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Assessment of Heavy Metal Contamination in the Sediment of Gumani River, Bangladesh

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Abstract: Gumani River is a typical river in Pabna, Bangladesh. It has been suffering an increasing environmental pressure due to the rapid development of population, social-economy and urbanization as well as a long-term over-cultivation. The present study was conducted to investigate heavy metals in the sediment samples of the Gumani river. Samples were collected from five different sampling locations and were analyzed for Pb, Cd, Cr, Mn, and As by atomic absorption spectrophotometer. The observed order of heavy metal concentration in sediments was Mn>Pb>Cd>As>Cr in mg/kg. The concentrations of heavy metals (Pb, Cd, Cr, Mn, and As) in water were found lower than the permissible level. Using advanced statistical techniques and different pollution indices, the ecological risk has been analyzed to find out the sediment contamination in the Gumani River system. According to the geo-accumulation index (I_{geo}), Cd might exert a moderately hazardous influence. The pollution load index (*PLI*) assessment suggested that the sediment samples are not contaminated. Though in the study area, there is a low presence of heavy metals, proper management and monitoring are needed to maintain the ecosystem of the river and the surrounding areas.

Keywords: *Heavy metals; Sediments; Ecological Impact; Gumani River; Pollution*

Introduction: Rivers are one of the most important natural resources on earth [1]–[3]. Bangladesh is known as the land of rivers because it has been shaped as deltaic plain at the confluence of the Ganges, the Brahmaputra (Jamuna) and the Meghna rivers and their tributaries [4]. In Bangladesh, rivers are the major supply source of irrigation, hydropower and recharging the groundwater table, storage of water, purification and shipping. But, at present, the rivers of Bangladesh are being contaminated hugely and in worsen victims of pollution [3].

Besides carrying completely different sorts of waste materials, rivers conjointly carry several particulates, nutrients and minerals that play a main role in maintaining the productivity of the water bodies [5]. Nowadays, the condition is being worsened because of the discharge of toxic contaminants at a huge scale from industrial sources. Several toxic metals like arsenic, lead, nickel, cadmium, copper, mercury, zinc, and metallic element exist in untreated or allegedly treated industrial effluents are carried by rivers in variable amounts [6].

Rivers receive sediment from numerous points and subtle sources that deposited at the bottom of the river and act as both carriers and potential sources of metal accumulation within the aquatic organic phenomenon by the method of biomagnifications [7]. Heavy metals can fix in sediment for short periods. A small quantity of these permanent heavy metals can enter into the superimposed water body and uptake by the aquatic accumulation, means by crops, enter the organic phenomenon, or migrate into water and atmosphere, therefore threatening the health and reproduction of humans and animals [8].

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Over the past 3-4 decades, studies on aquatic sediments have more and more been meted out for assessing the geochemical transport of components, particularly nutrients and trace metals from the terrestrial surroundings to river bodies and eventually to the oceans. Many researchers in Bangladesh have been working on several rivers to examine heavy metal contamination. Investigation are dole out on Buriganga River [9], Dhaleswari River [10], Turag River [11], Karnaphuli River [12], Passur River [13], Shitalakhya River [14], Meghna River [15], Old Brahmaputra River [16]. The current research of river sediments was meted out to assess the concentration of heavy metals of the Gumani river sediment.

The River Gumani is one amongst the foremost used rivers in Bangladesh, running by the side of Bera a developed upazila of Pabna and Baghabari, industrial area of Sirajgonj City. Several industries have started in and around the Gumani River throughout the last decade, and the number of new industries is continually increasing. Untreated effluents are received by this Gumani River from various industries such as industries, power plants, small factories, etc. [17].

Because of recently reported increasing unauthorized excavating activities in and around the river basin, the river is getting physically unstable and chemically toxic. And for this, it poses an impact on villagers who still depends on the river for cooking and bathing during the water crisis. It also poses a negative impact on the breeding of fish [18]. Unfortunately, no scientific research concerning heavy metal contamination in the sediment of the Gumani River has been conducted so far.

The objectives of this study are: (1) to investigate the heavy metal pollution in sediments of Gumani River, (2) to investigate the ecological impact of sediments: geo-accumulation index (I_{geo}), enrichment factor (EF), the degree of contamination (C_d), contamination factor (CF), pollution load index (PLI) and (3) to spot the similar pollution sites using cluster analysis. The present study provides primary and valuable information for the geochemistry of the river Gumani sediments and contamination status. It is expected that this analysis will contribute to the identification of heavy metal contamination sources and therefore the effective conservation & management of the Gumani River.

Materials and Methods

Geological information of the study area: Gumani River plays a very important role in minimizing rural poverty and supplying food to the poor fishing community as well as for local people. It is located at an elevation of 12 meters above sea level. Its coordinates are 24°10'0 N and 89°28'0 E [19]. It originates from the river Padma and meets with the Barani near Morkal Bazar. The joint flow of Gurnai and Baranai flows southeast as the Gurnai and meets with the Gurudaspur near Chanchkoir, Gurudaspur Upazila to the east of the cholon bil and flows as the Gumani. It is 25 km long with a width of 65 m and a depth of 5m [19]. Fig. 1 shows the map of the Gumani River. This river is receiving a huge amount of untreated effluents from fifteen different types of industries such as dairy factory, textile mill, oil refinery plant, cement factory, power plants, automobile repair shop etc. The river is being polluted and posing a serious threat to the aquatic ecosystem and public health. In the summer season, the river water layer gets down and water gets mixed with the pollutants discharged by these industries.

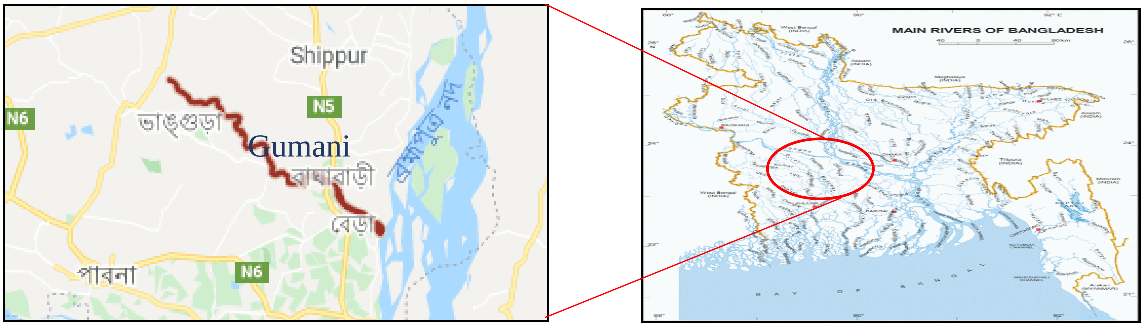

Fig. 1: Map of the Gumani River

Sampling sites: Five sample collecting stations were selected (as shown in Table 1 and Fig. 2) based on i) easy investigation site for the collection of samples, ii) all-year-round availability of water, iii) near the outlet of point sources which were maximum polluted. Sample 2, sample 3 and sample 4 were collected from the industrial impacted site (the distance between S-2 and S-3 was 558m, S-2 and S-3 was 498m). Sample 1 (1.2 km away from S-2) and sample 5 (2 km away from S-4) were collected from the pristine area. The disturbed sediment samples of the sampling sites were collected at a depth of 15-20 cm from the river bed by hand sampling and carried by a polythene bag. About 500g of the sample mass was collected in each case.

Table 1: Location of Sediment Sample Collection

Location	Location	Latitude	Longitude
S-1	Kheaghat	24°7'17.69"N	89°35'28.31"E
S-2	Patapura	24°7'39.14"N	89°35'21.44"E
S-3	Lawtara	24°7'52.32"N	89°35'22.03"E
S-4	Milkvita	24°8'5.57"N	89°34'52.46"E
S-5	Charashithilia	24°8'9.14"N	89°33'18.30"E

Fig. 2: Map showing the location of sampling points of the Gumani River

Testing method: After the collection of sediments, a portion of sediment samples was oven-dried at 105ºC temperature and ground using mortar and pestle. Some portion of samples were prepared for sieve analysis, moisture content (MC) and organic content test (OMC). Sieve analysis was conducted according to ASTM

D422 [20], moisture content analysis was conducted by ASTM D2216 [21] and the organic matter content test was conducted by the Bunsen burner ignition method. The tests were done accordingly and the average value of the result was tabulated. The heavy metal concentration was determined by atomic absorption spectrophotometer (AAS).

Preparation of sediment for analysis*:* The result of the particle size distribution of the sediment samples is presented in Fig. 3 (it is the average value of the five locations) and the result showed that 0.33% material was retained on #4 sieve, 95.5% material was retained on #8 to #200 sieve and 4.06% passing through #200 sieve, which indicates that the river contains a large amount of medium size of sediment particle. The lower particle size fraction (the fine portion of sediment samples passed through # 200 sieve) was than homogenized by grinding in an agate mortar. These samples were used to determine the MC, OMC and heavy metal analysis of sediment samples.

The average value of MC and OMC of the sediment samples were 50.7% and 6.98%, respectively. There is a relation between MC and OMC, OMC is increased with the increasing amount of MC (Fig. 4). Fig. 5 shows the relationship graph between moisture content and organic matter content. The moisture content of the sampling sites was observed to increase almost linearly with the increase of OMC (R^2=0.98). Similar trend was found in previous study [22]. The MC and OMC is found higher in the S-2 to S-4, which is industrial area. The lowest value in found in S-5 (42.1% MC and 4.6% OMC), which is far from the industrial area.

For conducting the heavy metal test, 5 gm. of each dried sample was digested with nitric acid and filtrated into a 100-ml volumetric flask using Whatman No. 41 filter paper to wash the residue. The samples were immediately sent in the BCSIR laboratory for heavy metal assessment. Finally, for each sample, five heavy metals (Pb, Cd, Cr, Mn, and As) concentration were determined from the BCSIR laboratory by using atomic absorption spectrophotometer (AAS).

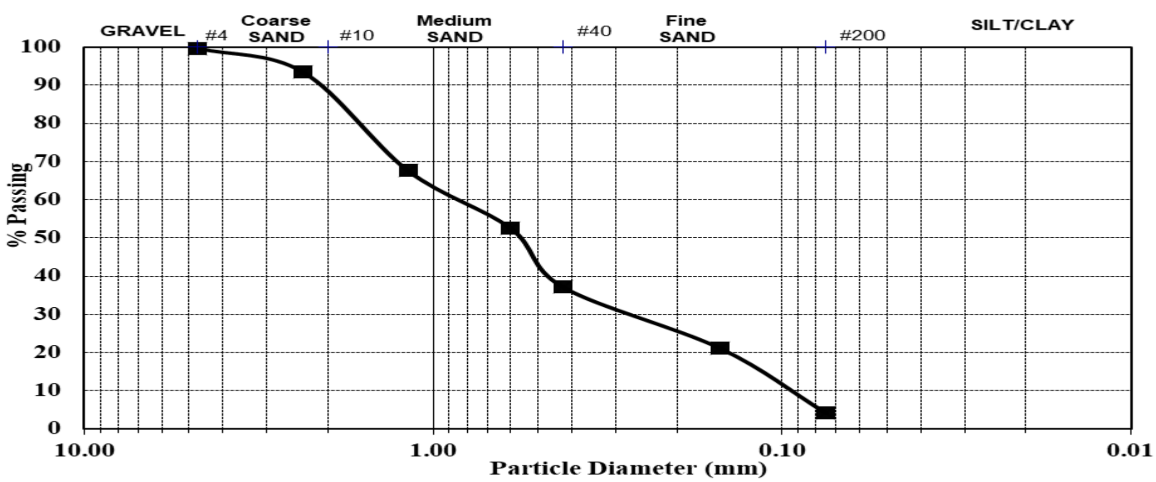

Fig. 3: Sieve analysis of the collected Sediment Samples (average value)

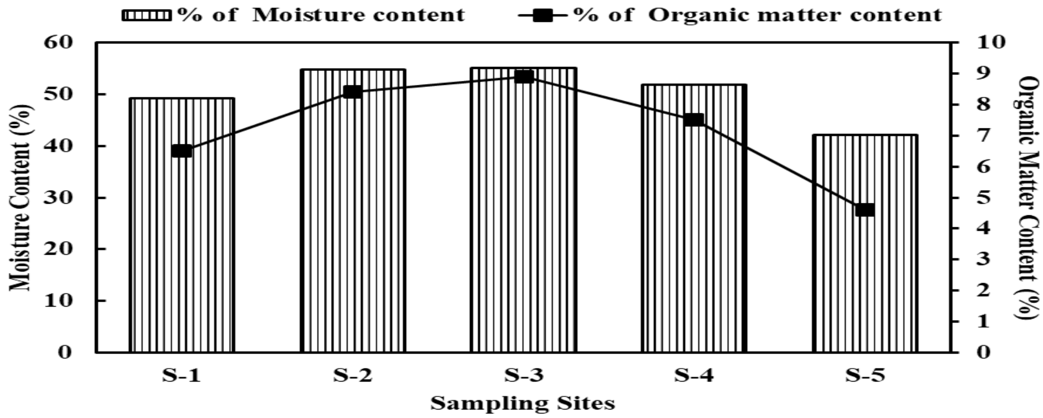

Fig. 4: Moisture Content (%) and Organic Matter Content (%) for the selected sampling sites

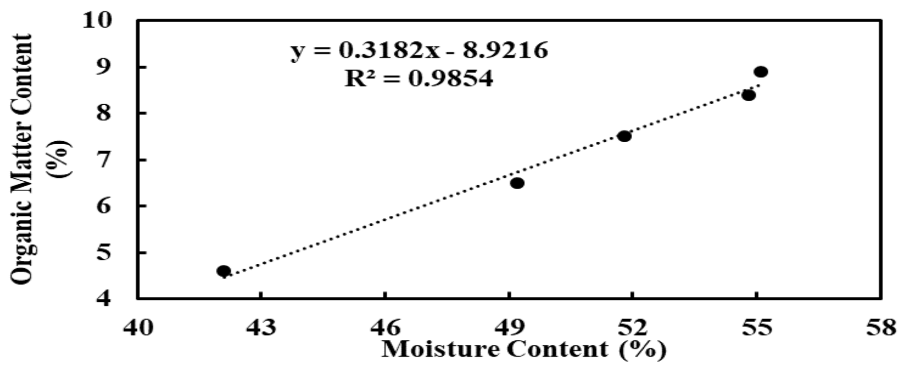

Fig. 5: Relationship between moisture content (%) and organic matter content (%)

Ecological Assessment method of sediment sample

Geo-accumulation index (I_{geo}): The Geo-accumulation index is a common criterion for the evaluation of heavy metal contamination in sediments. To detect heavy metal pollution in sediment, Muller [23] was proposed this criterion. It can be calculated by the following equation:

$$I_{geo} = \log_2\left[\frac{C_n}{1.5B_n}\right] \quad \text{eq. 1}$$

Here, C_n is the measure of heavy metal concentration in the sediment, B_n is the background concentration of the same metal and 1.5 is the factor used for a lithological variation of trace metals. The geo-accumulation index (I_{geo}) scale can be expressed by seven grades (0-6) ranging from unpolluted to highly polluted (shown in Table 2) [24].

Table 2: Muller's Classification for the Geo-Accumulation Index

I_{geo} Value	Class	Sediment Quality
≤0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly to extremely polluted
>6	6	Extremely polluted

Enrichment factors (EF): To evaluate the magnitude of contaminants in the environment, enrichment factors (EF) is considered as an effective tool. By comparing the concentration of a tested element with that of a reference element, enrichment factor (EF) is calculated [25]. The value of the enrichment factor was calculated using the following modified formula based on the equation:

$$\boldsymbol{EF} = \frac{\frac{C_n(sample)}{C_{ref}(sample)}}{\frac{B_n(background)}{B_{ref}(background)}} \qquad \text{eq. 2}$$

Where, $(C_n/C_{ref})_{sample}$ is the ratio of concentration of heavy metal (C_n) to that of concentration of reference element (C_{ref}) of the sediment sample, and $(B_n/B_{ref})_{background}$ is the ratio of metals (B_n) and reference element concentration (B_{ref}) of a background.

The most commonly used reference metals are Sc, Mn, Al, and Fe [26]. In this study, Fe was used to keep differences between natural from anthropogenic components, according to the hypothesis which quotes the content components in the earth crust have not been troubled or disturbed by anthropogenic activity affect and it has been chosen as the element of normalization because natural sources and natural process is approximated equal to (98%) of the all process that the earth evolved, so the natural sources greatly dominate its contribution [27]. Average shale values are taken from Turekian and Wedepohl [28]. Table 3 shows the classification of sediment according to the enrichment factor [29].

Table 3: Classification of sediment concerning EF

EF	Enrichment categories
<2	Deficiency to mineral enrichment
2-5	Moderate enrichment
5-20	Significant enrichment
20-40	Very high enrichment
>40	Extremely high enrichment

Contamination factor (CF): The degree of contamination (C_d) and contamination factor (CF) has been used to assess the contamination level of sediment. *CF* is is the proportion of the heavy metal concentration in the sediment to that of background value and it is calculated using the following equation [30]:

$$\boldsymbol{CFi} = \frac{C_i}{B_i} \qquad \text{eq. 3}$$

Here C_i = Measured concentration of metals, B_i = Background value of metals, CF_i = Contamination factor of heavy metal in the sediments

Degree of contamination (C_d): Degree of contamination (C_d) is a diagnostic tool to simplify pollution control which was proposed by Hakanson [31]. The degree of contamination (C_d) has been calculated as the sum of all contamination factors. Contamination factor (CF) and Degree of contamination (C_d) values for determining the contamination level has been shown in Table 4 [32]**.**

Table 4: The Classes of Contamination Factor (CF) and Level of Contamination

CF	C_d	Level of Contamination
CF< 1	$C_d<6$	Low degree of contamination
1≤ CF < 3	$6\leq C_d\leq12$	Moderate degree of contamination
3≤ CF < 6	$12\leq C_d\leq24$	Considerable degree of contamination
CF > 6	$C_d\geq24$	A very high degree of contamination

Pollution load index (PLI): The pollution load index (PLI) is a useful tool for assessing and monitoring the contamination level of sediment by heavy metal. The PLI is determined according to the following equation:

$$PLI = (CF_1 * CF_2 * CF_3 * \ldots\ldots\ldots\ldots CF_n)^{1/n} \quad \text{eq. 4}$$

Where, CF_n = Contamination factor of specific “n” number heavy metal. The PLI value greater than one ($PLI>1$) implies there exists heavy metal pollution. On the other hand, if PLI value is lesser than one ($PLI<1$) there is no heavy metal pollution [31].

Statistical analysis: SPSS V.22 software was used for the statistical analysis. Mean and SD of the heavy metal concentration were calculated. To identify the concentration of the heavy metal according to sites, one-way analysis of variance (ANOVA) was performed. Correlation between two sets of parameters (5×5), namely Pb, Cd, Cr, Mn and As has been studied, to identify the relationship between the metals. SPSS V20 software was used to compute Pearson correlation coefficient matrix (at a significant level of $P<0.05$). When one set of data is intensely connected with other (high correlation) correlation shows a value of -1 to 1, ‘1’ means a perfect positive correlation, ‘0’ means no correlation, and ‘-1’ is a perfect negative correlation. Cluster analysis (CA) (dendrogram) was performed to show the similarity among the heavy metals using SPSS V.22. CA is an effective tool to find out the similarity and variation with the influencing factors on different data sets [33].

Results and Discussion

Metal ion concentration: The total concentration of heavy metal found in sediment for each station is shown in Fig. 6. Heavy metal concentration in S-2, S-3, S-4 is high with comparison to S-1 and S-5. Cd, Cr and As level is found higher in S-1 because in this site agricultural activities and feeding of livestock was carried out and these are the main reason for this high concentration. The mean concentration of metals is found higher in S-2, S-3 and S-4 because industrial activities are carried out here. Pb, Mn and Cd contents are higher in those areas because of industrial waste, municipal waste, paints, and varnishes.

The fluctuation of heavy metal concentrations was as the following interval: Pb: 1.002-3.096 mg/kg; Cd: 0.98-1.85 mg/kg; Cr: 0.21-0.95 mg/kg; Mn: 1.559-3.776 mg/kg; As: 0.769-1.002 mg/kg. Mean concentrations of the sediment samples were Pb: 1.698 mg/kg; Cd: 1.37 mg/kg; Cr: 0.616 mg/kg; Mn: 2.588 mg/kg; As: 0.931 mg/kg. Fig. 7 shows the mean data of heavy metal content in the sediment of the Gumani River. The standard error of mean is high for Mn and Pb. Because of the variation of sample collection sites and their waste carrying types, this variation is seen. Pearson's correlation matrix of heavy metal has been represented in Table 6. The correlation matrix represents the degree of relationships among different variables. The correlation among heavy metals: Pb and Mn ($r=0.611$), Cd and Cr ($r=0.566$), Cd and Mn ($r=0.147$) indicates the strong positive correlation with each other. Pb and Cr ($r=-672$), Cd and As ($r=-0.866$), show a strong negative correlation with each other. In this study, the standard deviation between Mn and As is close to each other which may indicate the spatial distribution of metal contamination is uniform for these two metals. And for all other metal contamination is not uniform. There is another relationship found in this study, the sites which contain higher organic matter show higher heavy metal concentration Fig. 8.

Table 5: Statistical analysis for the distribution of heavy metals

Variable	Mean	Max	Min	SD	Background
Pb	1.698	3.096	1.002	0.896	20
Cd	1.37	1.85	0.98	0.424	0.2
Cr	0.616	0.95	0.21	0.304	97
Mn	2.588	3.78	1.56	0.995	459
As	0.931	1	0.77	0.1	1.8

Table 6: Correlation Matrix between Heavy Metals in Sediment Samples

	Pb	Cd	Cr	Mn	As
Pb	1	-.155	-.672	.611	-.134
Cd	-.155	1	.556	.147	-.886
Cr	-.672	.556	1	-.266	-.223
Mn	.611	.147	-.266	1	-.053
As	-.134	-.886	-.223	-.053	1

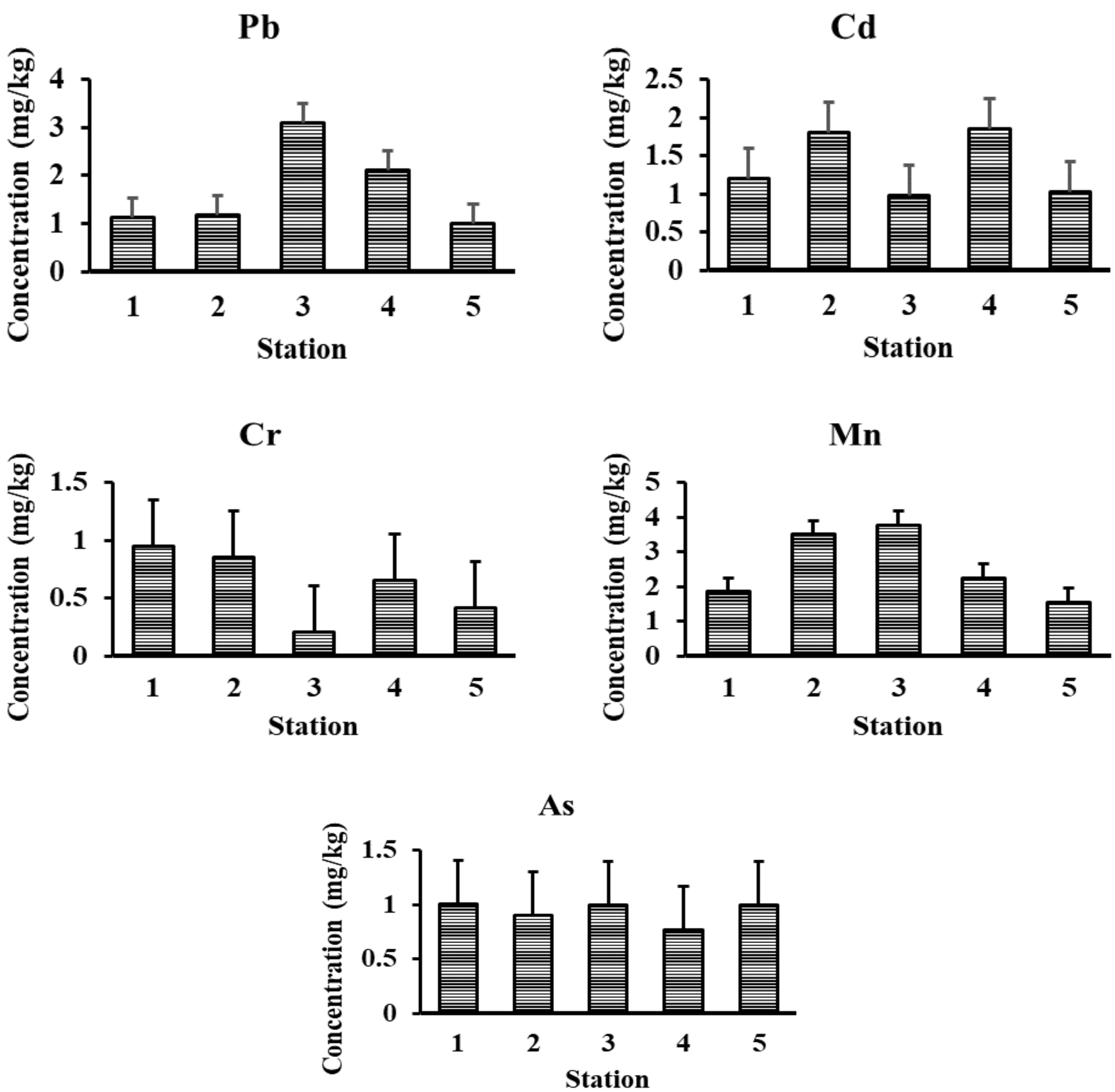

Fig. 6: Heavy metal concentration (mg/kg) of five stations (mean ± SD)

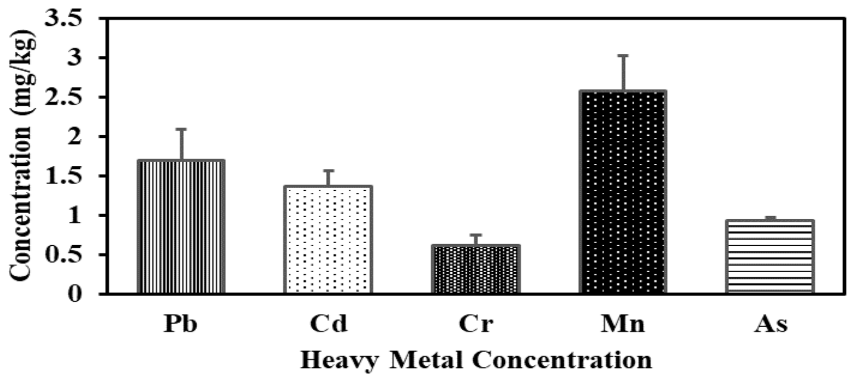

Fig. 7: Bar graph of heavy metal concentration in sediment of Gumani River

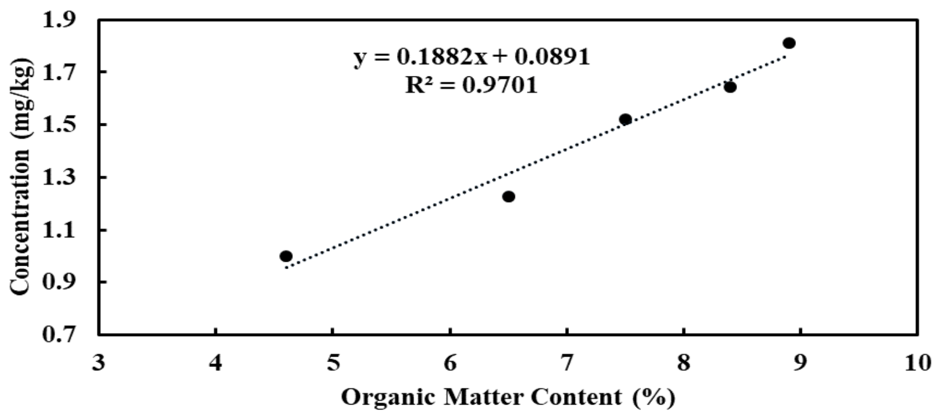

Fig. 8: Comparison between organic matter content (%) and heavy metal concentration (mg/kg)

Comparison of the metal concentration with other rivers: A comparison of the Gumani river has been made with the available data of other rivers in Bangladesh, which was previously analyzed and the result is tabulated in Table 7. From the Table, it is easily noticeable that the concentration of heavy metal in the sediment of the observed river is far below the concentration of heavy metal in the sediment of other rivers in Bangladesh. So, it can say that the observed river (Gumani) is flowing in a non-polluted form than the other river in Bangladesh.

Table 7: Comparison of the metal concentration of the Gumani River with other rivers of Bangladesh

Name of the river	Pb	Cd	Cr	Mn	As	Reference
Gumani River	1.698	1.370	0.616	2.588	0.931	Present Study
Old Brahmaputra	7.6	0.48	6.6	126.2	NT	[16]
Turag	3.56	NT	2.7	58.35	11.06	[34]
Passur	6.92	NT	19.37	NT	NT	[13]
Shitalakhya	NT	NT	74.82	NT	14.02	[35]
Meghna	6.98	0.53	6.81	ND	NT	[15]
Buriganga	31.4	1.5	173.4	4036	NT	[9]
Karnaphuli	9.85	6.46	69.56	NT	23.36	[12]

N.B: NT- Not Tested, ND- Not Detected

Assessment according to the united states environmental protection agency (USEPA): USEPA proposed a sediment quality guideline. We can evaluate the sediment contamination by comparing it with this sediment quality guideline. These criteria have been shown in Table 8. The present study shows that all the values of heavy metals are far below the EPA guideline ranges values for moderately polluted and heavily polluted. So none of the sites is being polluted by heavy metal.

Table 8: Comparison between USEPA Guideline for Sediment Quality and present study (mg/kg Dry Weights)

Metal	Not polluted	Moderately polluted	Heavily polluted	Present study
Pb	<40	40-60	>60	1.002-3.096
Cd			>6	0.98-1.85
Cr	<25	25-75	>75	0.21-0.95
Mn	<300	300-500	>500	1.56-3.78
As	ND	ND	ND	0.770-1.00

Assessments of anthropogenic pollution in sediment:

Geo-accumulation index (I_{geo}): According to the Muller scale, the calculated results of I_{geo} values (Shown in Table 9) indicated that I_{geo} values Pb, Cr, Mn and As are less than zero, which means I_{geo} class: 0, indicating that in those area has unpolluted sediment quality for those metal. But for Cd, the sampling areas were moderately polluted, because Igeo values for Cd of the five locations were positive, which exhibited I_{geo} class: 2 and 3, indicating that the sediment is moderately to strongly pollute for Cd. S-1, S-2, S-4 shows the I_{geo} value is within 2-3, which indicates that the sampling area was moderately to strongly polluted. For station S-3 and S-5, the value is within 1-2, which indicates that that area is moderately polluted for Cd.

Table 9: Geo-Accumulation Index Values of the Sediments Samples

Location	I_{geo}				
	Pb	**Cd**	**Cr**	**Mn**	**As**
S-1	-4.74	2.00	-7.26	-8.53	-1.43
S-2	-4.68	2.58	-7.42	-7.62	-1.59
S-3	-3.28	1.71	-9.44	-7.51	-1.44
S-4	-3.84	2.62	-7.81	-8.26	-1.81
S-5	-4.90	1.77	-8.44	-8.79	-1.44
Mean	-4.29	2.14	-8.07	-8.14	-1.54
Sediment Quality	Unpolluted	Moderately Polluted	Unpolluted	Unpolluted	Unpolluted

Enrichment factor (EF): The resulting EF values demonstrate that Pb, Cr, Mn and As has a low enrichment in sediment. The EF values for Cd are the highest among the metals and it has moderate enrichment Table 10). Stations that are near the industrial area have higher enrichment. S-1, S-2, S-4 shows higher enrichment. But the overall enrichment of all stations is <2, which indicated that the stations were deficient in mineral enrichment.

Table 10: Enrichment factor (EF) of toxic metals in sediment

Station No	EF						Categories
	Pb	**Cd**	**Cr**	**Mn**	**As**	**Mean**	
S-1	0.057	2.724	0.010	0.004	0.566	0.672	Mineral enrichment
S-2	0.060	4.086	0.009	0.008	0.506	0.934	Mineral enrichment
S-3	0.157	2.225	0.002	0.008	0.560	0.591	Mineral enrichment
S-4	0.107	4.200	0.007	0.005	0.434	0.950	Mineral enrichment
S-5	0.051	2.316	0.004	0.003	0.562	0.587	Mineral enrichment

Mean	0.086	3.110	0.006	0.006	0.525	0.747	Mineral enrichment

Contamination factor (CF) and Degree of contamination (C_d): Calculated contamination factor (CF) and the degree of contamination (C_d) for this study are shown in Table 11. In the present study, the contamination factor for Pb, Cr, Mn and As metal for all the selected stations was less than one (CF<1). But for Cd, it was within CF>6 for S-1, S-2, S-4, means those areas were strongly polluted and 3≤ CF<6 for S-3 and S-5, means those areas were moderately polluted. The mean of Cd for those areas was with 3≤ CF<6, which means for Cd the area was moderately polluted.

From the analysis, it is found that the study area is low contaminated. The degree of contamination of area S-1, S-2 and S-4 were within $6<C_d<12$, which means the area was moderately polluted and for S-3 and S-5, $C_d<6$ which means the area was low polluted. The mean of those areas indicates that the areas were moderately polluted.

Table 11: Degree of Contamination of the Sediment Sample

Sample location	Contamination factor (CF)					Degree of contamination (C_d)	
	Pb	Cd	Cr	Mn	As		
S-1	0.056	6.000	0.010	0.004	0.557	6.627	Moderate
S-2	0.059	9.000	0.009	0.008	0.498	9.573	Moderate
S-3	0.155	4.900	0.002	0.008	0.551	5.616	Low
S-4	0.105	9.250	0.007	0.005	0.427	9.794	Moderate
S-5	0.050	5.100	0.004	0.003	0.553	5.711	Low
Mean	0.0849	6.8500	0.0064	0.0056	0.5173	7.464	Moderate

Pollution load index (PLI): In this present study, the observed value of PLI for Pb, Cr, Mn and As for each site is below one. But for Cd the PLI>1, which means that the areas were heavily polluted for Cd. The overall areas PLI<1, which indicates that those areas were not polluted. The details of the PLI results are shown in

Table 12.

Table 12: Pollution Load Index of Sediment Sample

Sample location	Contamination factor (CF)					PLI	Comments
	Pb	Cd	Cr	Mn	As		
1	0.056	6.000	0.010	0.004	0.557	0.094	Not polluted
2	0.059	9.000	0.009	0.008	0.498	0.112	Not polluted
3	0.155	4.900	0.002	0.008	0.551	0.094	Not polluted
4	0.105	9.250	0.007	0.005	0.427	0.106	Not polluted
5	0.050	5.100	0.004	0.003	0.553	0.073	Not polluted
Mean	0.056	6.000	0.010	0.004	0.557	0.096	Not polluted

Cluster Analysis (CA): CA was executed using centroid clustering to show the similarity among the parameters that contribute hugely to sediment pollution. In the case of sediment, cluster 1 includes Cr and As; cluster 2: Pb and Mn; cluster 3: Cd (Fig. 9). Cr and As denote strong linkage with minimum cluster distance that designates those metals to have to influence power to pollution. Heavy metals that are assembled in less distance have a higher attraction with similar identical behavior during temporal variations and have a possible effect on each other. Pb and Mn formed cluster 2 with minimum cluster distance. Moreover, Mn has also strong linkage but lesser than cluster 1 and cluster 2 but contributes largely to the environment. This reflected the influence of effluents discharged from industries.

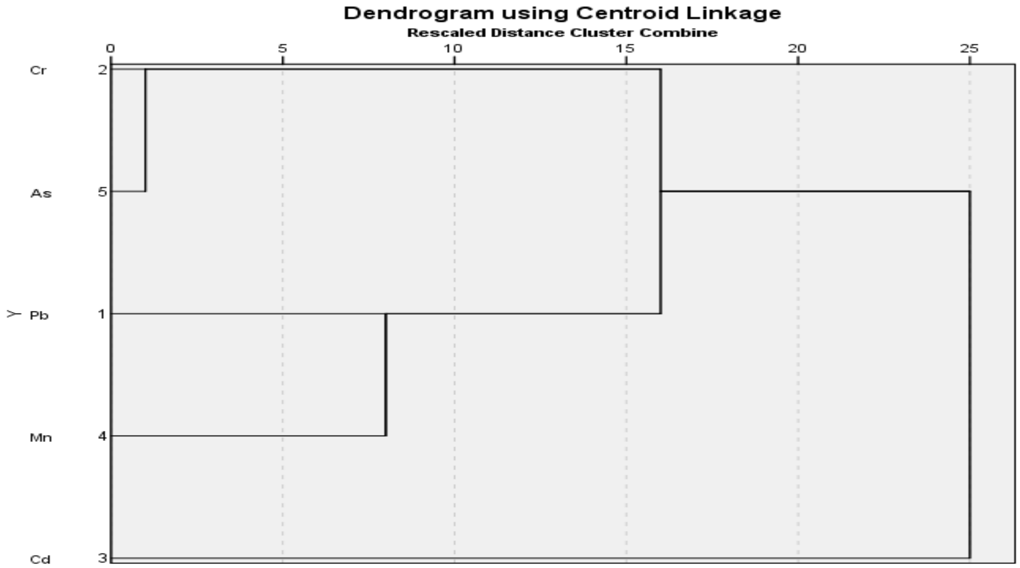

Fig. 9: Dendrogram showing the similarity among heavy metals

Conclusion: The result of this study provides important information about the heavy metal (Pb, Cr, Cd, Mn, and As) concentration and the physical characteristics of sediment collected from different sampling stations of the Gumani river. The observed order of heavy metal concentration in the sediment was as follows: Mn>Pb>Cd)>As>Cr. The sediments of the Gumani River assessed in this study have been found unpolluted for all the selected metals, as the concentration of selected metals were very low. The correlation among heavy metals: Pb and Mn, Cd and Cr, Cd and Mn indicates the strong positive correlation with each other. Pb and Cr, Cd and As show a strong negative correlation with each other. This indicates that those contaminants may have the same or similar source input. USEPA guideline comparison, geo-accumulation index, enrichment factor, contamination factor, degree of contamination, pollution load index (PLI) were successfully employed. According to the average value of geo-accumulation index, contamination factor, degree of contamination and pollution load index all the stations were not polluted. The results of the study indicate that, for every assessment, the result of heavy metal concentration was low, which indicates that the study area was not polluted by heavy metal contamination. Still, in all sites, there was the alarming presence of heavy metals. So, the government should come forward to stop the illegal disposal of industrial waste and excavation activities, which will help to reduce this heavy metal contamination.

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References Cited:

[1] EurekAlert, "Water covers 70 percent of the Earth's surface, but only a fraction is fresh," 2015.

[2] H. Singh, R. Pandey, S. K. Singh, and D. N. Shukla, "Assessment of heavy metal contamination in the sediment of the River Ghaghara, a major tributary of the River Ganga in Northern India," *Appl. Water Sci.*, vol. 7, no. 7, pp. 4133–4149, 2017.

[3] S. Rahman, "Air and River Pollution in Bangladesh: Causes and Solutions," *medium.com*, May-2017.

[4] M. J. Abedin, "The Land of Rivers," *Daily Sun*, Dhaka, Bangladesh, 22-Jul-2016.

[5] Y. Dong, D. Pruyne, and A. Bretscher, “Formin-dependent actin assembly is regulated by distinct modes of Rho signaling in yeast.,” *J. Cell Biol.*, vol. 161, no. 6, pp. 1081–92, Jun. 2003.

[6] P. U. Singare, A. G. Jagtap, and R. S. Lokhande, “Water pollution by discharge effluents from Gove industrial area of Maharashtra, India: dispersion of heavy metals and their toxic effects,” *Int. J. Glob. Environ. Issues*, vol. 11, no. 1, pp. 28–36, 2011.

[7] T. Zoumis, A. Schmidt, L. Grigorova, and W. Calmano, “Contaminants in sediments: remobilisation and demobilisation,” *Sci. Total Environ.*, vol. 266, no. 1–3, pp. 195–202, Feb. 2001.

[8] J. Wei, M. Duan, Y. Li, A. S. Nwankwegu, Y. Ji, and J. Zhang, “Concentration and pollution assessment of heavy metals within surface sediments of the Raohe Basin, China,” *Sci. Rep.*, vol. 9, no. 1, Dec. 2019.

[9] K. Mohiuddin, M. Alam, I. Ahmed, and A. Chowdhury, “Heavy metal pollution load in sediment samples of the Buriganga river in Bangladesh,” *J. Bangladesh Agric. Univ.*, vol. 13, no. 2, pp. 229–238, 2016.

[10] K. Ahmed, S. Ahamed, and S. Rahman, “Heavy Metals Concentration in Water , Sediments and their Bioaccumulations in Some Freshwater Fishes and Mussel in Dhaleshwari River , Bangladesh,” *Terr. Aquat. Environ. Toxicol.*, vol. 3, no. 1, pp. 33–41, 2009.

[11] Z. Banu, M. S. A. Chowdhury, M. D. Hossain, and K. Nakagami, “Contamination and Ecological Risk Assessment of Heavy Metal in the Sediment of Turag River, Bangladesh: An Index Analysis Approach,” *J. Water Resour. Prot.*, vol. 5, no. 2, pp. 239–248, 2013.

[12] M. M. Ali, M. L. Ali, M. S. Islam, and M. Z. Rahman, “Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh,” *Environ. Nanotechnology, Monit. Manag.*, vol. 5, no. January 2016, pp. 27–35, 2016.

[13] S. Shil, M. Islam, A. Irin, T. Tusher, and M. Hoq, “Heavy Metal Contamination in Water and Sediments of Passur River near the Sundarbans Mangrove of Bangladesh,” *J. Environ. Sci. Nat. Resour.*, vol. 10, no. 1, pp. 15–19, 2017.

[14] A. Irin, M. S. Islam, M. H. Kabir, and M. E. Hoq, “Heavy metal contamination in water and fishes from the Shitalakhya river at Narayanganj, Bangladesh,” *Bangladesh J. Zool.*, vol. 44, no. 2, pp. 267–273, 2017.

[15] M. Bhuyan and M. Islam, “Qualitative assessment of sediment from River Meghna, Bangladesh,” *Bangladesh J. Sci. Ind. Res.*, vol. 53, no. 2, pp. 89–98, 2018.

[16] M. S. Bhuyan, M. A. Bakar, M. Rashed-Un-Nabi, V. Senapathi, S. Y. Chung, and M. S. Islam, “Monitoring and assessment of heavy metal contamination in surface water and sediment of the Old Brahmaputra River, Bangladesh,” *Appl. Water Sci.*, vol. 9, no. 5, pp. 1–13, 2019.

[17] P. Talukdar, “Excavation work of Gumani river started,” *newspabna*, 06-Feb-2017.

[18] Editorial, “Sugarmill Waste throwing in River,” *ProthomALo*, 07-Feb-2018.

[19] Wikipedia, “Gumani River,” 2019. [Online]. Available: https://en.wikipedia.org/wiki/Gumani_River. [Accessed: 13-Oct-2019].

[20] ASTM (American Society for Testing And Materials), “ASTM D422-63, Standard Test Method for Particle-Size Analysis of Soils,” *J. Test. Eval.*, pp. 1–8, 2014.

[21] ASTM D2216, “Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass,” *ASTM Int.*, pp. 1–7, 2010.

[22] M. D. P. K. Saha; Hossain, “Assessment of Heavy Metal Contamination and Sediment Quality in the Buriganga River, Bangladesh,” in *2nd International Conference on Environmental Science and Technology*, 2011, vol. 6, no. June, pp. 384–388.

[23] G. Müller, “Index of geoaccumulation in sediments of the Rhine River,” *Geol. J.*, vol. 2, pp. 108–118, Jan. 1969.

[24] F. Ahmed *et al.*, “Spatial distribution and source identification of heavy metal pollution in roadside surface soil: a study of Dhaka Aricha highway, Bangladesh,” *Ecol. Process.*, vol. 5, no. 1, 2016.

[25] A. Franco-Uría, C. López-Mateo, E. Roca, and M. L. Fernández-Marcos, “Source identification of heavy metals in pastureland by multivariate analysis in NW Spain,” *J. Hazard. Mater.*, vol. 165, no. 1–3, pp. 1008–1015, Jun. 2009.

[26] J. M. Pacyna and J. W. Winchester, “Contamination of the global environment as observed in the Arctic,” *"Palaeogeography, Palaeoclimatol. Palaeoecol.*, vol. 82, no. 1–2, pp. 149–157, May 1990.

[27] V. K. Tippie, “An Environmental Characterization of Chesapeake Bay and a Framework for Action,” in *The Estuary As a Filter*, Elsevier, 1984, pp. 467–487.

[28] K. K. Turekian and K. H. Wedepohl, “Distribution of some major elements of the Earth’s crust,” *Geol. Soc. Am. Bull*, vol. 72, no. February, pp. 175–192, 1961.

[29] W. H. Liu, J. Z. Zhao, Z. Y. Ouyang, L. Söderlund, and G. H. Liu, “Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China,” *Environ. Int.*, vol. 31, no. 6, pp. 805–812, 2005.

[30] F. Shen, L. Mao, R. Sun, J. Du, Z. Tan, and M. Ding, “Contamination evaluation and source identification of heavy metals in the sediments from the lishui river watershed, southern China,” *Int. J. Environ. Res. Public Health*, vol. 16, no. 3, Feb. 2019.

[31] L. Hakanson, “An ecological risk index for aquatic pollution control.a sedimentological approach,” *Water Res.*, vol. 14, no. 8, pp. 975–1001, 1980.

[32] M. S. Hisham K. and O. Altamimi, “Assessment Of Contamination By Heavy Metals In Soil Of Laylan Area Of Iraq,” *Int. J. Adv. Res.*, vol. 4, no. 7, pp. 505–512, 2016.

[33] Y.-B. Wang, C.-W. Liu, P.-Y. Liao, and J.-J. Lee, “Spatial pattern assessment of river water quality: implications of reducing the number of monitoring stations and chemical parameters,” *Environ. Monit. Assess.*, vol. 186, no. 3, pp. 1781–1792, 2014.

[34] S. U. Masrura, “Heavy Metal Contamination Of Benthic Sediment Of Turag River Near Industrial Effluent Discharge Locations,” Bangladesh University of Engineering and Technology, 2019.

[35] S. M. D. Islam, M. A. H. Bhuiyan, T. Rume, and M. Mohinuzzaman, “Assessing Heavy Metal Contamination in the Bottom Sediments of Shitalakhya River , Bangladesh ; Using Pollution Evaluation Indices and Geo-spatial Analysis,” *Pollution*, vol. 2, no. 3, pp. 299–312, 2016.