mg/kg), Zn (1419.4 mg/kg), Pb (26.3 mg/kg), Ni (35.3 mg/kg), Hg (624.6 mg/kg), Fe (12721.34 mg/kg) and Mn (313.3 mg/kg). Geoaccumulation status shows that surface sediment is strongly to extremely polluted by Zn.

Keywords: Ecological risk factor; geoaccumulation; heavy metal; physicochemical parameters; pollution; sediment.

1. Introduction
The strategy taken for waste water management in Bangladesh has completely failed against industrial development. In recent years, therefore, adverse affect exerts on the environment and thereby, on human life. Bangladesh is a developing country. By the few couple of decades, there is a revolution occurred in textile and garments sectors in Bangladesh. But the revolution did not occur for the protection of environment. Most of the textile industries in Bangladesh are operated along on the bank of the River due to the easy accessibility of water and easy waste disposal processes. The waste contains different types of organic and inorganic contaminants such as dye, acid, alkali, heavy metals etc. which are hazardous for fish, aquatic weed, aquatic biota, and thereby, destroy the water ecosystem. This is a menacing challenge in Bangladesh as well as in the most industrially developing countries.

The Turag River is an important River flowing through the northern side of Dhaka city and itemizes Gazipur District from Dhaka. Rapid industrial growth occurred in the bank city, Tongi, of the Turag River and disposes their waste into the Turag River. Therefore, day by day Turag River is enriched by different heavy metals and water polluting organic and inorganic agents. Therefore, accumulation of heavy metals, organic and inorganic pollutants were intensified in this area. Due to their toxicity, bioaccumulation, high tendency of persistence, biomagnifications through food chain, heavy metals expose itself a potential threat to ecosystem and on human health and drew the attention of environmentalist [1-2]. River pollution has a menacing relationship with water cycle. The polluted water transported into the wreath of clouds, spread in the whole environment through rain fall and therefore, enters into the food chain. Beside this, heavy metals can enter into the food chain by irrigation. Accumulation of heavy metals occurred onto the soil and sediment by the mechanism of immobilization nature of heavy metals. This is occurred due to the adsorption on soil or sediment by coagulation, ion exchange with dissolved and suspended species in water, incorporate into the mineral lattice structure and precipitation due to the formation of insoluble species [3-5].

Dhaka water supply and sewerage authority (DWASA) supplies the water of Shitallakhya River for city dwellers as a source of drinking water. At downstream, the Turag River is incurred to the Shitallakhya River and

flown together. Recently, DWASA, divulges that they faced huge problems for the supply water treatment process due to pollution. Beside this the Turag River water is used for the cultivation. As a result, accumulation of heavy metals also occurs in agricultural products. For consuming these agricultural products, several health problems have been observed in recent couple of decades. These health problems are nausea, skin sore, irritation in respiratory tract, typhoid, dysentery, cholera, viral hepatitis, nervous disorder, abdominal pain, ulcer, kidney and liver damage [6-7]. Different anthropogenic and natural effects such as industrial, municipal, water vehicles, land runoff (fertilizer, pesticides) from agriculture field intensified the pollution of the Turag River. Several previous researchers [8;13-15] investigate the pollution status of the Turag River and noticed the high pollution level. Monitoring of physicochemical water quality parameter plays an important role for assessing the water environment, ecosystem, hydrochemistry and ecology [9]. The objectives of this study are to observe the physicochemical parameters of water and concentration of heavy metals in surface water and sediments and thereafter, assessing the ecological risk for the coexistence of heavy metals as well as geoaccumulation index.

2. Experimental

Water and sediment were collected from the Turag River from three preselected points (SP-1 = Tongi nodibondor, SP-2 = Hossin dyeing and SP-3 = Zaber & Zubair fabrics) during Dry (February) and Wet (June) season, 2015 and shown in Figure 1. Water sample was collected from 60 cm deep from surface and sediment samples were collected from undisturbed top 5 cm layer. After collection of sample, DO and pH were observed in the spot. Finally, they were carefully carried to laboratory and preserve in a refrigerator to prevent microbial decomposition of organic and inorganic materials present in the sample water. Before any analysis sample was taken to the normal temperature. Color was observed with eye sight and smell was observed sensually. The salinity, EC, TDS, pH and DO were measured instrumentally, originated by Hanna, Romania. COD was measured by condensation and potassium dichromate oxidation. TSS was measured gravimetrically by filtration, using Whatman filter paper (pore size 0.8 µm, diam. 47 mm) and thereafter dried in oven. BOD was measured by five days incubation. All reagents were purchased from Merck, Germany. Heavy metal concentrations were determined by 'VARIAN-240' and 'VARIAN-220' model atomic absorption spectrometer. *E. coli* was detected and enumerated by Horizontal method with most probable number technique [10].

Soil samples were dried in oven at 70 ^{o}C and then sieved for homogeneity. Finally, 1.0 g of sample was digested using 10 ml of HNO_3 and aliquot portion of water on a hot plate till to dryness. After that 5 ml of $HClO_4$ was added and then digestion was continued. The obtained solution was diluted to 100 ml with double distilled water.

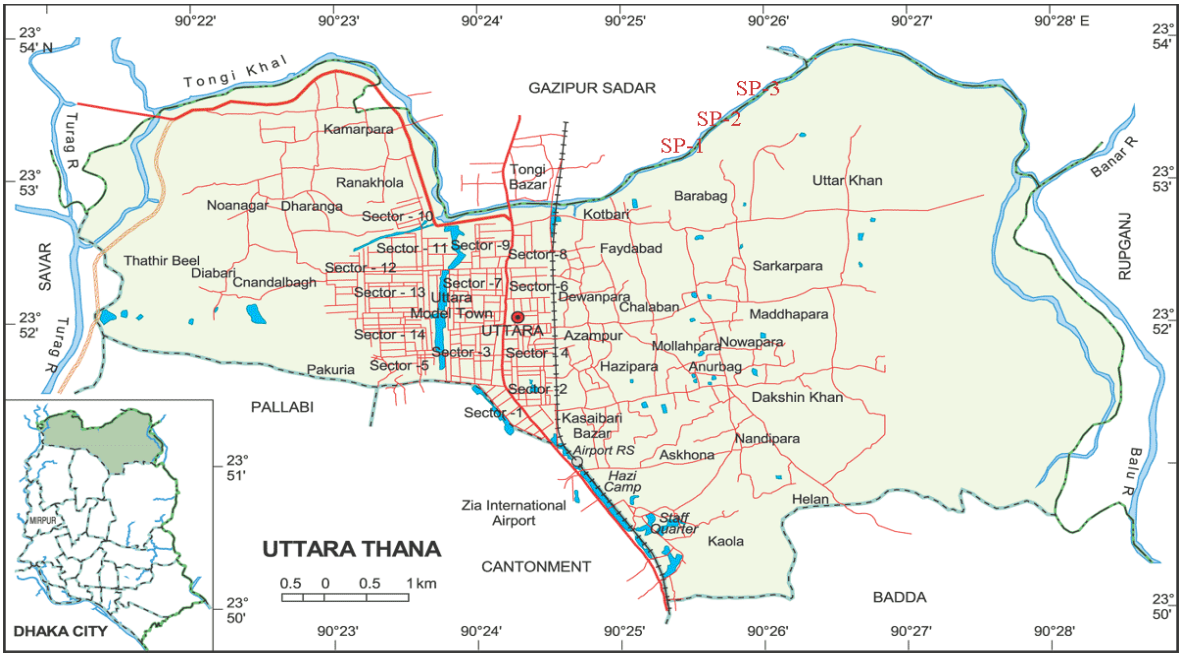

Figure 1: Sampling points of the Turag river.

3. Results and discussion

3.1. *Physicochemical Properties*

During dry season the color of the Turag River water was dark as well as acrid in smell and in wet season that was light dark in color with unpleasant smell. The standard value of physicochemical parameters for inland surface water and irrigable water by DoE [11] is shown in Table 1. The physicochemical parameters detected for the surface water are presented in Table 2. EC, DO, COD and BOD show exceeding limit of standard level according to Department of Environment (DoE), Bangladesh.

Table 1: DoE standard value for the physicochemical parameters.

Parameters	Inland Surface water	Irrigable land
pH	6-9	6-9
Temperature ^{o}C	40	40
Salinity	-	-
TDS (mg/L)	2100	2100
TSS	-	-
EC (µS)	1200	1200
DO (mg/L)	4.5-8	4.5-8
COD (mg/L)	200	400
BOD_5 (mg/L) at 20 ^{o}C	50	100
E. coli	-	-
Cr (mg/L)	0.5	0.1
Cu (mg/L)	0.5	3.0
Zn (mg/L)	5.0	10.0
Pb (mg/L)	0.1	0.1
Ni (mg/L)	1.0	1.0
Cd (mg/L)	0.05	0.5
Hg (mg/L)	0.01	0.01
Fe (mg/L)	2.0	2.0
As (mg/L)	0.2	0.2
Mn (mg/L)	5.0	5.0

Table 2: Physicochemical parameters in the Turag River.

Time	Salpling point	Color	Smell	pH	T (^{o}C)	Salinity (mg/L)	TDS (mg/L)	TSS (mg/L)	EC (µS)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	*E. Coli* (Cfu/100 mL)
Dry (Feb)	SP-1	Dark	Acrid	9.43	27.2	596	872	193.5	1253	0.8	340**	218	<18000
	SP-2	Dark	Acrid	9.45**	27.3	612**	898**	182.6	1350	0.6	320	232**	<18000
	SP-3	Dark	Acrid	9.44	26.9*	603	892	196.8**	1362**	0.6*	338	230	<18000
Wet (Jun)	SP-1	Light Dark	Unpleasant	8.23*	32.7**	436*	687	112.7	1095	1.2	260	96	<18000
	SP-2	Light Dark	Unpleasant	8.30	32.5	502	684*	97.0*	1018	1.4**	240	82*	<18000
	SP-3	Light Dark	Unpleasant	8.25	32.1	487	693	108.4	985*	1.3	232*	88	<18000
Average				8.85	29.78	539.33	787.67	148.5	1177.17	0.98	288.33	157.67	<18000

*Minimum value; **Maximum value

T = Temperature; TDS = Total Dissolve Solid; TSS = Total Suspended Solid; EC = Electrical Conductivity; DO = Dissolve Oxygen; COD = Chemical Oxygen Demand; BOD = Bio-chemical Oxygen Demand; *E. coli* = *Escherichia coli*

DO is an important water quality parameter, therefore, correlate with aquatic life by giving information about bacterial activity, photosynthesis, availability of nutrients, stratification etc. [12]. If DO declines, the water environment does not remain habitable for aquatic biota [9]. In this present study, DO varied from 0.6 to 1.4 mg/L with average value of 0.98 mg/L which is lower than that observed by Rahman et al. and Mobin et al. [8;13] near these points. The DO value declines such an alarming rate due to the industrial waste water load from Tongi industrial area as well as municipal waste load which require higher level of oxygen for chemical oxidation and decomposition. Beside this, SP-1 is a River terminal, therefore, every day a large number of human wastes and untreated oil are thrown into the River which may be potential source of DO decline.

COD refers to the organic content in the water body. Higher COD value indicates the higher organic pollution [9]. The COD level varied in this present study in between 232 to 340 mg/L with average value of 288.3 mg/L which is higher than that observed by Banu et al. and Sikder et al., [14-15]. The higher value of COD is due to the industrial and municipal discharge load. Beside this in dry season, the water flow declines and therefore, the growth of microorganism increases profoundly which is another potential source of higher value of COD.

BOD is another common water quality assessing parameter. It may represents, how much oxygen is required for microbes to oxidize for a given quantity of organic matter [16]. BOD varies from 82 to 232 mg/L with average value of 157.7 mg/L. The reasons of higher value of BOD are the same as for DO value decline and COD value increase.

EC indicates the total ionic species in the water. The concentration of EC varied from 985 to 1362 µS with average value of 1117 µS which is almost doubled compared to the Sikder et al., [15]. Untreated textile effluent discharged into the Turag River can be the major source of EC. Beside this, tannery industries, battery industries and some other industries are operated in the Tongi industrial zone can be other sources of the higher value of EC.

Saline content in water advocates the appropriateness of water use for drinking, washing and irrigation purpose [9]. Salt content affects the soil construction, permeability and aeration which affect the plant growth [17]. Salinity varied from 436 to 612 mg/L with average value of 539 mg/L.

TDS depicts the dissolved inorganic and organic content in water which may comprise in the form of both colloidal and dissolved state. Turbidity of water increases with the increase of TDS value [18]. Industrial, municipal and agricultural untreated discharge is the main cause of TDS increase in the Turag River. TDS varied from 684 to 898 mg/L with average value of 787 mg/L which is similar to that reported by Mobin et al., [13].

TSS is generally composed of fine clay, plankton, organic and inorganic compounds, colloidal substance and other microorganism. Untreated industrial, municipal and agricultural wastage intensify the TSS value. TSS is susceptible to pH variation. With pH change, the dissolved matter can be aggregate and precipitated [19]. TSS varied from 97 to 196 mg/L with average value of 148 mg/L.

pH is an important parameter for assessing the water quality which determine the corrosive nature of water [9]. The organism which can persist in a specific pH level cannot adapt with slight pH variation [20]. Photosynthesis quantity of water body depends on the pH value of water. By the decrease of photosynthesis rate the incorporation of carbon dioxide and bicarbonates increases which are eventually responsible for the increase in pH [21]**.** pH varied from 8.23 to 9.45 with average value of 8.85 which indicate the alkaline nature of water. This alkaline pH causes from the untreated industrial (mainly, textile and tannery) discharge in the Turag River.

The water temperature plays an important role for chemical, photochemical activity in water. Drastic change of water temperature is fatal for fish and aquatic biota [22;9]. Temperature varied from 26.9 to 32.7 ^{o}C with an average value of 29.8 ^{o}C which is similar to that observed by Mobin et al., [13].

E. coli showed the higher value (<18000 cfu/100 mL) throughout the study period. It is an important assessing parameter for drinking water. In the downstream the Turag flow incurred to the Shitallakhya River and the Shitallakhyar River water is used for drinking purpose by DWASA. Due to the untreated industrial discharge the Turag River water is safe medium for *E. coli* growth.

3.2. Heavy Metals

The concentration of heavy metals (Cr, Cu, Zn, Pb, Ni, Cd, Hg, Fe, As and Mn) measured in the surface water and surface sediment are presented in Table 3. Among all the metals Fe, Zn, Hg, Mn, Cu and Cr show higher concentrations in both water and sediment as well as As and Cd show lower concentration.

Table 3: Metal concentration in water and sediments of the Turag River.

Concentrations (mg/L) of metals in surface water							
Metal	Dry (Feb)			Wet (Jun)			Average
	SP-1	SP-2	SP-3	SP-1	SP-2	SP-3	
Cr	0.0715	0.0923	0.1270**	0.0150	0.0110*	0.0180	0.0558
Cu	0.2200	0.3800**	0.3200	0.1203*	0.1711	0.1734	0.2308
Zn	0.3400	0.4100	0.4500**	0.1860*	0.1880	0.1970	0.2952
Pb	0.0150	0.0170	0.0290**	0.0078*	0.0089	0.0102	0.0146
Ni	0.1319	0.1323	0.1333**	0.1282*	0.1298	0.1299	0.1309
Cd	0.0116	0.0116*	0.0119	0.0191	0.0195**	0.0122	0.0143
Hg	0.0119	0.0121	0.0151**	0.0009*	0.0015	0.0019	0.0072
Fe	2.1360	3.0070	3.4610**	2.9850	2.0120*	2.0530	2.6060
As	0.0053	0.0055**	0.0054	0.0010*	0.0013	0.0017	0.0034
Mn	0.9410	0.9670	0.9780**	0.4381*	0.4441	0.4830	0.7085
Concentrations (mg/kg) of metals in sediment							
Cr	162.325	162.576	163.005**	89.284*	92.361	92.887	127.073
Cu	261.4**	260.92	260.98	178.533*	184.259	197.222	223.885667
Zn	1645.6	1698.35	1700.38**	1023.73*	1203.34	1245.27	1419.445
Pb	29.98	29.97	30.22**	21.54*	23.16	23.22	26.3483333
Ni	40.1	40.43	40.87**	29.46*	29.71	31.23	35.3
Cd	0.168**	0.163	0.152	0.059*	0.0673	0.08	0.11488333
Hg	846.051	845.743	846.886**	378.94*	406.53	423.46	624.601667
Fe	24364.74	25124.523	25981.472**	278.47*	296.39	282.44	12721.3395
As	0.833	0.807	0.923**	0.238	0.274	0.198*	0.5455
Mn	396.407	400.845	413.218**	201.92*	217.64	249.58	313.268333

*Minimum value; **Maximum value

Iron (Fe) is an important element of earth crust. In this present study, Fe varied from 2.012 to 3.461 mg/L with average value of 2.6 mg/L in surface water as well as 278.47 to 25981.47 mg/kg with average value of 12721.34 mg/kg in surface sediment. These higher values of Fe are related to the terrestrial input from different industries (metallurgy, paint and pigments, alloy) and untreated waste water. The Fe concentration in water is similar that reported by Sikder *et al.*, [15].

Zinc (Zn) is one of the most essential trace elements for enzyme and protein [23]. But the high concentration of Zn would be hazardous for aquatic life. The concentration varied from 0.186 to 0.45 mg/L with average value of 0.295 mg/L in surface water as well as 1023.73 to 1700.38 mg/kg with average value of 1419.45 mg/kg in surface sediment. These higher concentrations of Zn are related to the industrial discharge and natural sources. According to Hamed et al. and Naymangara et al. [24-25], at alkaline pH, Zn can be precipitated as $ZnCO_3$ which is suspected for lower concentration of Zn in surface water and higher concentration in sediment.

Mercury (Hg) is one of the trace elements which are hazardous for public health. In this study, the concentration of Hg in surface water varied from 0.0009 to 0.0151 mg/L with average value of 0.007 mg/L where as in surface sediment 378.94 to 846.886 mg/kg with average value of 624.6 mg/kg. WHO [26] reported that, even any area without Hg emitting source, can be enriched by Hg because of global Hg cycling occurs through the air and water.

Manganese (Mn) is an essential element for both animal and plant and its deficiency may cause brutal skeletal and reproductive abnormalities for animal [27]. The concentrations of Mn in surface water varied from 0.4381 to 0.978 mg/L with average value of 0.708 mg/L as well as in surface sediment from 201.92 to 413.218

mg/kg with average value of 313.3 mg/kg. This large concentration of Mn may be input from the industrial waste water and from natural source. NAS [28] reported that 0.1 % of earth crust comprises of Manganese.

Copper (Cu) is an essential element for enzyme, but the high consumption of Cu can cause severe health problems [29]. The concentration of Cu in surface water varied from 0.1203 to 0.38 mg/L with average value of 0.23 mg/L where as in surface sediment 178.533 to 261.4 mg/kg with average value of 223.88 mg/kg. Aksu and Isoglu [30] reported that cleaning and plating industries can be the potential source of copper. Lower concentration of Cu detected in water may be the result of forming complex with organic compound [31].

Chromium (Cr) is hazardous trace element for public health if the daily intake is exceeded by permissible limit 0.05 mg/L but the deficiency of Cr can cause glucose, protein and lipid metabolism disturbance [32]. The concentration of Cr in surface water varied from 0.011 to 0.127 mg/L with average value of 0.056 mg/L where as in surface sediment 89.284 to 163.005 mg/kg with average value of 127.1 mg/kg. This high value of Cr can be the source of industrial sewage (tannery, plating, pigment and dying industries). Beside this, cooling tower cab be a potential source of Cr in the Turag River [6]

Lead (Pb) is used in battery and paint industries. Lead concentration in surface water varied from 0.0078 to 0.029 mg/L with average value of 0.015 mg/L as well as in surface sediment from 21.54 to 30.22 mg/kg with average value of 26.35 mg/kg

Nickel (Ni) is a carcinogenic metal and long term exposure to it can cause heart and liver damage, decreased body weight and skin irritation [33]. The concentration of Ni in surface water varied from 0.1282 to 0.1333 mg/L with average value of 0.1309 mg/L where as in surface sediment 29.46 to 40.87 mg/kg with average value of 35.3 mg/kg.

Arsenic (As) is a hazardous element for human. The consumption of As is exceeded by the permissible level can cause sore on skin. The concentration of As in surface water varied from 0.001 to 0.005 mg/L with average value of 0.003 mg/L where as in surface sediment varied from 0.198 to 0.923 mg/kg with average value of 0.56 mg/kg.

Cadmium (Cd) is a hazardous trace element, used in battery, pigment and paint industries. The concentration of Cd in surface water varied from 0.0116 to 0.0195 mg/L with average value of 0.0143 mg/L where as in surface sediment 0.059 to 0.68 mg/kg with average value of 0.115 mg/kg. El-biary *et al*., [34] found the highest mortality relation as a consequence of high intake of Cd on red tilapia which also affects on the decrease of sperm number. Cadmium is carcinogenic and can cause acute and chronic illness for human [25].

3.3. Heavy Metal Uptake from Surface Water to Sediment

Figure 2(a) shows the significant correlation for the uptake of Cr from surface water to sediment (R^2 = 0.726). The uptake capacity of Cu from surface water to sediment is insignificantly correlated (R^2 = 0.262) which signifies the higher concentration of Cu in surface water (Figure 2(b)). Zinc shows the highly significant correlation (Figure 2(c)) for the uptake from surface water to sediment (R^2 = 0.931). The uptake of Pb (Figure 2(d)) from surface water to sediment also shows significant correlation (R^2 = 0.567). Figure 3(e) shows the significant correlation for the uptake of Ni form surface water to sediment (R^2 = 0.794). Cadmium shows significant negative correlation (R^2 = 0.528) for the uptake from surface water to sediment (Figure 3(f)). According to Figure 3(g), Hg shows the significant positive correlation for the uptake from surface water to sediment (R^2 = 0.802). Figure 3(h) shows the positive correlation for the uptake of Fe from surface water to sediment (R^2 = 0.600). According to Figure 4(i), As shows the positive correlation for the uptake from surface water to sediment (R^2 = 0.789). The uptake capacity of Mn (Figure 4(j)) from surface water to sediment shows highly positive correlation (R^2 = 0.992).

3.4. Geoaccumulation Index

To evaluate the status of environment and the heavy metal contamination of surface sediment of the Turag River geoaccumulation index (I*geo*) were applied using the following equation [35]:

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

Where, C_n is the concentration of the observed metal in the studied surface sediment and B_n is the geochemical background of a given metal [As = 5, Pb = 6, Cu = 10, Zn = 31, Cr = 17, [36]] and the factor 1.5 is the matrix correction factor of the background due to the lithogenic effects. Muller [35] divided the I*geo* into seven classes (Table 4). The I*geo* value for the three studied area is tabulated in Table 5. According to Muller [35] scale, the

calculated I*geo* value for Zn lie in the class number 5 which reveal that the sediment in this region are strongly to extremely polluted, Cu lie in the class number 4 which state that the sediment in this region is strongly polluted by Cu metal, Cr lie in the class number 3 which indicate that the sediment is moderately to strongly polluted by Cr, Pb lie in the class number 2 which state that the sediment is moderately polluted and As in all studied sediments belong to the zero class which indicate that the sediments in all stations are uncontaminated by this metal.

3.5. Ecological Risk Assessment

Ecosystem, potential ecological risk factor and risk index was used to estimate the ecological risk by toxic metals to the Turag River. Ecological risk index introduced by Hakanson [37], was obtained by following equations.

$$E^i_r = T^i_r \frac{C^i}{C^i_o}$$

$$E_{RI} = \Sigma E^i_r$$

Where E^i_r is the ecological risk factor, C^i and C^i_o are the average (dry and wet season) concentration of specific metal and its permissible reference value in sediment, respectively. T^i_r is the toxicity factor (Cr = 2, Cd = 30, Ni = 5, Cu = 5, Pb = 5, As = 10 and Zn = 1) of respective metals [37;38]. Hakanson [37] suggested heavy metal permissible reference value for surface sediment (Cr = 90, Cd = 1.0, Ni = 35, Cu = 50, Zn = 175, Pb = 70 and As = 15) were used. E_{RI} is the potential ecological risk of a region based on the sensitivity of biological communities to various metals.

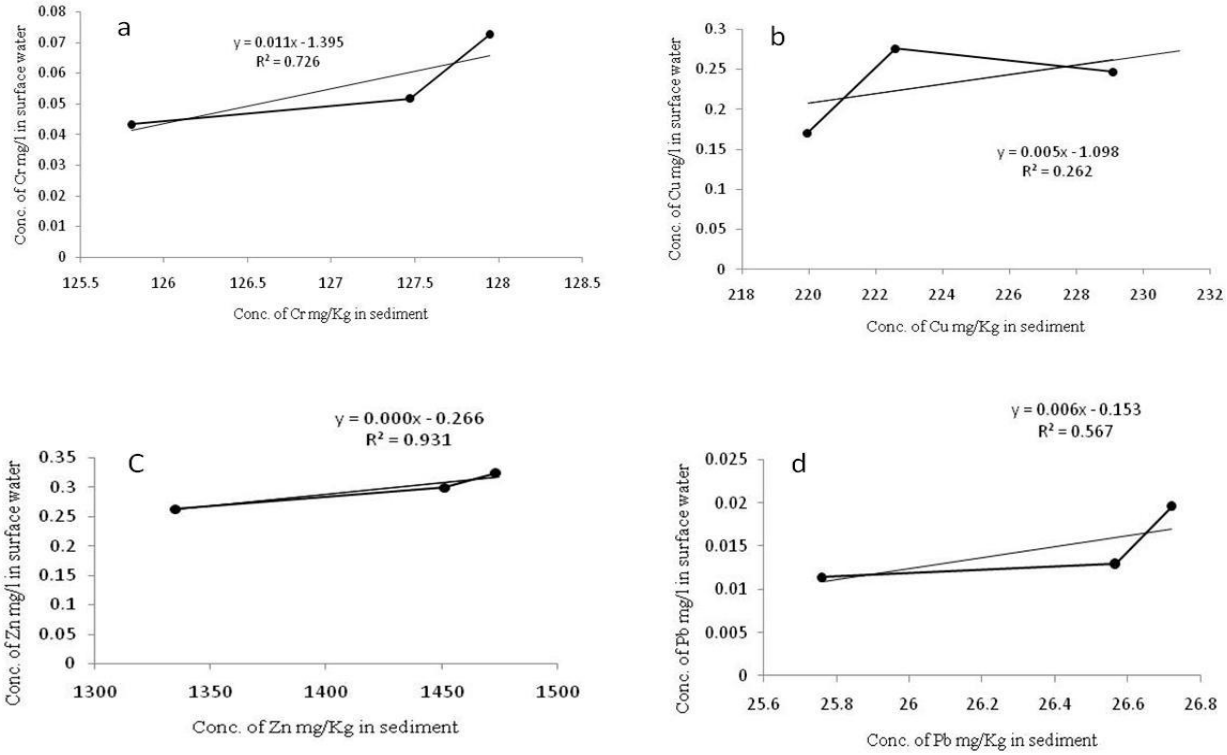

Figure 2: Pearson correlation (2-tailed) for (a) Cr, (b) Cu, (c) Zn and (d) Pb.

The calculated values of E^i_r and E_{RI} for metals in the three studied stations are presented in Table 6. Higher value of E^i_r and E_{RI} indicates the higher risk for ecosystem. According to Gen *et al*., [39], the potential ecological risk of sediment exposed by toxic metals can be classified as:

Low risk: $E^i_r < 30$, $E_{RI} < 100$
Moderate risk: $30 \leq E^i_r < 50$, $100 \leq E_{RI} < 150$
Considerable risk: $50 \leq E^i_r < 100$, $150 \leq E_{RI} < 200$
Very high risk: $100 \leq E^i_r < 150$, $200 \leq E_{RI} < 300$
Disastrous risk: $E^i_r \geq 150$, $E_{RI} \geq 300$

Among the toxic metals observed, Cu is the highest ecological risk metal and all the three points are in the range of moderate potential ecological risk (E_{RI} value for three sampling points are SP-1 = 45.18, SP-2 = 46.37 and SP-3 = 47.10). The average value of E^i_r for Cu is 22.39 ± 0.47 which indicates that Cu concentration did not highly vary through station to station. The station SP-3 is the ecologically highest risk station (E^i_r = 22.91, E_{RI} = 47.10). The other six metals have lower ecological risk than Cu (average E^i_r values are Cd = 3.45 ± 0.0.4, Ni = 5.04 ± 0.10, Zn = 8.11 ± 0.42, Pb = 1.86 ± 0.04 and As = 0.37 ± 0.02).

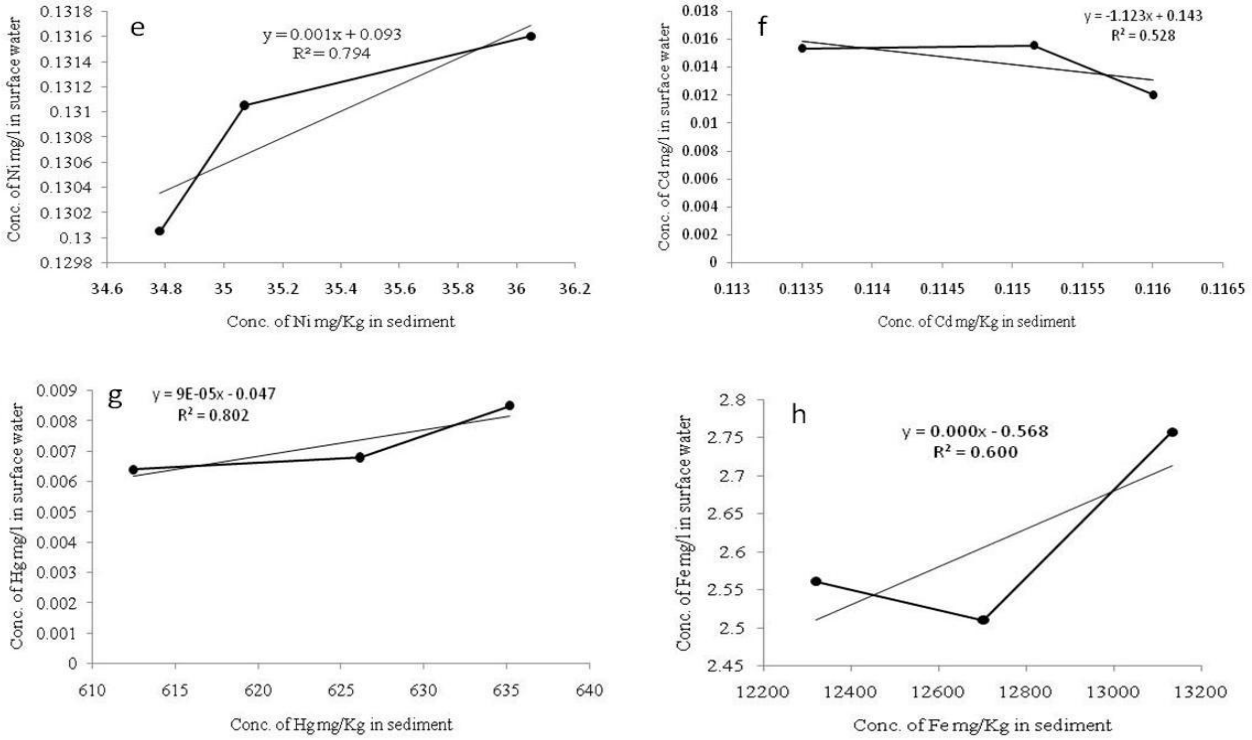

Figure 3: Pearson correlation (2-tailed) for (e) Ni, (f) Cd, (g) Hg and (h) Fe.

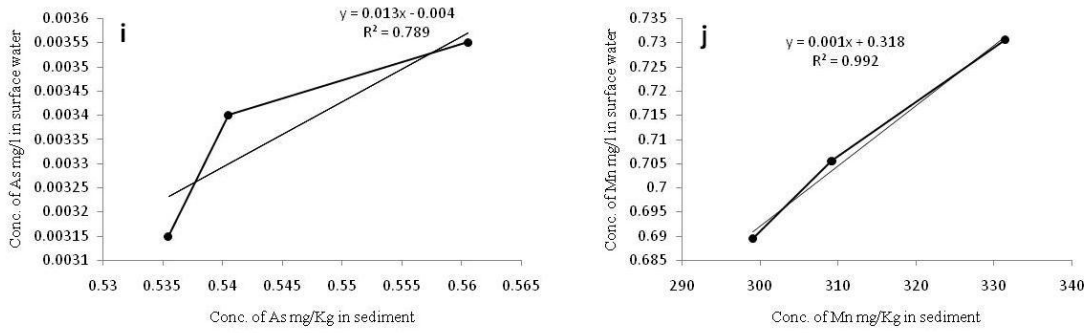

Figure 4: Pearson correlation (2-tailed) for (i) As and (j) Mn

Table 4: Muller's classification for the geoaccumulation index.

I*geo* value	Class	Quality of sediment
≤0	0	Unpolluted
0-1	1	Unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	Moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	Strongly to extremely polluted
≥ 6	6	Extremely polluted

Table 5: Geoaccumulation index (I*geo*) value of heavy metals of sediment samples in the investigated sampling stations.

Sampling station	Cu	Pb	Zn	Cr	As
SP-1	3.874	1.520	4.843	2.303	-3.808
SP-2	3.891	1.517	4.964	2.323	-3.789
SP-3	3.933	1.570	4.985	2.300	-3.742

Table 6: Ecological risk factor and potential ecological risk index for toxic metals in the Turag River.

Station	E_r^i							E_{RI}
	Cr	Cd	Ni	Cu	Zn	Pb	As	
SP-1	2.79	5.60	4.97	21.99	7.63	1.84	0.36	45.18
SP-2	2.83	5.74	5.01	22.25	8.29	1.84	0.39	46.37
SP-3	2.79	5.55	5.15	22.91	8.42	1.91	0.37	47.10
Average	2.81	5.63	5.04	22.39	8.11	1.86	0.37	46.21
SD	± 0.02	± 0.10	± 0.10	± 0.47	± 0.42	± 0.04	0.02	± 0.97

Conclusion

The pollution status of the Turag River is menacing for the use of drinking, washing, irrigation purpose as well as for aquatic life and ecosystem. During dry season the water was highly polluted and acrid in smell and in wet season dilution is occurred. The investigated heavy metals also show higher level of contamination in surface water and sediment except Arsenic. Geoaccumulation status show Zn is strongly to extremely polluted and As shows uncontaminated in surface sediment. According to ecological risk factor Cu is the highest ecological risk metal in the surface sediment for all the three sampling points. According to the Pearson's correlation, all the metals show significant correlation for the uptake from surface water to sediment except Cd.

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