Int. J. Adv. Res. Biol. Sci. (2023). 10(4): 22-45

International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
(A Peer Reviewed, Referred, Indexed and Open Access Journal)
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 10, Issue 4 -2023

Research Article

DOI: http://dx.doi.org/10.22192/ijarbs.2023.10.04.003

Heavy metal contamination in surface water and sediment of the Meghna River ecosystem

Dr. Md. Shafiqul Islam[1], Md Kamrul Hassan[2], Md. Deen Islam Bhuiyan[1], Mazharul Islam Sajeeb[1]

[1] Institute of Marine Sciences, University of Chittagong, Bangladesh.
[2] Department of Environment, Chattogram, Bangladesh
*Corresponding author: Md. Deen Islam Bhuiyan, Institute of Marine sciences, University of Chittagong.
Email: *deenbislam114@gmail.com*

Abstract

Heavy metals are the most hazardous pollutant that can pose serious threat to human and environment health. One of the main causes of heavy metal intrusion is unplanned industrialization and urbanization. To determine, quantify, and compare the heavy metal concentration from the Meghna River ecosystem this study used atomic absorbance spectrophotometry. Mean concentration of the detected Copper (Cu), Chromium (Cr), Nickel (Ni), Cadmium (Cd), Lead (Pb) in water was 2.69, 3.59, 4.66, 2.11, and 1.82 (ml/l) and in sediment was 4.03, 3.32, 17.27, 3.17, and 5.19 (mg/kg). The measured values exceed the permissible limits of safe water set by WHO and EU. To assess the level of pollution of the measured heavy metal Geo-accumulation Index (Igeo) was applied. This index showed that the study area is extremely polluted by Cd which is too much dangerous for human and aquatic health. On the other hand, studied area is slightly polluted by Cu, Cr, Ni, and Pb. Descending order of analyzed heavy metal pollutants Cd>Ni>Cu>Pb>Cr. The concentration of the measured metals is in acute toxicities and greater than the standard values set by international agencies and experts. The findings also revealed that the sediment is more contaminated in comparison to water and Ashuganj power plant area are highly polluted compare to the other stations. This study indicates the severe contamination by the industrial effluents. Urgent and effective steps should be taken to protect this River from severe and rapid contamination and to minimize the environmental risk.

Keywords: Heavy metal, geo-accumulation index, contamination, water, sediment.

1. Introduction

Bangladesh is a riverine country with over 230 major and minor rivers (Hasan et. al., 2019). However, nearly all the rivers in the nation are severely contaminated with heavy metals brought on by human interference, primarily through the irresponsible discharge of industrial effluents (Hasan et. al., 2019, Kibria et. al., 2016, Ustaoğlu and Islam, 2020). One of the most significant rivers in the country, the Meghna River (950 km long), flows toward the Bay of Bengal with the other two main rivers, the Ganges, and the Brahmaputra (Hossain., 2019). The Meghna River, the largest and widest river in Bangladesh, is vital for transportation, irrigation, fish spawning and shelter, industrial uses, and providing drinking water for millions of neighboring residents (Rahman et. al., 2021).

The biggest estuary in Bangladesh serves as the upstream portion of the Ganges-Brahmaputra-Meghna (GBM) river system, which yearly transports 1330 km^3 of water, more than 1060 million tons of suspended material, and 173 million tons of total dissolved load (Datta & Subramanian 1998; Milliman, 2001). The river basin's sediment is a vital and dynamic component that collects heavy metals from numerous sources that can exist in a variety of chemical forms (Ali et. al., 2016). The stability of the heavy metals is controlled by a few physicochemical mechanisms, including adsorption, ligand exchange, and complexation (Bai et al., 2011; Chen et al., 2016). More than a thousand times as many heavy metals as there are in water can collect in sediment from the water column and may stay there for a very long time (Siddique et. al., 2021). A change in the environment could also cause the metals that are bonded to the sediment to be released back into the lower waters (Liu et. al., 2020). As a result, sediment serves as an indicator of the typical water quality and serves as a foundation for recreating many aspects of human activity in the coastal and marine environments (Siddique et. al., 2021; Bermejo et al., 2003; Jha et al., 2003; Rubio et. al., 2002).

Heavy metal concentrations in natural systems may have an impact on the environment due to their toxicity, persistence, bio-assimilation, and bioaccumulation traits (Liu et. al., 2020; Rashdi et. al., 2015; Siddique & Aktar, 2012). Natural causes, such as the weathering and erosion of geological formations, and anthropogenic pollution, such as agricultural runoff, industrial waste, and sewage effluents, are the two main sources of heavy metals in sediment (Ip et. al., 2007; Liaghati et. al., 2004; Li et. al., 2009). The pollution caused by extensive industrialization, fast urbanization, and newly accepted farming techniques has a disproportionately negative impact on the natural environment in coastal regions worldwide (Jha et. al., 2003; Rahman et. al., 2019; Xia et. al., 2011). Higher levels of heavy metals in the sediment and water could have long-term and significant effects on ecosystems and human health (Siddique et. al., 2021; Sun et. al., 2010; Wong et. al., 2006).

Heavy metals are the natural components of the Earth's crust, they are serious pollutants because they are stable compounds, non-biodegradable (Tilzer and Khondher, 1993), not readily removed by oxidation, precipitation, or any other natural processes (Hossain et al. 2001). Heavy metals are so deleterious for their high toxicity (Olowu, 2010), stability and bioaccumulation ability (Cemsi et al. 2006; Pekey, 2006). Metal compounds are moving between the atmosphere, hydrosphere, lithosphere, and biosphere, spontaneous constituents of all ecosystems (Floera and Dietrich, 2006).

Trace and heavy metals are produced by anthropogenic activities, rapid industrial development (point source), agricultural runoff (non-point source), etc. These trace metals then enter aquatic habitats and have a serious adverse effect on the living organisms there (Hajeb et. al., 2009; Yi et. al., 2011). Fish and other aquatic invertebrates can become contaminated by pollutants from both point and non-point sources that have not been properly or insufficiently treated. For instance, the main sources of heavy metals contamination include surface water pollution, the disposal of agricultural and industrial effluents, the use of chemical fertilizers, and pesticides (Hezbullah et. al., 2016). Despite the fact that some trace metals are necessary to keep the human body's metabolism functioning, they can be harmful in higher doses. Some are also extremely toxic by nature, such as Cd, Pb, and Hg (Ahmed et. al., 2012). These metals gradually dissolve in water, deposit on sediment columns as a result of exceeding the allowable optimum amounts, and then accumulate in fish bodies by being fed polluted water from benthic and pelagic species. This causes discrepancies in the rates of intake and elimination (Sarker et. al., 2020). It can also be absorbed in a variety of ways, such as by absorbing particulate solids dispersed in water, exchanging ions, and adhering to tissue and skin surfaces (Ahmed et. al., 2016). These pollutants consequently adapt to via consumption and negatively impact our wellbeing (Wei et. al., 2014).

Bangladesh's recent economic transformation has resulted in rapid industrialization and unplanned urbanization, which has caused a tremendous amount of untreated industrial pollutants, agrochemicals, poultry wastes, medical wastes, and domestic wastes to be discharged into the rivers. Bangladesh is a developing country (Khan et. al., 2019; Kibria et al., 2016; Tamim et. al., 2016). Significant concentrations of dangerous heavy metals are transported by the river flow to the Bay of Bengal (Bibi et. al., 2006). Studies on the presence and distribution of heavy metals in estuary and coastal sediments of several rivers in Bangladesh have covered a wide variety of topics. Variable trace metal distribution, occurrence, and possible origins in silt from the Korotoa River (Islam et al., 2015), Meghna River Estuary (Ahmed et. al., 2019), Meghna Ghat industrial area (Rahman et. al., 2020), Meghna River (Rahman et. al., 2021), Karnaphuli river (Ali et. al., 2020), Khiru River (Rashid et. al., 2012), Turag River (Banu et. al., 2013), Halda River (Islam et. al., 2020) have been investigated. Any aquatic habitat's sediment is an ecologically vital component and is crucial to sustaining the trophic status (Zhang et. al., 2017) and biogeochemical cycling (Burton et. al., 2001) of the aquatic ecosystem. Heavy metal contamination of sediment causes serious environmental problems. Sediments have therefore been extensively studied for their anthropogenic impact on the aquatic environment (Siddique et. al., 2021).

The Meghna River is one of the major sources of many important biological species and economic trends, and the local population is either directly or indirectly involved in the commercial catch fisheries. A further 3500 tons of specific fish species actively contribute each year to the commercial fish marketing sector (Ahmed et. al., 2019). However, a significant number of harmful materials have been dumped into the rivers in recent years from a variety of milling and processing companies and drainage waterlines, damaging the majority of rivers in Bangladesh (Bhuyan et. al., 2016). Typically, the discharged and wastage of poorly treated industrial effluents serve as a potential source of trace metals in the Meghna River (Sarker et. al., 2020).

2. Materials and Methods

2.1 Sampling sites

The Ashuganj thermal power plant and the Ashuganj fertilizer factory are located on the banks of the Meghna River. Moreover, many new power plants are being prepared also on the bank of Meghna River on ashuganj side. All these settlements make the downstream prone to water pollution as well as aquatic. A Large number of industries and urbanizing infestations along with mechanical fishing efforts and fuel transportation which are the prior key factors to the water quality degradation. A larger number of settlements, towns, ports, and industries have sprung up on both banks of Ashuganj and Bhairab Bazar. Heavy metal analysis sites are-

1. Ashuganj thermal power plant area (Station 1-3)
2. Ashuganj fertilizer industrial area (Station 4-6) and
3. Bhairab Bazar industrial area (Station 7-9)

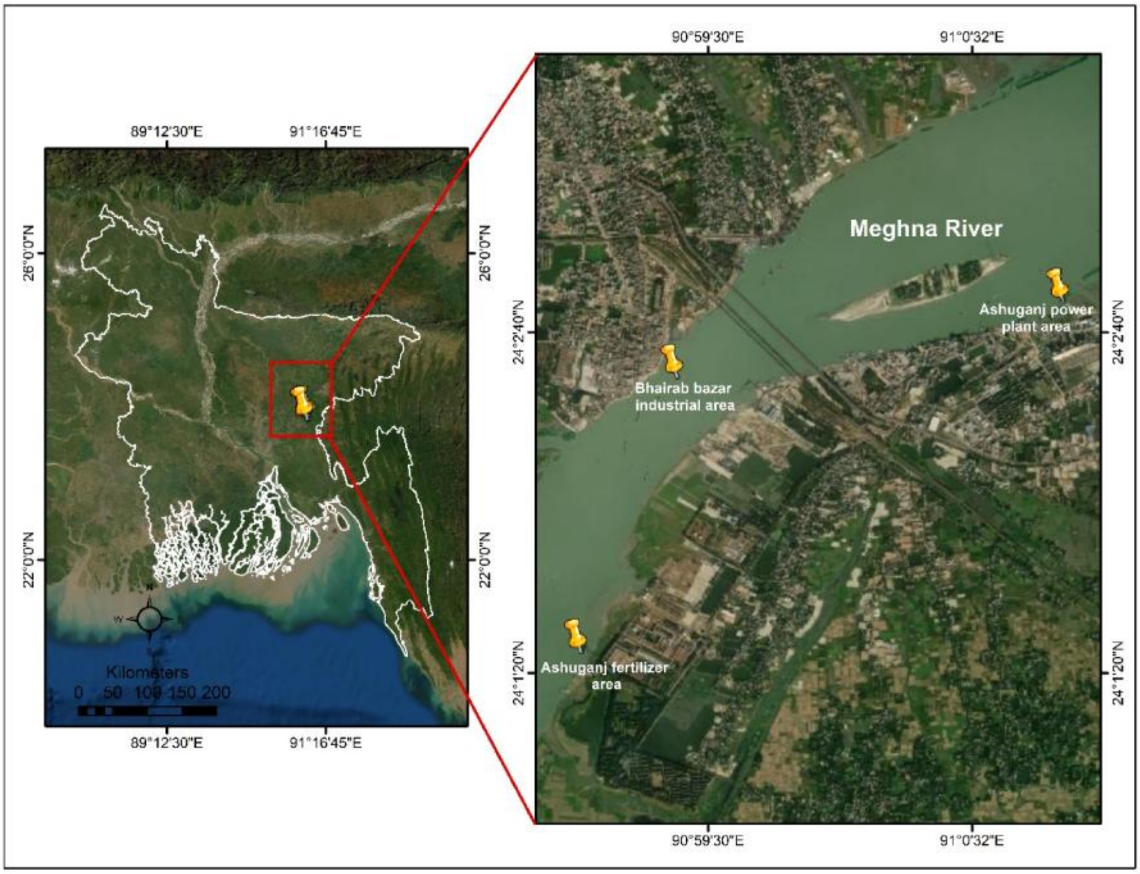

Fig-1: Location of the study area.

2.2 Sample collection and preservation

A total of 18 samples (9 water and 9 sediment samples) was collected randomly from the sampling sites. Plastic container of 500 ml was used for water sampling and LED plastic bags were used for sediment samples. Sediment samples were collected from the river bed using hand held grab sampler (Shanbehzadeh et al., 2014). For measuring heavy metal concentration, immediately after collection of the water sample, 1 ml of 65% concentrated HNO_3 was added to each of the samples, mixed one minute, and transferred to the laboratory for analysis. Water samples were properly labeled and preserved at 20^0C to preclude the risk of hydrolysis and oxidation. Sediment samples were preserved at 4^0C immediately after collection.

2.3 Heavy metal determination

Collected water and sediment samples were analyzed by the AAS (Model: is 3300, Thermo Scientific, designed in UK, Made in China) using standard analytical procedure (Table 1). Samples were carefully handled. Recommended clean powder free latex gloves and lab coats were used during the samples handling for avoiding contamination. Glassware was properly cleaned by chromic acid solution and distilled water. Analytical grade chemicals and reagents were used throughout the study. Blank determinations were used to get the correct instrument readings.

2.4 Sample preparation

The samples were weighed accurately by a suitable quantity (10–20 g) in a tarred silica dish. After that the samples were dried at 120°C in a laboratory oven. These dishes were then placed in the mu e furnace at ambient temperature and slowly raised temperature to 450 °C at a rate of 50 °C/h. The samples were ignited in a Mu e furnace at 450 °C for at least 8 h. Precaution was to be taken to avoid losses by volatilization of elements.

After cooling the dishes of the samples were removed from the furnace. Then samples were digested in desired amount of 50% nitric acid on a hot plate. After that the samples were filtrated into a 100 ml volumetric flask using Whatman No. 44 filter paper and washed the residue. All the preparation time of each sample solution was made up to the mark with distilled water.

The collected water samples were put into the PVC bottle and about 100 ml water of each sample was taken in a beaker. Then the samples were digested with adding 5 ml conc. HNO_3 on a hot plate. After that the samples were filtrated into a 100 ml volumetric flask using Whatman No. 44 filter paper and made up to the mark with distilled water.

2.5 Standard preparation

The metal standard solution was prepared for calibration of the instrument for each element being determined on the same day as the analyses were performed due to possible deterioration of standard with time. All samples were prepared by the chemicals of analytical grade with distilled water. About 1gm of Cadmium, Copper, Lead, Nickel was dissolved in HNO3 solution; 1 g of Cobalt, Iron, Manganese, Zinc, Aluminum was dissolved in HCl solution; 2.8289 g $K_2Cr_2O_7$ (=1 g Chromium) was dissolved in water and made up to 1 l in a volumetric flask with distilled water, thus stock solution of 1000 mg/l of Cd, Cu, Pb, Ni, Co, Fe, Mn, Zn, Al and Cr were prepared (Cantle, 1982). Then 100 ml of 0.1, 0.25, 0.5, 0.75, 1.0 and 2.0 mg/l of working standards of each metal except iron was prepared from these stocks using micropipettes in 5 ml of 2N nitric acid. 100 ml of 2.0, 2.5, 5.0, 10.0 and 20.0 mg/l of working standards of iron metal was prepared from iron stock solution. Reagent blank was also prepared to avoid reagent contamination.

2.6 Precaution

Samples were carefully handled (Lab coats, Gloves, Goggles, mask were used) to avoid unexpected hazards. For cleaning instruments, detergent, deionized water, the rectified spirit was used. For the correction of instrumental reading, reagents, the blank determination was used.

2.7 Analysis of samples

Atomic Absorption Spectrophotometer was setting up with flame condition and observance were optimized for the analyses. Then the blanks (deionized water), standards, sample blank and samples were aspirated into the flame in AAS (Model- iCE 3300, Thermo Scientific, designed in UK, Made in China). The calibration curves obtained for concentration vs. absorbance. Data were statistically analyzed using the fitting of a straight line by the least square method. A blank reading was also taken and necessary corrections were made during the calculation of concentration of various elements.

Table-1: Spectral lines used for emission measurements for the elements measured by using AAS:

Elements	Cr	Cd	Cu	Ca	Ni	Pb
Wavelength (nm)	357	228	324	422	232	217

2.8 Geo-accumulation Index (Igeo)

The geo-accumulation index (Igeo), originally defined by Muller is a common principle to assess heavy metal pollution in aquatic sediments. To characterize the pollution levels of sediments, Igeo is an effective tool which can be defined by the following equation (Muller, 1969):

$$\text{Igeo} = \log_2 \left[\frac{C_n}{1.5 \times B_n}\right]$$

Where Cn is the concentration of element ‘n’, and Bn is the geochemical background value. The factor 1.5 is introduced to minimize the effect of possible variations in the background values which might be attributed to lithologic variations in the sediments. The average shale as undisturbed sediment values were in (ppm):

Table-2: World average shale concentration of few heavy metals.

Background concentration	Cu	Cr	Ni	Cd	Pb	References
World average shales (ppm)	22.5	67.3	31	0.1	21	Turekian and Wedepohl (1961)

By using the average shale value, the geo-accumulation index was calculated Turekian and Wedepohl (1961). Generally, Igeo classified into seven grades (Muller, 1969):

Table-3: Grade classification of Geoaccumulation Index.

Class	I_{geo} Value	Quality of Sediment
0	≤ 0	unpolluted
1	0-1	slightly polluted
2	1-2	moderately polluted
3	2-3	moderately severely polluted
4	3-4	severely polluted
5	4-5	severely extremely polluted
6	> 5	extremely polluted

2.9 Statistical analysis

One Way Analysis of Variance (ANOVA) was done to show the variations in concentration of heavy metal in terms of seasons. The graph was used for graphical presentation of heavy metal against seasons (SPSS v. 22). Pearson's product moment correlation matrix was done to identify the relation among metals to make the result strong obtained from multivariate analysis (SPSS v.22). Additionally, the site map was tailored by the 'Arc GIS (v. 10.8) software.

3. Results

3.1 Heavy metal concentration in water

In Ashuganj power plant area Cu, Cr, Ni, Cd, and Pb concentration was found 1.6-2.2, 3.7-4.5, 8.4-10.5, 2.4-3, and 3.0-3.5 (mg/l) respectively. In fertilizer industrial area found Cu, Cr, Ni, Cd, and Pb concentration was 2.4-4, 1.8-2.4, 1.2-2, 2.1-2.7, 0.2-0.5 (mg/l) respectively. In Bhairab bazar industrial area Cu, Cr, Ni, Cd, and Pb concentration was 2.5-3, 4-5.1, 2.7-3.5, 1.1-1.9, and 1.5-2.2 (mg/l) respectively. Among the measured heavy metals in water Ni was highly concentrated (3.7±0.17) and was found in Ashuganj power plant area. The lowest concentrated (0.2±0.12) metal is Pb was found in the station ashuganj fertilizer area (Figure-2).

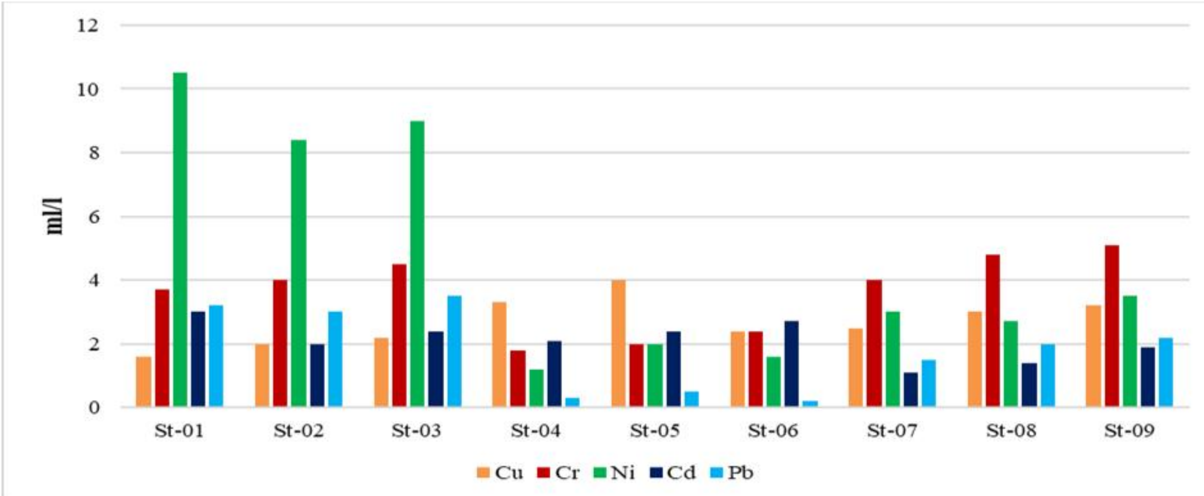

Figure-2: Heavy metal concentration in water (mg/l) of different stations over the study area.

3.2 Heavy metal concentration in sediment

The concentration of sediment varied from 1.4-2.4 (mg/kg), 3.2-3.6 (mg/kg), 37-40.6 (mg/kg), 3.5-4.0 (mg/kg) and 3.5-4.0 (mg/kg) for Cu, Cr, Ni, Cd and Pb respectively in the station Ashuganj power plant area. In Ashuganj fertilizer area the concentration of sediment for Cu, Cr, Ni, Cd and Pb varied from 2.4-8 (mg/kg), 0.9-3.6 (mg/kg), 11-12 (mg/kg), 1.2-3.5 mg/kg and 6-9 (mg/kg) respectively. In the Bhairab-Bazar industrial area the concentration of sediment varied from 1.8-8.4 (mg/kg), 1.2-5.6 (mg/kg), 1-11.5 (mg/kg), 2-4.1 (mg/kg) and 4-9 (mg/kg) respectively. The result of heavy metal concentration showed that in the Ashuganj power plant area Ni is the highest concentrated heavy metal with a value of 40.6 (mg/kg) among other heavy metals, and in the Ashuganj fertilizer area the lowest concentrated heavy metal is Cr with the value of 0.9 (mg/kg) among other heavy metals (Figure-3).

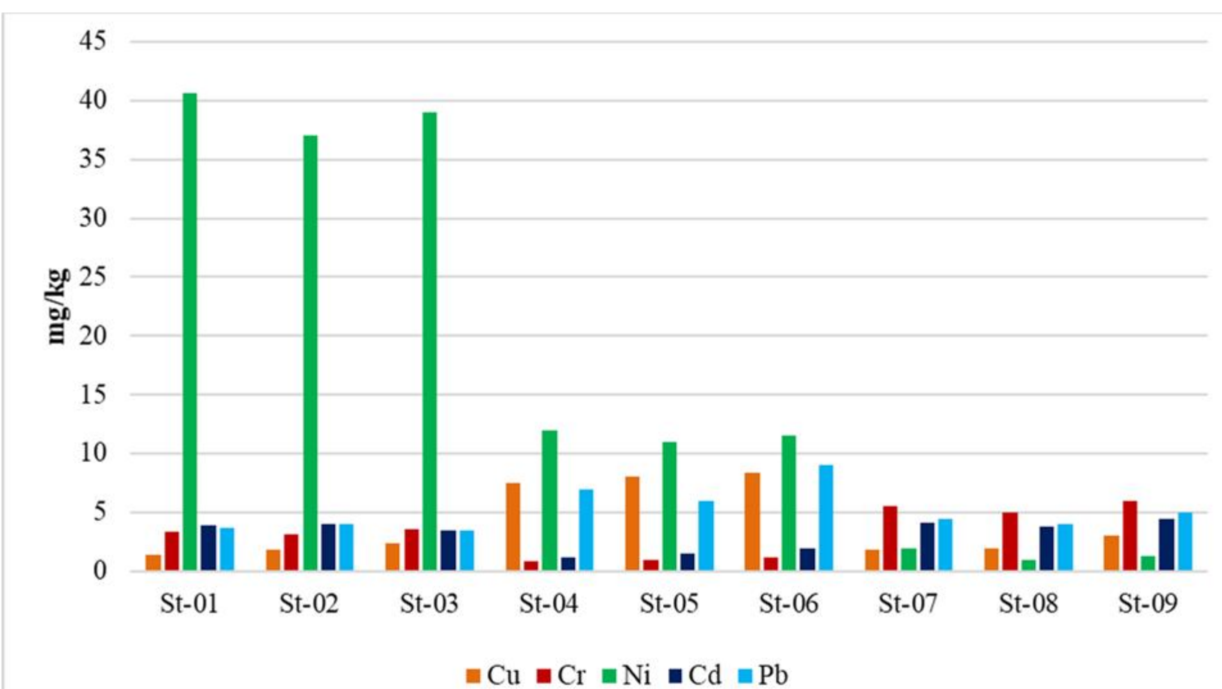

Figure-3: Heavy metal concentration in sediment (mg/kg) of different stations over the study area.

3.3 Spatial variation in water

The following graph shows the spatial variation in water of heavy metals (Cu, Cr, Ni, Cd and Pb). The mean value of Cu (3.23 mg/l) is highest in the Ashuganj fertilizer area and lowest (1.93 ml/l) in the Ashuganj power plant area. 4.63 (ml/l) is the highest average and 2.07 mg/kg is the lowest average for Cr in the Bhairab bazar industrial area and Ashugnaj fertilizer area respectively. The highest average is 9.3 (ml/l) and lowest average is 1.60 (ml/l) for Ni in the Ashuganj power plant area and the Ashuganj fertilizer area respectively. Cd is highest in the station Ashuganj power plant area with a value of 2.47 (ml/l) and 1.47 (ml/l) lowest in the Bahirab bazar industrial area. Pb mostly found in Ashuganj power plant area and less found in Ashuganj fertilizer area with the values of 3.23 (ml/l) and 0.33 (ml/l) respectively. Ni is the mostly found heavy metal among other heavy metals in water (Figure-4).

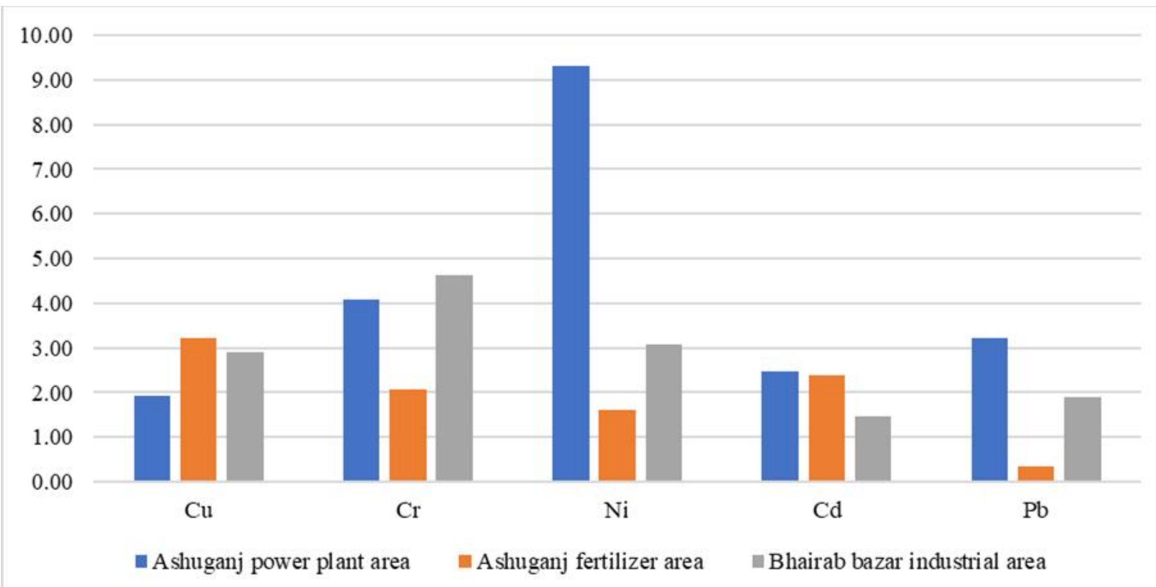

Figure-4: Spatial variation of measured heavy metal concentration in water (ml/l).

3.4 Spatial variation in sediment:

The following graph shows the overview of spatial variation in sediment for various types of heavy metals. Cu is mostly found in the Ashuganj fertilizer area with the value of 7.97 (mg/kg) and less found in 1.87 mg/kg in the station Ashuganj power plant area. 5.5 (mg/kg) is the highest value and 1.03 is the lowest value for the Cr in Bhairab bazar industrial area and Ashuganj fertilizer area respectively. The highest amount of Ni (38.87 mg/kg) found in Ashuganj power plant area and lowest amount of Ni (1.43 mg/kg) found in Bhairab bazar industrial area. 4.13 mg/kg Cd found in Bhairab Bazar industrial area and in the Ashuganj fertilizer area Cd was 1.47 (mg/kg). In the Ashuganj fertilizer area the highest amount of Pb (7.33 mg/kg) was found and lowest Pb (3.73 mg/kg) was in Ashuganj power plant area (Figure-5).

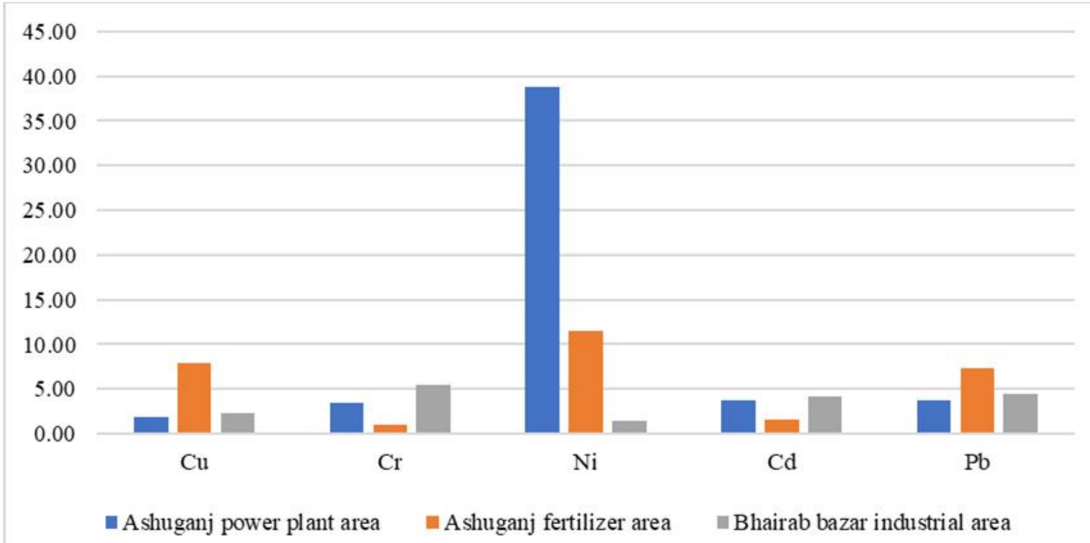

Figure-5: Spatial variation measured heavy metal concentration in sediment (mg/kg).

3.5 Geo-accumulation Index for water

The Igeo values for Cu, Cr, Ni, Cd, and Pb in most of the stations fell in class 0 which indicates that the water of these stations was almost unpolluted (Figure-6). For Cu, Cr, and Cd the Igeo values are zero for all stations which indicates that the water of these stations is almost unpolluted.

For Ni in most of the stations, the Igeo values are zero except for stations 1, 2, and 3. The water is slightly polluted in stations 1, 2, and 3. Pb is slightly different from other heavy metals for different stations. Most of the Igeo values fell in class 1 which indicates that water is slightly polluted for those stations. The Igeo values are not detected in stations 4, 5, and 6.

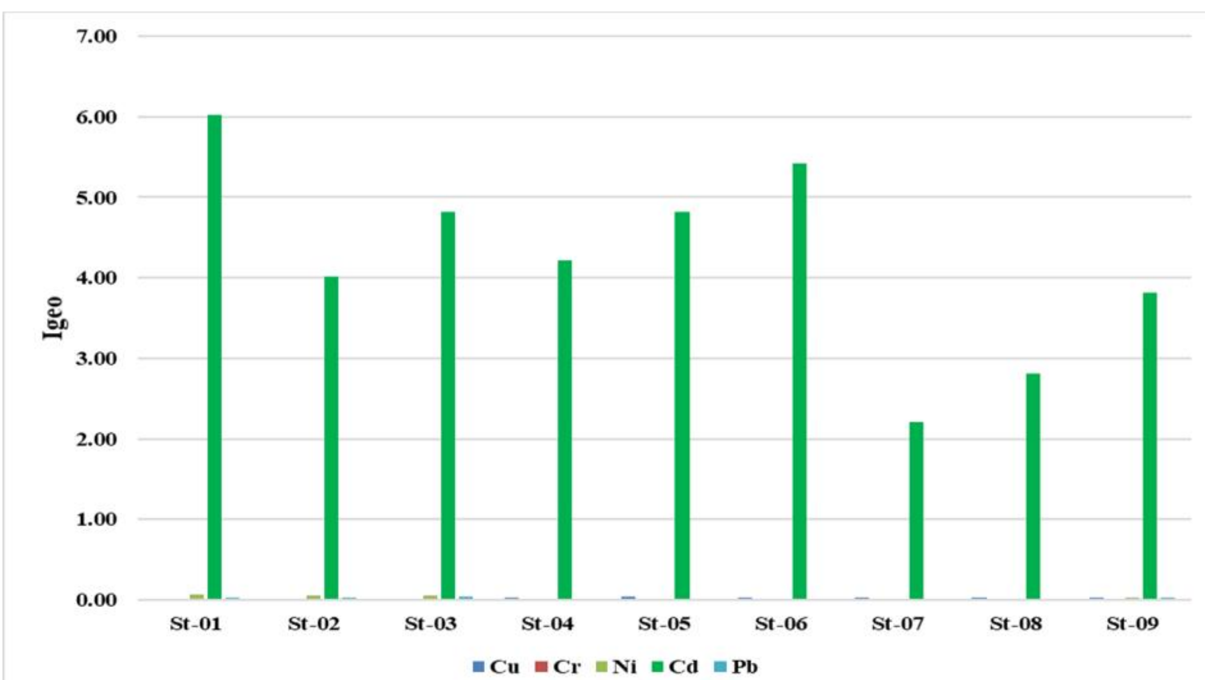

Figure-6: Geo-accumulation index of the analyzed heavy metal from the water in the study area.

3.6 Geo-accumulation Index for sediment

According to the index (Figure-7), the Igeo values for Cu in most stations fell in class 1 (unpolluted to slightly polluted). The Igeo values for Cu are not detected in stations 2, 3, 4, 5, 7, 8, and 9. For stations 1 and 6, the Igeo values fell in class 1. So, the sediments of stations 1 and 6 are slightly polluted.

For Cr the Igeo values mostly fell in class 0 (unpolluted) except for station 1 which fell in class 1 means the sediment of station-1 slightly polluted.

The Igeo values for Ni in most stations fell in class 1 (unpolluted to slightly polluted). The Igeo is not detected in stations 7, 8, and 9. The highest value of Igeo for the station-1.

For Cd the highest Igeo value is 7.83 which fell in class 6 means that the sediment of this station is extremely polluted than other stations. The Igeo values for Cd are not detected in most of the stations except station 1.

The Igeo values for Pb in most of the stations fell in class 1 which means that the sediment of these is slightly polluted. The highest Igeo value is 0.07 for station 4.

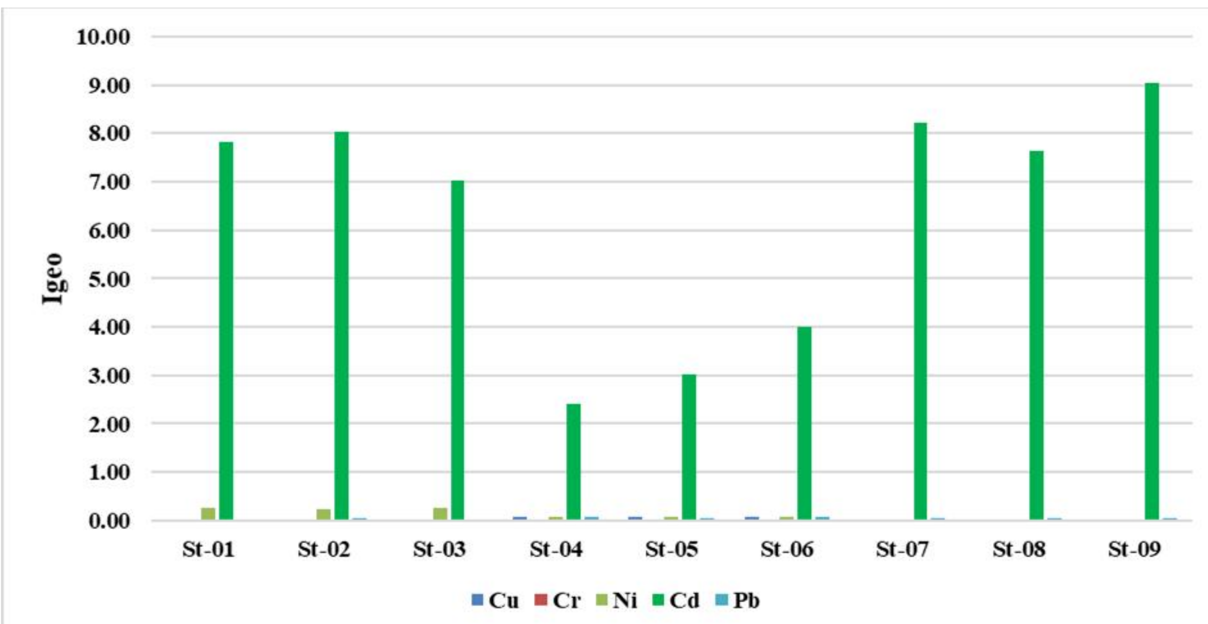

Figure-7: Geo-accumulation index of the analyzed heavy metal within the sediment of the study area.

4.7 Correlation matrix of heavy metals in water

Station-01: Ashuganj power plant area

In Ashuganj power plant area the correlation matrix of heavy metals showed a positive correlation between Cu vs Cr (0.94) and Ni vs Cd (0.99). Moderate positive correlation between Cr vs Pb (0.70). Low positive correlation between Cu vs Pb (0.43). Weak positive correlation between Ni vs Pb (0.17) and Cd vs Pb (0.29). Very strong negative correlation between Cu vs Ni (-0.82). Moderate negative correlation between Cu vs Cd (-0.74). Moderate negative correlation between Cr vs Ni (-0.58) and a weak negative correlation between Cr vs Cd (-0.48).

Table-4: Correlation matrix of heavy metal in the water of the Ashuganj power plant area.

	Cu	Cr	Ni	Cd
Cr	0.94			
Ni	-0.82	-0.58		
Cd	-0.74	-0.48	0.99	
Pb	0.43	0.70	0.17	0.29

Station-02: Ashuganj fertilizer area

In Ashuganj fertilizer area the a very strong positive correlation between Cu vs Pb (0.97) and Cr vs Cd (0.98). Moderate positive correlation between Ni vs Cd (0.50) and Ni vs Pb (0.65). Low positive correlation between Cu vs Ni (0.44), and Cr vs Ni (0.33). Moderate negative correlation between Cu vs Cr (-0.71), Cu vs Cd (-0.56), and Cr vs Pb (-0.50). And the weak negative correlation between Cd vs Pb (-0.33).

Table-5: Correlation matrix of heavy metal in the water of the Ashuganj fertilizer area.

	Cu	Cr	Ni	Cd
Cr	-0.71			
Ni	0.44	0.33		
Cd	-0.56	0.98	0.50	
Pb	0.97	-0.50	0.65	-0.33

Station-03: Bhairab Bazar industrial area

In water, the very strong positive correlation between Cu vs Cr (1.00), Cu vs Cd (0.93), Cu vs Pb (1.00), Cr vs Cd (0.92), Cr vs Pb (1.00), and Cd vs Pb (0.93). A moderate correlation between Ni vs Cd (0.72). Low positive correlation between Cu vs Ni (0.41), Cr vs Ni (0.40), and Ni vs Pb (0.41).

Table-6: Correlation matrix of heavy metal in the water of the Bhairab Bazar industrial area.

	Cu	Cr	Ni	Cd
Cr	1.00			
Ni	0.41	0.40		
Cd	0.93	0.92	0.72	
Pb	1.00	1.00	0.41	0.93

3.8 Correlation matrix of heavy metal in sediment

Station-01: Ashuganj power plant area

In sediment, very strong positive correlation between Cu vs Cr (1.00), Cu vs Ni (1.00), Cu vs Cd (1.00), Cr vs Ni (1.00), Cr vs Cd (1.00), and Ni vs Cd (1.00). weak negative correlation between Cu vs Pb (-0.14), Cr vs Pb (-0.14), Ni vs Pb (-0.12) and Cd vs Pb (-0.11) in the Ashuganj power plant area.

Table-7: Correlation matrix of heavy metal in the sediment of the Ashuganj power plant area.

	Cu	Cr	Ni	Cd
Cr	1.00			
Ni	1.00	1.00		
Cd	1.00	1.00	1.00	
Pb	-0.14	-0.14	-0.12	-0.11

Station-02: Ashuganj fertilizer area

In the Ashuganj fertilizer area result of the correlation matrix of heavy metals in sediment showed that very strong positive correlation between Cu vs Cr (0.97), Cr vs Cd (1.00), and Cu vs Cd (0.98), strong positive correlation between Cr vs Pb (0.79) and Cd vs Pb (0.76). moderate positive correlation between Cu vs Pb (0.60). Low positive correlation between Ni vs Pb (0.33). Moderate negative correlation between Cu vs Ni (-0.55). Low negative correlation between Cr vs Ni (-0.33) and Ni vs Cd (-0.37).

Table-8: Correlation matrix of heavy metal in the sediment of the Ashuganj fertilizer area.

	Cu	Cr	Ni	Cd
Cr	0.97			
Ni	-0.55	-0.33		
Cd	0.98	1.00	-0.37	
Pb	0.60	0.79	0.33	0.76

Staion-03: Bhairab Bazar industrial area

The result from the correlation matrix for Bhairab bazar industrial area showed that very strong Cr vs Cd (0.98), Cr vs Pb (0.99) and Cd vs Pb (1.00). Strong positive correlation Cu vs Cr (0.70), Cu vs Pb (0.78) and Cu vs Cd (0.83). Low positive correlation between Cr vs Ni (0.40). Weak positive correlation between Ni vs Cd (0.21) and Ni vs Pb (0.29). Low negative correlation between Cu vs Ni (-0.37).

Table-9: Correlation matrix of heavy metal in the sediment of the Bhairab Bazar industrial area.

	Cu	Cr	Ni	Cd
Cr	0.70			
Ni	-0.37	0.40		
Cd	0.83	0.98	0.21	
Pb	0.78	0.99	0.29	1.00

4. Discussion

The Meghna River in Bangladesh is a prospective site for heavy metal contamination as it is near an industrial hub and has been contaminated by industrialization, seeping oil from ships, waste products, local sewage, and agricultural inputs. The highest concentration of Cr (5.1 ml/l in water and 6 mg/kg in sediment) was found in the Bhairab Bazar industrial area, which exceeds the permissible limit (0.05 ml/l) set by the WHO (1993) and EU (1998). According to the geo-accumulation index, this area is slightly polluted by the Cr. A previous study also found a higher concentration of heavy metals in this area. Begum et al. (2009) and Ahmad et al. (2010) higher value of Cr. Alam et al. (2003) recorded a higher value of Cr (3–13 mg/kg) in the rainy season than the concentration in the dry season (1.2–8 mg/kg). Khan et al. (1998) recorded the higher concentrations of Cr in the water of the GBM (Ganges-Brahmaputra-Meghna) estuary.

The average Cd concentration was 2.64 (mg/kg), which exceeds the drinking water standard of WHO (1993) and EU (1998). The concentration of Cd was found higher in sediment than in the water. In sediment, the highest concentration of Cd found in the Bhairab Bazar industrial area was 4.5 (mg/kg), and the lowest in the fertilizer area was 1.2 (mg/kg). The highest concentration of Cd in water was found in Ashuganj power plant area 3 (ml/l) and the lowest concentration in Bhairab Bazar industrial area 1.1 (ml/l). According to the calculated geo-accumulation index, this area is extremely polluted by Cd. Similar results were recorded by Ayas et al. (2007) in Nallihan Bird Paradise, Turkey, and Alam et al. (2003) in the Buriganga River.

In sediment, the maximum amount of Ni (40.6 mg/kg) was found in the Ashuganj power plant area and the minimum found (1.00 mg/kg) in the Bhairab Bazar industrial area. In water, maximum concentration of Ni (10.5 ml/l) found in the Ashuganj power plant area, and the minimum was found (1.2 mg/kg) in the Ashuganj fertilizer industrial area. According to measured geo-accumulation index, this area is slightly polluted by Ni and exceeded the allowable limit of WHO (1993) and EU (1998). The findings of Ahmad et al. (2010) verify this result.

The mean concentration of Cu was 3.36 (mg/kg) which exceeds the permissible limit (3 mg/kg) Set by WHO (1993). Higher concentration found in sediment than the water samples. Highest value of Cu (8.4 mg/kg) found in the fertilizer industrial area and lowest value (1.4 mg/kg) found in Ashuganj power plant area. According to geo-accumulation index this area is slightly polluted by Cu. Ahmad et al. (2010), Ahmed (1998) and Rao et al. (1985) also reported similar concentration.

Mean concentration of Pb was 3.50 (mg/kg) that is higher than the safe limits set WHO (1993) and EU (1998). Highest amount (7.00 mg/kg) of Pb found fertilizer production area than the other study area. According to the geo-accumulation index study area is slightly polluted by Pb. Similar results also were found in the Buriganga River Ayas et al. (2007).

The Geo-accumulation index of sediment showed that the Cadmium (Cd) contain the highest value (7.83) among other heavy metal, which fell in class 6 means that the sediment of station-01 (Ashuganj power plant area) is extremely polluted than other stations. The Geo-accumulation index of sediment showed that Lead (Pb) is slightly different than others heavy metal for different stations. Most of the Igeo values fell in class 1, indicating that water is slightly polluted for those stations.

5. Conclusion

In recent years, heavy metal and metalloid contamination from both geological and industrial sources has grown to be a significant problem for the people of Bangladesh. The literature's findings made it abundantly evident that industrialization, seeping oil from ships, waste products, local sewage, and agricultural inputs are the key risk factors for Bangladesh's heavy metal and metalloid exposure.

This study also implies that it is impossible to assess metal contamination solely by looking at metal concentrations. To provide a more accurate assessment of the fate and transport of metals from anthropogenic sources and the subsequent environmental impact of these materials on intertidal sediments, a complementary approach integrates sediment standard criteria, enrichment factor, and geo-accumulation index should be taken into consideration.

However, further investigation of the potential for anthropogenic pollution rivers of Bangladesh is important. In addition, investigating pollution sources, violating industrial waste regulations, and initiating environmental monitoring programs are equally important. According to all pertinent sectors, the Bangladeshi government must immediately take steps to manage the country's heavy metal and metalloid pollution.

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Appendix-01: Detected heavy metal concentration in water of the study area.

Stations	Cu	Cr	Ni	Cd	Pb
St-01	1.6	3.7	10.5	3	3.2
St-02	2	4	8.4	2	3
St-03	2.2	4.5	9	2.4	3.5
St-04	3.3	1.8	1.2	2.1	0.3
St-05	4	2	2	2.4	0.5
St-06	2.4	2.4	1.6	2.7	0.2
St-07	2.5	4	3	1.1	1.5
St-08	3	4.8	2.7	1.4	2
St-09	3.2	5.1	3.5	1.9	2.2
Mean	2.69	3.59	4.66	2.11	1.82
Minimum	1.60	1.80	1.20	1.10	0.20
Maximum	4.00	5.10	10.50	3.00	3.50

Appendix-02: Detected heavy metal concentration in the sediment of the study area.

Stations	Cu	Cr	Ni	Cd	Pb
D1	1.4	3.4	40.6	3.9	3.7
D2	1.8	3.2	37	4	4
D3	2.4	3.6	39	3.5	3.5
D4	7.5	0.9	12	1.2	7
D5	8	1	11	1.5	6
D6	8.4	1.2	11.5	2	9
D7	1.8	5.6	2	4.1	4.5
D8	2	5	1	3.8	4
D9	3	6	1.3	4.5	5
Mean	4.03	3.32	17.27	3.17	5.19
Minimum	1.40	0.90	1.00	1.20	3.50
Maximum	8.40	6.00	40.60	4.50	9.00

Appendix-03: Geo-accumulation index of the analyzed heavy metal from the water of study area.

Station	Cu	Cr	Ni	Cd	Pb
St-01	0.01	0.01	0.07	6.02	0.03
St-02	0.02	0.01	0.05	4.01	0.03
St-03	0.02	0.01	0.06	4.82	0.03
St-04	0.03	0.01	0.01	4.21	0.00
St-05	0.04	0.01	0.01	4.82	0.00
St-06	0.02	0.01	0.01	5.42	0.00
St-07	0.02	0.01	0.02	2.21	0.01
St-08	0.03	0.01	0.02	2.81	0.02
St-09	0.03	0.02	0.02	3.81	0.02

Appendix-04: Geo-accumulation index of the analyzed heavy metal from the sediment of the study area.

Station	Cu	Cr	Ni	Cd	Pb
St-01	0.01	0.01	0.26	7.83	0.04
St-02	0.00	0.00	0.03	0.00	0.04
St-03	0.00	0.00	0.03	0.00	0.03
St-04	0.00	0.00	0.01	0.00	0.07
St-05	0.00	0.00	0.01	0.00	0.06
St-06	0.01	0.00	0.01	0.00	0.09
St-07	0.00	0.00	0.00	0.00	0.04
St-08	0.00	0.00	0.00	0.00	0.04
St-09	0.00	0.00	0.00	0.00	0.05

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DOI:10.22192/ijarbs.2023.10.04.003	

How to cite this article:
Md. Shafiqul Islam, Md Kamrul Hassan, Md. Deen Islam Bhuiyan, Mazharul Islam Sajeeb. (2023). Heavy metal contamination in surface water and sediment of the Meghna River ecosystem. Int. J. Adv. Res. Biol. Sci. 10(4): 22-45.
DOI: http://dx.doi.org/10.22192/ijarbs.2023.10.04.003