Toxic Metal Contamination on the River near Industrial Area of Dhaka

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Abstract:

The present study investigates the anthropogenic metal input in to the river system, the toxic metal contamination in the sediment of the river and evaluates the dissolution of metal from soil to surface water or leaching through soil profile. Nine sampling stations along the river channel and three in the industrial canals are chosen and a set of surface water and sediment samples from each station were collected. Samples are analyzed for Fe, Mn, Cu, Cr, Pb, Ni, Cd, As and Zn by Atomic Absorption Spectrophotometer (AAS). The findings show that, toxic metals content among all the samples are distributed in a decreasing sequence of Fe>Mn>Zn>Ni>Cu>Cr>As>Pb>Cd. The content of the most toxic metals in wastewater and sediments of the industrial canals are much higher than that of river water and sediments. Moreover, most of the toxic metal contents are found to exceed the background concentration in all sediment samples. Higher geoaccumulation values are observed for Zn, Ni and Cu probably due to the anthropogenic metal supply with uncontrolled discharge of industrial effluents into the river. Further, higher enrichment factors are found for Zn, Ni and Cu suggesting also anthropogenic source of metals. Significant correlation is also observed among these, indicating the same source of occurrence. Partition coefficient, K_d values are found in the order: Ni>Zn>Cr>Cu>Pb and lower K_d values are found in the sediments near industrial area indicating much leaching or dissolution. Therefore, it can be concluded that sediments of the river close to industrial area is contaminated by toxic metals which enter into the food stuff and give rise to various health hazards of the inhabitants.

Keywords: Toxic metals, River sediment, Partition coefficient, Geoaccumulation, Enrichment factors

1.0 Introduction:

Now a days environmental pollution is a great matter of concern. This is considered as a global problem because of its adverse effects on human health, plants and animals. Most of the industries discharge their wastes directly to the river, canal or sea without any treatment. This is one of the major causes of water pollution in Bangladesh. In Bangladesh major industrial hot-spots are located close or in the major cities and are preferably sited adjacent to rivers or water bodies that facilitates disposal of effluents. Since our country is networked with small and big rivers, the pollution load from different sites has been added up and finally destroyed the fresh water aquatic ecosystem of the country. It especially ruined diversified fish community which contributes an important share in the domestic protein demand of the country (Khan, 2008). Almost all tributaries of major river system are already saturated (and are already declared Dead Rivers) with pollution. Water pollution is more pervasive than that of land and air pollution. Because of the change in hydrological pattern of the country the pollutants

are not flashed out properly and also in the dry period the situation becomes severe. The pollution is now detected by mere visual observation. Some study (Isotopic Analysis) reveals that this contaminant river is contributing to the nearby groundwater recharge system which is accelerated by the over-extraction from the aquifer (Khan, 2008).

The pollution effects have harmful consequences over environmental resources like water which follows hydro geologic cycle that encompasses both surface water and groundwater (Mahfouz et al.2011). Degradation of any one will affect the other. Thus improper and over exploitation of these resources has made them unsuitable for both plant and animal habitants that include human. Two terms-soil contamination and soil pollution-have been defined differently in various publications. The recent definition given by Knox et al. (1993) refers to soil contamination as soil whose chemical state deviates from the normal composition but does not have a detrimental effect to organisms. Pollution occurs when an

element or a substance is present in greater than natural (background) concentrations as a result of human activity and has a net detrimental effect on the environment and its components. The authors stated: "From a plant, animal, and human health perspective, soils are not considered polluted unless a threshold concentration exists that begins to affect biological processes."

Environmental problems related to heavy metals have a long history. Heavy metals have toxic properties, leading to adverse effects on human and ecosystem health even in small doses. Another problem-causing property is their non-degradability: once they enter the environment they will remain there for long time. Metals tend to accumulate in soils and sediments, with immobilization due only to geological and therefore extremely slow processes. Accumulation in the food chain may lead to an increase stock in biota, thereby magnifying the human dose (Khan, 2008). For some heavy metals, toxic levels can be just above the background concentrations naturally found in nature. Therefore, it is important for us to inform ourselves about the heavy metals and to take protective measures against excessive exposure. If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life (Ferner, 2001) (Pendias and Pendias, 2000). In Bangladesh context some of the major known toxic bio-accumulative metal pollutants from industrial sectors which are particularly dangerous are Mercury, Lead, Arsenic, Chromium, Nickel, Copper, Zinc and Cadmium (Faisal et al., 2004). Textile is the most important sector of Bangladesh's economy. Textile industry uses a large quantity of water in its production process and highly polluted and toxic waste waters are discharged into sewers and drains without any kind of treatment (Chindah et al., 2004). Although most of the industries are supposed to have effluent treatment plant, however, so far only a few industries have installed the plants. Even then most of the plants operate only occasionally.

Contaminant from the textile and dyeing unit of the industrial area has repeatedly been reported in the press and electronic media (The Daily Star, 2009). With a possibility that some of groundwater recharge of capital Dhaka comes from this industrialized frontier region, the pollution would encompass threat/health hazard to millions of people. BISIC (Bangladesh Small and Cottage Industries Corporation) industrial area at Konabari is located along the bank of the river Turag of Gazipur, Dhaka. Textile and dyeing unit of that

area is an environmental "hot spot" that have been identified in the country. Concerns over surface water quality are gradually emerging due to the disperse locations of polluting industries and adverse effects of surrounding land and aquatic ecosystems as well as subsequent impacts on the livelihood systems of the local community. The extreme impacts of these type of effects are observed in this area because here industrial effluents are discharged into nearby land and water bodies without any treatment (BCAS, 2001; The Daily Star, 2009). So the present study is focused on the investigation of the contamination of some toxic metals on the aquatic environment of Turag river and industrial canal near the industrial area of Dhaka and also elucidation of the degree of potential leaching of metals and their bioavailability in sediments through the analysis of relative partitioning of metal between sediment particles and solution.

2.0 Materials and Method:
2.1 Geology and Geomorphology of the Study Area:
The study area is the industrial area at Konabari is located along the bank of the river Turag of Gazipur, Dhaka. It is in the Madhupur and Barind tract which contain Mahhupur clay. Mahhupur clay is considered to be a marine formation of Plio-Pleistocene age. It is remarkably homogeneous in appearance both vertically and laterally. Extensive areas of the Barind Tract and parts of the Madhupur Tract have almost level, terrace-like topography (FAO Bangladesh, 1971). Stratigraphic units exhibit iron and manganese rich deposits which are oxidized. There are traces of paleo-magnetic age dating unveils that these deposits ranged from Lower Pleistocene to Upper Pleistocene. The upper Paleosol layer of Madhupur Formation represents a Pseudogley soil. Such soil type is formed in sediments where groundwater level is low from the surface, and soil development is done under the influence of percolating rain water. Whenever such soil has impervious layer, water may stagnate on top of such a layer during the part of a layer. On the contrary, according to DNDP classification, that has demarked 15 hydrogeological zones, the study area falls under 'Zone J' that covers part of Dhaka, Tangail and Mymensing District. Surficial deposits of it consist of older alluvium known as the Madhupur Clay. In most areas, the presence of a thick sequence of surficial clay inhibits vertical recharge. Thus it has been suggested that shallow tube well development in the area is not suitable

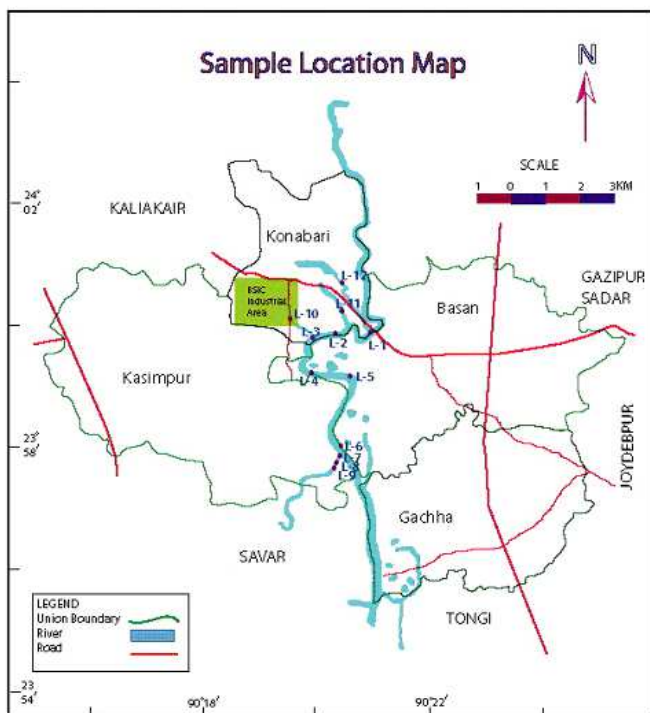and the water column probably uninterrupted by sediment layers (Khan, 2008).

Fig.1 Map of the sample location

2.2 Sample Collection:

For the assessment of the aquatic environment of Turag river, three wastewater (L_{10} WW-L_{12}WW) and three waste sediment samples (L_{10}WD-L_{12}WD) were collected from the industrial canal connected to the river and nine river water labeled as 'RW', nine sediment samples labeled as 'SD' were collected from the Turag river. Water samples were collected from the river with a plastic jar from the surface without disturbing the flow condition or stir. Among them three sites (L_1-L_3) were selected at Konabari, Gazipur where huge influx of waste-water were being discharged through the connected industrial canals or storm sewers, three sites (L_4-L_6) at Kashimpur, Gazipur where there were a few number of discharge points and three sites (L_7-L_9) at Rajendra Khal, Kashimpur which is an isolated part of the Turag river due to the construction of road across it with almost no discharge points (Fig.1). Sampling sites were selected at least 50 m away from the point sources. The sample was stored in plastic containers of 3 liter volume and labeled with sample ID, type, date and location on the sticker tag. Sediment samples were labeled and stored in the same way.

2.3 Sample Analysis:

Wastewater, waste sediment, river water and river sediment, collected from the study area were preserved, prepared and analyzed in the laboratories of Analytical Research Division, Bangladesh Council of Scientific and Industrial Research (BCSIR) Dhaka. The sediment samples were air dried, sieved (1mm) and after oven dried at 80°C, ground to powder. Sediment samples were digested according to Agemian & Chau (1976) and Mendham *et al*. (2000). This method has been written to provide digestion procedure for the preparation of sediments, sludges and soil samples for the analysis by Atomic Absorption Spectrophotometer (AAS). After digestion, a quantitative analysis of toxic metals such as Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Arsenic (As), Zinc (Zn), Cadmium (Cd) and Lead (Pb) of the soil were determined by Atomic Absorption Spectrophotometer (AAS), VARIAN, Model-GTA120' and AA240FS'. Toxic metals were analyzed using AAS (Atomic Absorption Spectrometer) giving values in ppm level mostly. In the laboratory, water samples were preserved with HNO_3 and stored at low temperature. Sample preparation before taking measurements involves-acidification, filtration and volume preparation with required dilution. For the analysis with AAS, construction of the calibration curve is the first step. Calibration curve for individual trace elements was constructed by plotting the measured absorbance and corresponding concentration for four known standard solutions. Then absorbance for the samples were measured by the instrument and plotted in the calibration curve to fetch the concentration level of that pollutant present in the sample. Many samples were required to dilute by 5T to 2500T to keep the absorbance within the calibration curve limit. In such cases, the given concentrations have been multiplied with the dilution factor to get the actual concentration in mg/l or µg/l level, that is, ppm or ppb level respectively.

2.4 Data Analysis:
2.4.1 Assessment of Sediment Quality of the River:

Assessment of sediment contamination and potential leaching of metals and their bioavailability was done using the following methods.

A) Index of Geoaccumulation (I_{geo}):

The Index of Geoaccumulation (I_{geo}) was first proposed by Müller (1969) and described by

Förstner et al. (1990) as a quantitative measure of the degree of metal pollution in aquatic sediments. It uses the relationship between the measured concentration (C_n) of the element in the sediment ($<2\ \mu m$ fraction) and the background concentration (B_n) in the shale sediment (Eq.1), and 1.5 is a correction factor due to lithogenic effluents.

$$I_{geo} = \log_2 [C_n / 1.5 B_n] \ \dots\dots\dots\dots\dots\dots\dots\dots\ (1)$$

The total concentrations of trace metals in this study were measured in <2 mm fraction of sediment according to the method followed by Lin et al. (2008) and the study used the median values of elements in soils from the USGS survey as the background concentration (Bn) (Sparks, 2003). The following classification is given for the index of geoaccumulation by Förstner et al. (1990) : <0 = practically unpolluted, 0–1=unpolluted to moderately polluted, 1–2=moderately polluted, 2–3= moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to very strongly polluted, and >5=very strongly polluted.

B) Enrichment Factor (EFₘ):

Enrichment Factor (EF_m) can be expressed as:

$$EF_m = C_n / C_R \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Where EF_m is ratio between the measured metal concentration (C_n) and the reconstructed background metal concentration (C_R) instead of the average metal concentration in shale. In order to investigate the metal contamination in Turag river, metals in sediments from anthropogenic inputs were evaluated by using Enrichment factors (Panichayapichet et al., 2007). EF_m values greater than 1.0 were indicated that the sources of metals in the samples were likely to be anthropogenic sources (Lu et al., 2005). The study used the median values of elements in soils from the USGS survey as the background concentration (Bn) (Sparks, 2003).

C) Metal Partitioning:

Potential leaching of metals and their bioavailability in soils were analyzed by using the relative partitioning of metal between soil particles and soil solution (Watmough et al., 2005). The dissolved metal pool reflects the soil metal fraction that is susceptible to leaching and could therefore contaminate groundwater or surface waters. The partitioning coefficient or distribution coefficient, K_d (g l^{-1}) is the ratio of the total metal concentration in sediment (mg kg^{-1}) over the

concentration of dissolved metal in soil solution ($\mu g\ l^{-1}$).

K_d = Total metal in sediment/ Dissolved metal in surface water……………………………………..(3)

2.5 Statistical Analysis

In present Study, the Pearson Coefficients (PC) were conducted using SPSS for windows 12.0 in order to study the interrelationship among the trace elements.

3.0 Results and Discussion

3.1 Concentration of Toxic Metals in the Wastewater and Waste Sediments:

The average concentrations of the toxic metals such as Mn, Fe, Cr, Cd, Cu, Zn, Ni, Pb and As of the surface water of the Turag river were found 0.267, 0.442, 0.017, 0.017, 0.056, 0.013 ppm ,0.93 and 0.325ppb respectively. Further, the average concentrations of the toxic metals such as Mn, Fe, Cr, Pb, Cu, Zn, Ni and As of the river sediments were found 481.82, 32049.84, 16.8, 1.53, 32.07, 154.49, 39.04 and 2.97 mg/kg respectively.

3.2 Concentration of Toxic Metals in the River Water and River Sediments:

The average concentrations of the toxic elements such as Mn, Fe, Cr, Cu, Zn, Ni, Pb and As of the surface water of the river were found 0.31, 1.08, 0.0076 , 0.001, 0.0048, 0.0164, 0.00506 ppm, 0.2225 and 2.2 ppb respectively.

Further, the average concentrations of the toxic elements such as Mn, Fe, Cr, Pb, Cu, Zn, Ni and As of the river sediments were found 471.25, 31,926.36, 14.32, 1.97, 29.40, 131.62, 39.41 and 4.73 mg/kg respectively.

3.3 Sequence of Trace Elements in the Samples:

Sequence of toxic elements in all types of samples were shown in order to know the distribution of the metals in the study area. It is found that in the river sediment toxic element concentrations were decreased in sequence of Fe>Mn>Zn>Ni>Cu>Cr>As>Pb>Cd which were equally followed by WSD, RW and WW. For every metal, the highest concentration occurs in sediments that are explained by the chemical precipitation and adsorption by under lying clay layer. The present result agrees with the investigation made by Duman et al. (2007) in the surface sediment of Lake Sapanca, Turkey where the heavy metal concentration in the surface sediment were decreased in the sequence of

Fe>Mn>Zn>Ni>Cu>Cr>Pb>Cd. Ozmen *et al*. (2004) also investigated heavy metals concentrations in bottom sediments of Hazar Lake and reported the sequence to be in Mn>Zn>Ni>Cr>Cu>Co.

3.4 Comparative Analysis to Determine Contamination and Possible Sources:
3.4.1 Comparison of Toxic metals of WW with RW and WSD with RSD:

It is noted that the concentration of toxic elements such as Cr, Pb, Cu, Zn and Ni in the wastewater is much higher than the river water which indicates that canals are more contaminated than river. Higher content of Fe was observed in both RW and WW. It is probably the release of it into the water from the upper ferruginous clay layer of the study area (Fig.2).

Further, average content of toxic elements of waste sediments were compared with the river sediments where higher concentration of Mn, Fe, Cr, Cu and Zn in WSD than RSD was also observed. It means that most important sources of metal contaminants were located in the industrial area (Table-1).

3.4.2 Comparison of Toxic Metals of WW with Standards for Industrial Waste water(DoE, 1997):

It is found that the average value of toxic elements of waste water lies within the limit of DoE (1997). The result of toxic metal however, does not give the actual concentration originally present in the waste water at the time of discharge into the river because a portion of the toxic metal may already have accumulated in the sediment underneath (Khan, 2008). This is suggested from highest concentration found in the waste sediment.
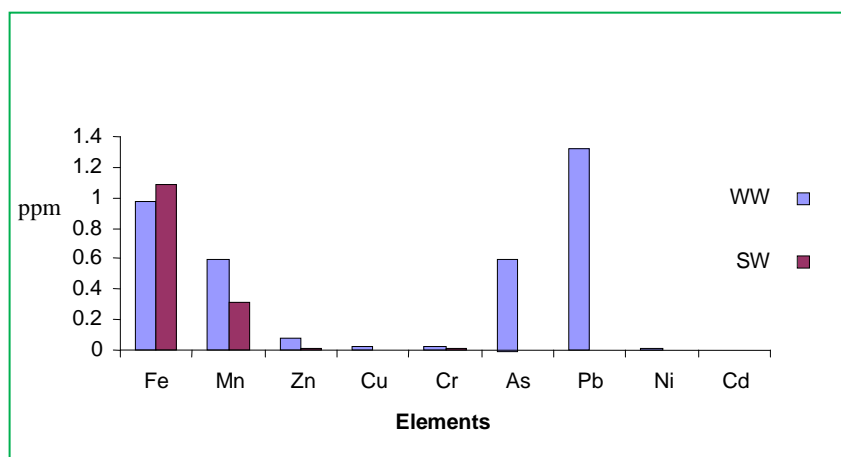

Fig.2: Comparison of the concentration of toxic metals of WW with RW.

Table1: Concentrations of toxic metals in the surface and waste sediments with background value.

Element	Observed Values in SD Samples (average) ppm	Observed Values in WS Samples (average) ppm	Median values of soil surveyed by USGS(Sparks, 2003, *Wedepol1995*)
Fe (ppm)	31,926.91	32,049.84	26,000
Mn (ppm)	471.25	481.82	550
Zn (ppm)	131.62	154.50	60
Cu (ppm)	29.42	32.04	25
Cr (ppm)	14.32	16.8	54
As (ppm)	4.19	2.97	7.2
Pb (ppm)	1.97	1.53	19
Ni (ppm)	39.42	39.04	19

3.4.3 Comparison of Toxic Metals of Wastewater and River Sediments with Background Value:

Average contents of trace elements were compared with typical values of soil (Wedepol, 1995, Spark, 2003). Metal contents of major elements including Cu, Ni and Zn were quite high, whereas, Cr and Pb contents were rather low (Table-1). The concentration of Mn in the sediments was comparable to the background value (Spark,2003). It is known that Fe–Mn oxides are excellent scavengers for trace metals (Tessier *et al.*, 1979). Li and Thornton (2001) found that Fe–Mn oxides were important scavengers of heavy metals in soils collected at historical Pb–Zn mining sites (Derbyshire in central England), particularly at high pH range (pH>7.0).

3.5 Assessment of Sediment Quality of the River:

3.5.1 Index of Geoaccumulation:

The present investigation reveals that the Index of geoaccumulation of the surface sediment falls in the unpolluted to moderately polluted class. I_{geo} ranged from about 0.021 to 0.915 for all the SD Samples (Fig. 3), suggesting unpollution and moderate pollution. Higher I_{geo} values were observed for Zn, Ni and Cu probably due to the anthropogenic metal supply with uncontrolled discharge of industrial effluents into the river. Lin *et al.* (2008) measured the I_{geo} value and found that the sediment at Jilin City was moderately contaminated by Cu, and the sediment of the Second Songhua River in China was moderately contaminated by Pb and Zn. The findings are agreed with the present investigation in terms of Cu and Zn.

3.6 Enrichment Factor:

The present investigation showed that the Enrichment Factors of Cr and Pb were less than 1 (Fig. 4), showing no enrichment of these metals (Lin *et al.*, 2008). Cu was slightly enriched in most sampling sites with 0.76 to 1.87 of EF_m value. All the EF_m values for Zn and Ni were greater than 1.2 which indicated that the sources of metals in the samples were likely to be anthropogenic sources (Lu *et al.*, 2005).
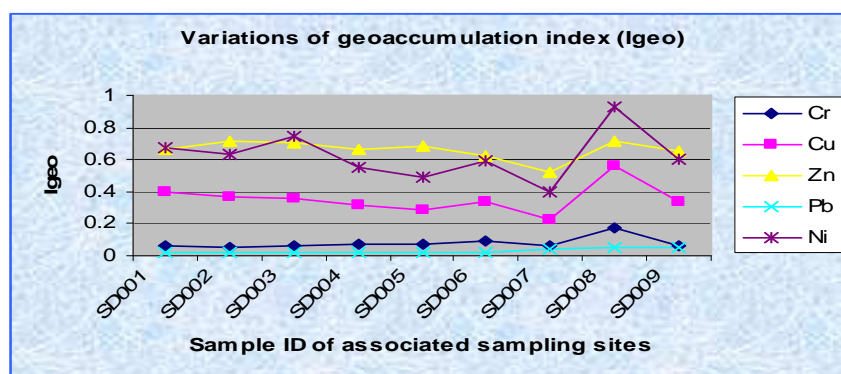

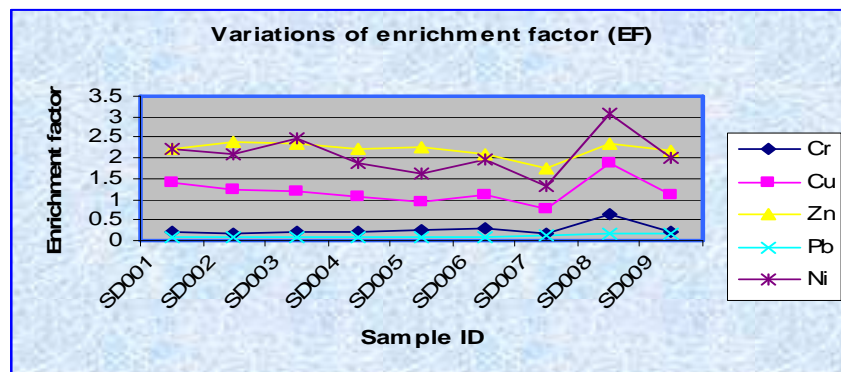**Fig.3:** Variations of geoaccumulation index of the toxic metals in the sediments.

Fig.4: Variations of enrichment factors of toxic metals in the samples.

3.7 Metal Partitioning:

The K_d values (l/kg) of trace elements Categorized by locations are shown in table 2. The calculated K_d values were in the order: Ni>Zn>Cr>Cu>Pb. The K_d values of trace elements in a pb-contaminated watershed as reported by Panichayapichet *et al.* (2007) were in the order: Cr > Pb >Ni > Cu > Cd > Zn. The order Zn>Cd>Cu>Ni>Pb>Cr was congruent with the results obtained by Smith and Huyck (1999) for mobility study under oxidizing conditions with Fe-rich particulates and pH of greater than 5. Similarly, Pendias and Pendias (2000) reported the order: $Cr^{3+}<Pb^{2+}=Ni^{2+}<Cd^{2+}$ for cation mobility in an aqueous phase under an oxidation regime of soil. Zn is very mobile elements and basically retained in the soil by exchange reactions, while Cu and Pb form inner-sphere complexes with organic matter and with Fe, Al, and Mn oxides (Silveira *et al.*, 2003). In the present investigation, the higher K_d values were observed in all the locations. According to Yang

and Rose (2005), dissolved metals in runoff water that percolated through the soil profile were adsorbed and/or co-precipitated with hydrous iron and manganese oxides. Leaching of heavy metals bound in oxides is limited by the slow rate of dissolution of these substances (Ponizovsky and Mironenko, 2001). The complexation of Pb by organic matter also restricts Pb movement in soil profiles; hence, it tends to accumulate in topsoils (Agbenin, 2002). In the study area, the upper paleosol layer of Madhupur formation represents a Pseudogley soil of ferromagnesian origin which has impervious layer (Khan, 2008) that may restrict the movement of elements through the soil profile, result of which is the higher K_d values in the topmost sediment layer. However, much lower partition coefficient, K_d values were found in the :industrial area than away from the industrial area indicating much leaching or dissolution from the river sediment near industrial area.

Table 2: Partition coefficient K_d values (l/kg) of toxic metals in the sediments categorized by locations.

Sample ID	Location	Cr	Cu	Zn	Pb	Ni
SD1	Near the	735.21	2745.90	14741.11	19.71	5163.41
SD2	industrial area	862.83	5179.66	8141.71	15.3	7829.41
SD3		872.00	4338.24	7910.17	10.47	7461.90
SD4	Away from	1179.05	3140.48	8274.38	16.44	4849.32
SD5	industrial area	3996.97	3050.57	7637.64	5.13	4541.18
SD6		1836.05	4116.42	3695.85	2.63	4915.78
SD7	Less influenced by	2219.57	7003.70	12084.88	19.67	13157.89
SD8	industrial area	12260.71	42590. 91	33766.67	7.93	53172.73
SD9		19816.67	11244.00	9822.38	8.68	27385.71

Table.3: Correlation matrix table, lower triangle for Sediment samples

	Cr	Cu	Ni	Zn	Fe	As	Pb	Mn
Cr	1.00							
Cu	0.80	1.00						
Ni	0.19	0.95	1.00					
Zn	0.01	0.64	0.71	1.00				
Fe	0.62	0.91	0.93	0.68	1.00			
As	0.94	0.89	0.82	0.31	0.74	1.00		
Pb	0.66	0.47	0.40	0.30	0.32	0.60	1.00	
Mn	0.003	0.43	0.53	0.56	0.57	0.26	-0.31	1.00

3.8 Statistical Correlation:

The study also showed that the concentrations of the metals are to a large extent linearly correlated; Table 3 is the correlation matrix of SD Samples, which shows good correlation between Ni and Cu ($r = 0.95$), Cr and As ($r=0.94$), Ni and Fe ($r=0.93$), Cu and Fe ($r=0.91$), Cu and As ($r=0.89$), Ni and As ($r=0.82$), Cr and Cu ($r=0.80$), Fe and As (0.74), Ni and Zn ($r=0.71$), Zn and Fe ($r=0.68$), Cr and Pb ($r=0.66$), Cu and Zn ($r=0.64$), Cr and Fe ($r=0.62$), As and Pb ($r=0.60$) , Fe and Mn ($r=0.57$), Zn and Mn ($r=0.56$), Ni and Mn ($r=0.53$). From the analysis it may be inferred that, Cu, Ni and Zn, the major contaminants, are found to have significant

correlation among them except Ni and Cu & Mn and Cu, suggesting the same source of occurrence. More over, these metals found in higher quantities also showed significant correlation with Fe and Mn, signifying strong affinity of these metals to organic matter, oxides of Fe and Mn and clay minerals.

4.0 Conclusions:

This research work entails the evolution of environmental deterioration of the study area by analyzing toxic metal contamination in the surface water of Turag river and river sediment in terms of their concentration level. Twenty four water and sediment samples of the study area were analyzed for Fe, Mn, Cu, Cr, Pb, Ni, Cd, As and Zn by Atomic Absorption Spectrophotometer (AAS). The analyzed data revealed that, toxic metals content among all the samples were distributed in a decreasing sequence of Fe>Mn>Zn>Ni>Cu>Cr>As>Pb>Cd. Among the nine toxic metals analyzed in the river water, iron and manganese had much higher concentration than that of standards for drinking water. Comparison of wastewater and sediments with river water and sediment revealed the enrichment of Cu, Ni, Cr and Zn, which suggesting that the most important sources of metal contaminates were located in the industrial area. Further, toxic metal such as Fe, Zn, Cu and Ni contents of the sediments of both river and industrial canal exceed the background value indicating contaminated this area by Fe , Zn, Cu and Ni. Higher I_{geo} values were observed for Zn, Ni and Cu probably due to the anthropogenic metal supply with uncontrolled discharge of industrial effluents into the river. Further, higher Enrichment Factors were found for Zn, Ni and Cu suggesting anthropogenic source of metals. Significant correlation was also observed between Ni and Fe(r=0.93), Ni and Cu (r=0.95), Ni and Zn (r=0.71), suggesting the same source of occurrence. Much lower partition coefficient, K_d values were found in the industrial area than away from the industrial area indicating much leaching or dissolution from the river sediment near industrial area. Finally, higher concentration of toxic metals in the industrial canal indicated that these toxic metals are originated from the industries and uncontrolled release of industrial effluent contaminate the river situated in the study area. Therefore, it is necessary to install effluent treatment plants in each industry or common effluent treatment plant in this area

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