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Pollution loads identification and ecological risk assessment of heavy metals in Patuakhali coastal sediment of Bangladesh

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ABSTRACT

The purpose of this research was to evaluate ten toxic metals from Bangladesh's Patuakhali coastal sediments: iron (Fe), manganese (Mn), nickel (Ni), arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), copper (Cu), chromium (Cr), and zinc (Zn). The ecological risk was calculated using the enrichment factor (EF), pollutant load index (PLI), geo-accumulation index (Igeo), and pollution factor (CF). The concentration range were Fe (10805-36255) mg/kg, Zn (26.91-407.75) mg/kg, Cu (11.25-65.75) mg/kg, Cr (5.425-7.11) mg/kg, Ni (119.94-246.24) mg/kg, Mn (110.88-178.18) mg/kg, As (0.0026-0.097) mg/kg and Hg (0.02-0.12) mg/kg. Compared to the US- sediment EPA guideline, this area was highly contaminated with Fe, Cu, and Ni and moderately contaminated with Mn and Zn. The EF and Igeo results were as follows: Zn>Ni>Fe>Cu>Hg>Cr>As and Ni>Zn>Cu>Fe>Mn>Hg>Cr>As, respectively. The Potential Ecological Risk Index (PERI) ranged from 94.03-241.021, demonstrating a moderate to potential ecological risk.

Keywords: Coastal sediment**;** Heavy metals**;** Pollution; Digestion; Ecological risk assessment

Introduction

The coastline of Bangladesh is more vigorous and diverse in terms of hydrology and geomorphology (Islam *et al.* 2018). Although the coastal region is a nexus of numerous biological and economic process, including mangroves (the world's biggest mangrove covers 6,017 km^2), the estuaries, tidal plane, sea grass, accreted lands, over 70 islands, seashores, rural settlements, a peninsula, urban and developed districts, ports, etc., these are aggravated by the infusion of various hazardous substances (Hossain, 2001 and Iftekhar, 2006). Severe natural and anthropogenic events disrupt these coastal areas on a yearly basis, increasing the level of sediment contamination. As a result, it is critical to examine the dispersal and contamination of pollution in coastal sediments in order to establish reference levels and track changes due to anthropogenetic actions in near future. Based on the research findings, evaluation of pollution control program is absolutely essential for contributing to coastal embankment management and the development of the blue economy concept.

Heavy metals are recognized as inorganic group of chemicals that are fallen dangerous category if they exist the USEPA permissible limit (Wuana and Okieimen, 2011). Poisonousness, enduring persistence, and eventual accretion in aquatic ecosystems make heavy metal poisoning of coastal sediments a serious global concern (Islam *et al.* 2018 and Sin *et al.* 2001). As, Cr, Cd, Cu, Pb, Fe, Mn, Ni, Hg, Zn and other heavy metals are the most frequently discovered in contaminated sites (Raknuzzaman *et al.* 2015). Several causes contribute to the presence of heavy metals in coastal sediment, including recurrent discharges of unprocessed industrial effluents, the use of chemical fertilizers and pesticides,

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rapidly and uncontrolled urbanization, and atmospheric dust/aerosol installation, the use of wastewater in irrigation, weathering and erosion of the original materials, unregulated application of sewage sludge (Islam *et al.* 2018 and Raknuzzaman *et al.* 2015). The accretion and dispersion of heavy metals in sediments are controlled by the mineralogical content, structure, and physical mobility of the sediment, which have historically been recognized as the causes of anthropogenic pollution (Raknuzzaman *et al.* 2015; Buccolieri *et al.* 2006 and Marchand *et al.* 2006). By consuming food, food items, and some vegetables grown in coastal locations, these elements can get into the human body via the food chain (Chen and Lu 2018).

However, investigation on the current status of toxic heavy metals and their imposing ecological risk on coastal sediment of Bangladesh's south-central region are still scarce, and previous literature has focused on other specific locations (southern, south western) either river, estuarine (Islam *et al.* 2018; Bhuiyan and Islam, 2017: Raknuzzaman *et al.* 2015) or ship breaking coastal area (Hasan *et al.* 2013; Siddiquee and Akter 2012). There has been no systematic research on the spatiotemporal distribution and trace elements ecological risk assessment in coastal sediments of the Patuakhali region of Bangladesh. This research aims to measure the concentration, chemical characterization, and spatiotemporal distribution of toxic heavy metals in the Patuakhali coastal regions of Bangladesh, and to investigate the ecological risk of some targeted toxic metals by means of different PLI such as CF, EF, Igeo, and PERI.

Materials and methods

Study area

The Patuakhali coastal region was chosen as the study area. This region is a part of the Barisal division and is located in Bangladesh's south-central coastal region. Patuakhali coastal zone exists within the tropical zone between 21°50'-22°50' N and 89°50'-90°50' E. The annual minimum and maximum temperatures in the area are approximately 21.67°C and 31.17°C, respectively. Major geomorphic units are estuaries, sea grass, different types of landmasses, beaches, accreted land, municipal and industrial areas, rural settlements, and ports, etc.

Sample collection and preservation

Samples were taken from ten distinct coastal sites based on the proximity to various anthropogenic activities (agriculture land, market area, industrial area, new char land, launch ghat, kuakata sea beach, canal, residential area etc.). Three replicates were chosen for each of the ten targeted heavy metals (As, Fe, Hg, Zn, Cu, Ni, Mn, Pb, Cr, and Cd) analysis in the Patuakhali regions, which were nominated as P1, P2, P3, P4, P5, P6, P7, P8, P9, and P10. The locations of every sampling point as well as their known activities in the research areas were shown in Figure 1.

Sediment samples were collected from a depth of 0 to 15 cm

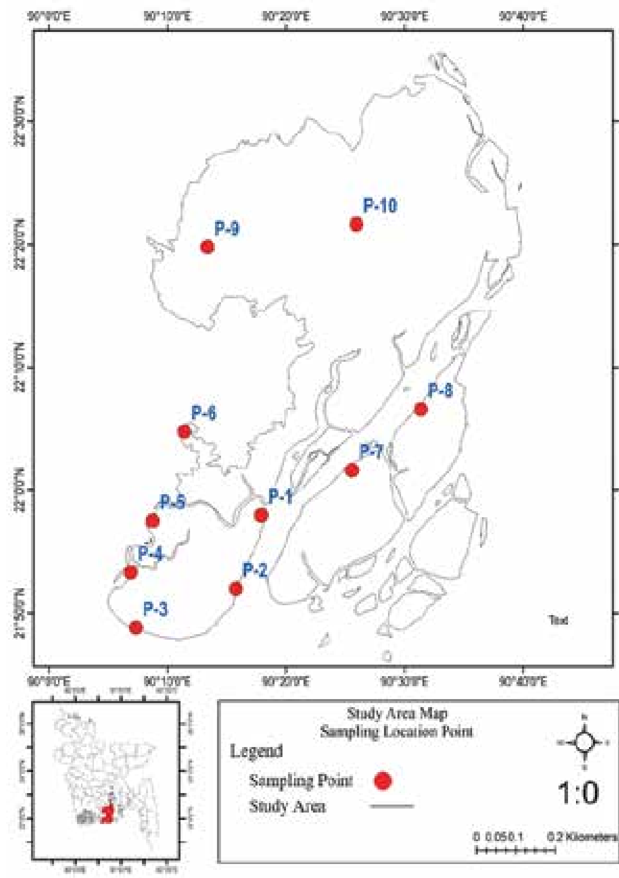


Fig. 1. Geographical location of the Patuakhali coastline study area

using a clean shovel. To avoid possible sources of pollution, the shovel was thoroughly cleaned with distilled water before being used to gather sediment samples. A medium-sized, spotless zip-lock plastic bag was used to keep the sediments. To measure the specific location of the sample, a handheld GPS tracker was used. The sediment samples were air-dried for a week using a solar panel before being ground up in an agate mortar, sorted through a 2 mm mesh screen, and stored in a sealed zip-lock bag to avoid contamination. For the digestion process, the fine powder was stored at room temperature.

Sample preparation for heavy metal analysis

The sampling preparation technique was carried out following Hossain *et al.* (2022). 1g of crushed sediment was weighed using an electronic balance and placed in separate 250 mL beakers. Each beaker received 15 mL of aqua-regia (35% HCl and 70% high purity HNO3 in a 3:1 ratio) and was covered with a watch glass. The samples were pre-digested overnight at room temperature. The samples were placed on a hot plate at 150^{o}C for three hours to progress the digestion procedure, then volumed to 50 mL in a volumetric flask with deionised water and cooled to room temperature. After 5 minutes of stirring, they were filtered (0.8 m) through a glass funnel containing Whatman no. 42 filter paper. The volumetric flasks used were selected based on the expected concentration of the sample. To recover any residual metals, the reaction vessels and watch glasses were rinsed with distilled water. The filtrate was stored in an airtight plastic bottle for subsequent analysis with an air-acetylene flame atomic absorption spectrophotometer (novAA, 400P, analytikjena, Germany).

Ecological risk assessment

Ecological risk assessment of heavy metals

Sediments background shale values are an important issue in elucidating several geochemical formulas. Despite the limitations of regional geochemical background shale values, this research used the average geochemical shale standards described by Turekian and Wedepohl (1961) to assess sediment contamination levels. The following formulas were developed to ensure the degree of contamination: EF, CF, PLI, Igeo and PERI (Piazzolla *et al.* 2015).

Enrichment Factor

To estimate the quantity of contaminants in the environment, the EF was computed relative to the abundance of species in the source material to that observed in the Earth's crust, and EFc was calculated by the following equation, as recommended by Atgin *et al.* 2000.

$$EFc = \frac{\frac{C_M}{C_{Mn}} Sample}{\frac{C_M}{C_{Mn}} Earthcrust}$$

Where, (CM/CMn) is the ratio of toxic heavy metals (HM) to manganese (CMn) concentration in the sediment sample, and (CM/CMn) is the same reference ratio exists in the Earth's crust. Turekian and Wedepohl (1961) shale values were utilized to calculate average shale values.

Five contamination groups are identified based on the enrichment factor.

- 2<EF<5 deficiency to moderate enrichment
- EF = 5-10 moderately severe enrichment
- EF = 10-25 severe enrichments
- EF= 25-50 very severe enrichment and
- EF >50 extremely high enrichments

Geo-accumulation Index

The Igeo indexes allow for something like the assessment of pollution by correlating metal concentrations attained currently owing to their pre-industrial levels. The metal's Igeo index is calculated with the following equation (Muller, 1969):

$$I_{geo} = \frac{\text{Log}_2 \text{Cn}}{1.5\text{Bn}}$$

Where, Cn = the metal concentration in the sediment, Bn = the baseline value of a specific metal in shale (Turekian and Wedepohl, 1961) and to adjust for potential differences in background values, the factor 1.5 is used.

Muller (1969) presented a geo-accumulation index with seven classes., which are as follows:

- $I_{geo} < 0$ uncontaminated
- $0 < I_{geo} < 1$ uncontaminated to moderately uncontaminated
- $1 < I_{geo} < 2$ moderately contaminated
- $2 < I_{geo} < 3$ moderately to severely contaminated
- $3 < I_{geo} < 4$ severely contaminated
- $4 < I_{geo} < 5$ severely to enormously contaminated
- $5 < I_{geo}$ enormously contaminated

Contamination Factor

The CF is aone kind of sediment contamination indicator applied for assessing pollution in a coastal environment by a particular toxic material. The level of CF was intended as by the following formula:

$$CF = \frac{\text{Cn sample}}{\text{Bn shale}}$$

Where, Cn = the quantity of a specific metal in sediment, and Bn = the shale background value of a specific metal (Turekian and Wedepohl, 1961)

The following CF values are employed to convey the contamination level (Hakanson, 1980):

1. CF < 1 low contamination
2. 1 ≤ CF < 3 moderate contamination
3. 3 ≤ CF < 6 considerable contaminations
4. CF> 6 very high contamination

Pollution load index

The PLI was proposed by Tomlinson *et al*. (1980) for identifying pollution, which allows for identifying pollution levels at various locations and times. The PLI was provided a CF of each heavy metal in relation to the soil background value. For an individual site, the PLI is calculated as the nth root of the n multiplied CF values.

This index was designed in the following manner:

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

Where *n* is the amount of toxic heavy metals.

The PLI value of 0 denotes perfection, a value of 1 represents baseline contamination, and a value more than 1 indicates increasing degradation of a coastal ecosystem (Tomlinson *et al.* 1980).

Potential ecological risk index

To measure the possible ecological damage of trace elements, Hakanson, 1980 introduced the PERI (Table I). This approach fully takes into account the interaction, hazardous level, concentration, as well as environmental sensitivity of heavy metals (Singh *et al.* 2010 and Douay *et al.* 2013). Degree of contamination (CD), potential risk factor of ecological, and toxic-response factor (TR) makes up the three fundamental modules that make up PERI (ER). The following calculations can be utilizedto compute the possible ecological risk index (ERi) of a single element and the entire possible ecological risk index (RI).:

$$C_D^i = C_f^i / C_R^i$$

$$E_R^i = T_R^i \times C_D^i$$

$$RI = \sum ER$$

where,

C_D^i = the heavy metal concentration measured at individual sampling point;

C_f^i = reference value, that used here as the background value for individual heavy metal in soil;

C_R^i= the contamination of a single component factor;

E_R^i= the single element's possible ecological risk index;

RI = inclusive possible ecological risk index;

And T_R^i = a single component's biological toxic factor.

T_R^i is determined for Cu = 5, Cd = 30, Cr = 2, Zn = 1, Pb = 5, and Ni=5 (Hakanson, 1980). PERI stands for the inclusive-possible ecological index, which includes all of ERi. It depicts the biological community's vulnerability to toxicants and illustrates the possible ecological risk produced by cumulative contamination (Islam *et al.* 2014).

Statistical analysis

Statistical software packages, notably the Statistical Package for Social Sciences (SPSS), were used for analysis. Excel was used to compute the comparative median, mean, standard

Table I. Potential ecological risk classification for a single regulator and PER

Class	Risk for single regulator	Pollution Degree	Potential Ecological Risk (PER)
1	E_r^i	Low	PER > 95
2	$40 \leq E_r^i \leq 80$	Moderate	95 ≤ PER ≤ 190
3	$80 \leq E_r^i \leq 160$	Considerable	190 ≤ PER ≤380
4	$160 \leq E_r^i \leq 320$	High	PER ≥ 380
5	$E_r^i \geq 320$	Very High	

deviation, and pollution indices for heavy metals. The spatial distribution was displayed using Arc-map version 10.8.

Results and discussion

Heavy metal concentrations in coastal sediments

Heavy metals concentrations among the ten sampling sites are summarized in Figure 2. From the ten targeted heavy metals (Fe, As, Cu, Hg, Zn, Mn, Ni, Cr, Pb, and Cd), only eight heavy metals (Fe, As, Cu, Hg, Zn, Mn, Ni, and Cr) were detected. The concentrations of Pb and Cd were under the detection limits. Various types of physiochemical parameter-si.e., salinity, pH, temperature, moisture content, organic carbon, geomorphologic structure and terrestrial or agricultural surplus may affect the heavy metals spatio-temporal distribution in sediments (Raknuzzaman *et al*. 2016). The concentration ranges (mg/kg) of all metals were illustrated in Table II, that was indicated decreasing order Fe (10805-36255)> Ni (119.94-246.24)> Zn (26.91-407.75)> Mn (110.88-178.18)> Cu (11.25-65.75)> Cr (5.425-7.11) > Hg (0.02-0.12)> As (0.026-0.097). The mean concentration (mg/kg) was differentiated with the US sediment EPA guideline, 2014 and the average concentration of Fe (23421), Ni (200.48), Zn (189.37), and Mn (149.46) were exceeded the maximum permissible limit. Though Fe is mainly earthing curst element, the highest deposition in marine environment generally originates from machinery tools, pigments, paints, and debasing in numerous industries (Islam *et al.* 2012). Vehicle emission is responsible for increasing Ni and Zn concentration in sediments (Zhang *et al.* 2016). Mn is the fingerprint elements for soil parent but industrial facilities, landfills, soil leaching and underground injection also responsible for escalating Mn concentration (Chen and Lu, 2018). The mean concentration of Cu (38.847 mg/kg), As (0.021 mg/kg), Cr (7.75 mg/kg), and Hg (0.07 mg/kg) were found under permissible limit. The comparison results between ten sampling sites were revealed that P1, P6, P4 and P10 stations were exhibited greater variation than the other sites. These sites were situated in the upstream zone merely influenced by anthropogenic interrupted due to their semi-urbanized catchment areas. Sampling sites P10 were located near the industrial area, on the other hand P1 were located near agricultural land. P4, were laid in launch ghat areas, as well as, P6 were located near the bazar areas. All these sites are directly received untreated sewage, urban runoff, domestic sewage and construction waste from housing, commercial and industrial areas.

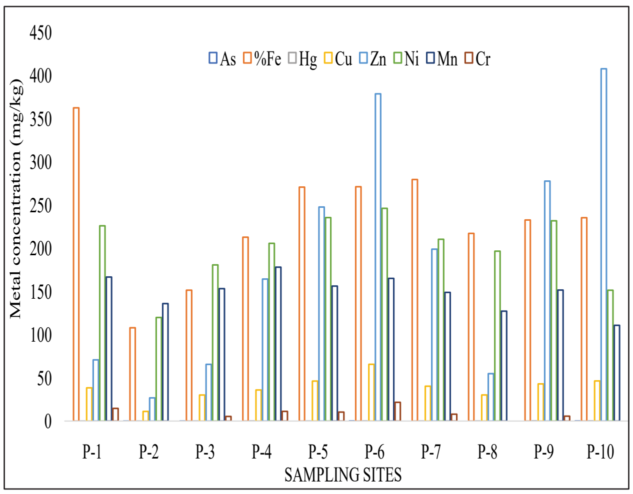
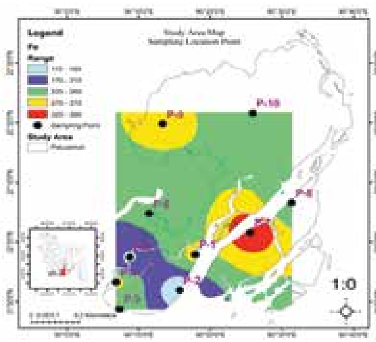


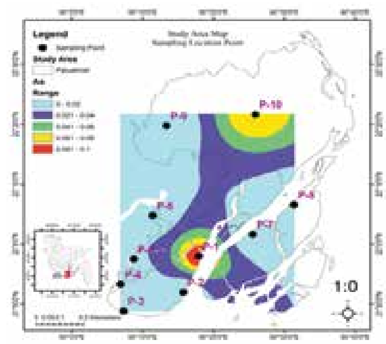
Fig. 2. Heavy metals concentration range at ten selected sampling sites in Patuakhali coastal region of Bangladesh

Table II. Chemical composition of heavy Metals in Patuakhali coastal sediment of Bangladesh

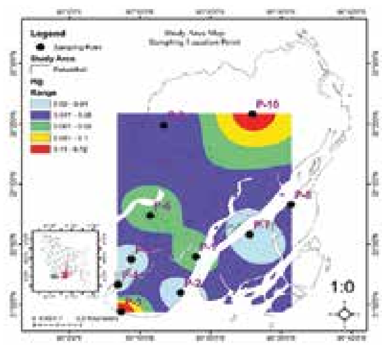
Heavy metals	Mean (mg/kg)	Concentration range (mg/kg)	US-EPA (2014) (mg/kg)	Standard deviation
As	0.021	0.026-0.097	6	0.038
Fe	23421	10805-36255	20,000	70.51
Hg	0.06	0.02-0.12	0.02	0.038
Cu	38.847	11.25-65.75	28	14.049
Zn	189.37	26.91-407.75	120	137.15
Ni	200.48	119.94-246.24	16	39.97
Mn	149.46	110.88-178.18	460	19.99
Cr	7.75	5.425-7.11	55	7.11



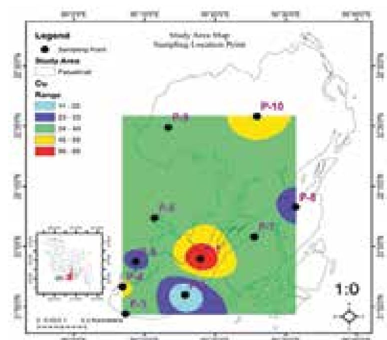
(a) Spatial distribution of Fe



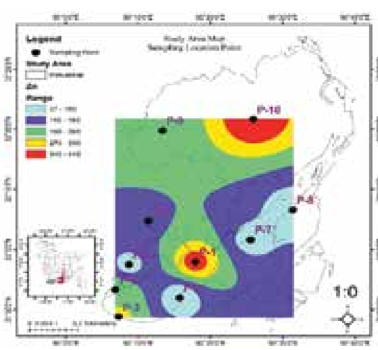
(b) Spatial distribution of As



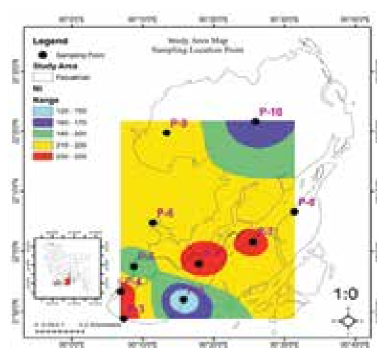
(c) Spatial distribution of Hg



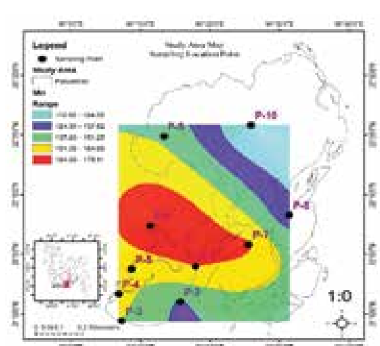
(d) Spatial distribution of Cu



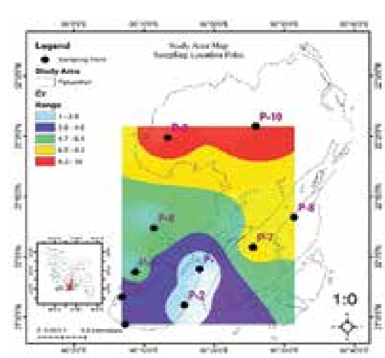
(e) Spatial distribution of Zn



(f) Spatial distribution of Ni



(g) Spatial distribution of Mn



(h) Spatial distribution of Cr

Fig. 3. Spatio-temporal distribution of specific heavy metals (a, b, c, d, e, f, g, h,) concentrations at the Patuakhali coastal region of Bangladesh

Spatio-temporal distribution of heavy metals in coastal sediment

Figure 3 illustrates the spatial distribution of eight toxic substances (As, Fe, Cu, Cr, Zn, Ni, Mn, Hg) using Arc-GIS version 10.8. This distribution pattern was created for analysing metal migration and transformation processes in the Patuakhali coastal regions. The interpolation model was used by a special arc tools box to perform a spatial analysis and describe the toxic heavy metal content in suspended form or bottom sediments. The purpose of the research was to calculate the concentration dispersion of metals at selected coastal sampling sites at depths ranging from 0 to 15 cm. Based on these maps, it was discovered that the concentration range of Fe was greater than that of any other metal (As, Hg, Cr, Cu, Zn, Mn, Ni etc.). Fe created the buffer zone to represent concentration fluctuation across the ten selected sampling sites. Simultaneously, Cu, Ni, Zn, Cr and Mn concentrations were visualized in the medium to high range. However, As and Hg were showed a low concentration range and these were uncontaminated elements for these specific sampling sites.

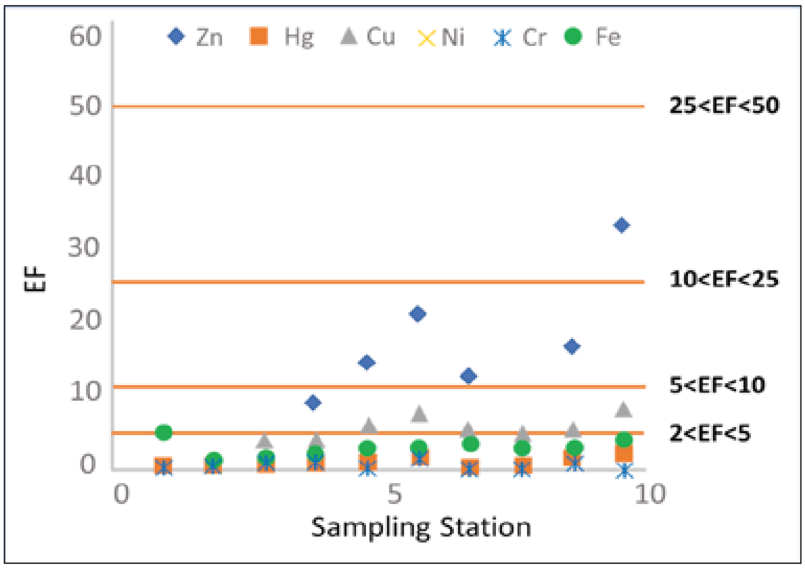


Fig. 4. Enrichment factor values for coastal sediments of Patuakhali district

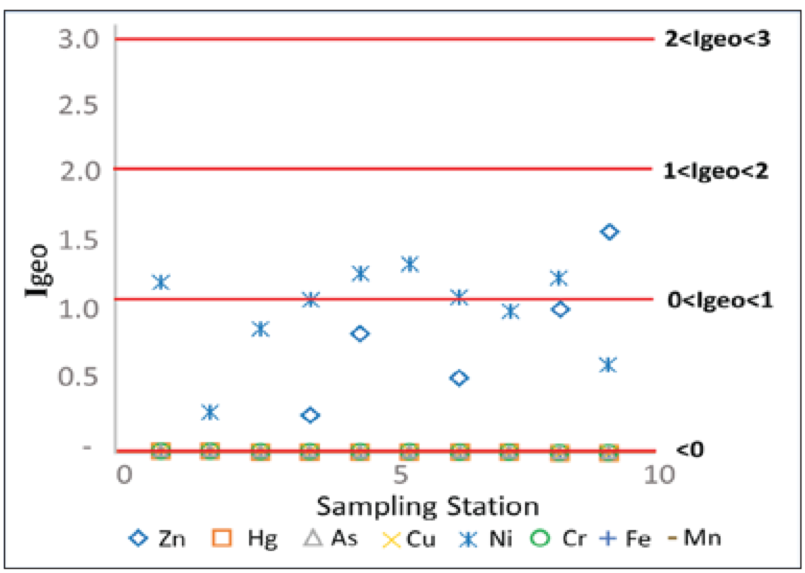


Fig. 5. Geo-accumulation index values for ten targeted heavy metals in Patuakhali coastal sediments

Ecological risk calculation

Enrichment factor

The enumerated EF data were compared to the five categories of EF contamination level reported by Martin *et al*. (2003) in Figure 4. In order to discriminate between components that are naturally occurring and those that are man-made, Mn was used in this analysis as a conservative marker. The following ordering was displayed: Zn>Ni>Fe>Cu>Hg>Cr>As to show the enrichment value for the study's subjects. Among all the metals that were targeted in terms of EF values, only Zn, Ni, Fe, and Cu demonstrated notable responses. EF values of Zn were fluctuated from 1.77 to 32.90, classifying all sites as having small to highly high enrichment factors. The Ni enrichment factor were extended from 11.02 to 19.32, representing a moderate to severe enrichment factor. EF values of Cu were ranged from 1.56 to 7.92, while Fe values were extended from 1.43 to 3.92, representing a moderate level of enrichment existence. The EF values of Hg, Cr, Ni, and As were reported that these metals had no contamination for Patuakhali coastal regions.

Geo-accumulation index

The pollution intensity was explained by a forwarding order of Ni>Zn>Cu>Fe>Mn>Hg>Cr>As based on calculated Igeo results. According to Muller's scale, only Ni had an average Igeo value greater than 0. The Igeo results for the analysed metals in the coastal sediments are depicted in Figure 5. Among metals, Ni had the highest Igeo accumulation values at P5 (1.58) sampling sites, indicating moderate contamination. Zn had the second maximum geo-accumulation value of 1.52 at the P10 sampling sites, indicating that the P10 region was also moderately contaminated. The Igeo values ranged from -0.97 to -2.71 for Fe, -0.04 to -2.58 for Cu, 1.52 to -2.40 for Zn, -5.05 to -10.08 for Hg, and -7.65 to -12.87 for As, Cr-2.63 to -4.64, Ni 1.27 to 0.23, and Mn-2.68 to-3.52. Because of their Igeo values, the Igeo revealed that the coastal sediment of the Patuakhali district was not contaminated by Fe, Hg, As, Cu, Cr, and Mn.

Contamination factor

Figure 6 depicts the outcomes of CF values for Hg, As, Fe, Cu, Cr, Ni, Mn, and Zn. The average contamination factor values were organized as follows: Ni>Zn>Cu>Fe>Mn>Hg>Cr>As: Ni>Zn>Cu>Fe>Mn>Hg>Cr> As. Whereas the average Ni values showed the highest contamination values, the average As values showed the lowest CF under the same environmental conditions. The highest CF values of Ni were found at P5 (3.62) sampling sites, while the lowest value was found at P2 sites (1.76). Form all targeted heavy metals, Zn had the highest concentration CF values at P10 (4.29) sampling sites due to industrial activities in this area where sediment sample was collected from Patuakhalisadar industrial region. The CF values for Zn revealed moderate pollution in certain sampling sites, while Ni exhibited moderate contamination in all sampling sites. Other metals including Cu, Fe, Hg, Mn, Cr, and As remained below the contamination threshold.

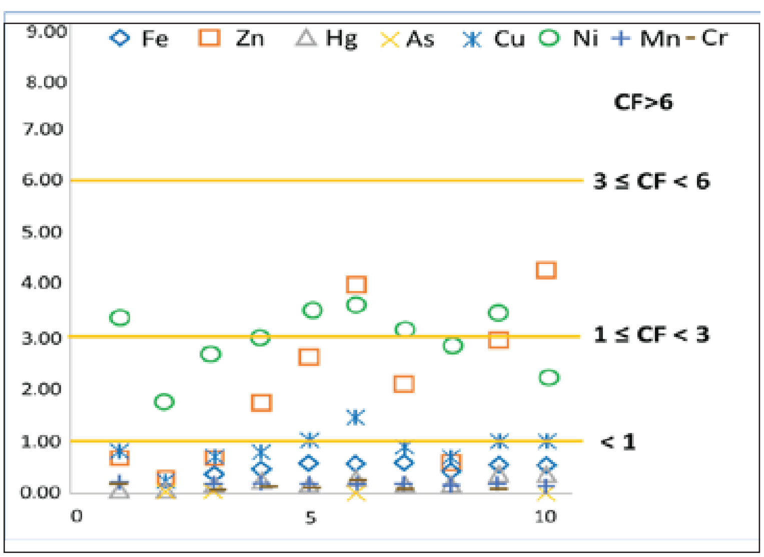


Fig. 6. Contamination factor values of selected heavy metals in Patuakhali coastal sediments

Pollution load index

PLI values was similar to 0 means there was no contamination of coastal sediment, PLI values will enrich 1 indicates the existence of baseline pollution (Mohiuddin *et al.* 2011). But if the value reaches greater than 1, it will demonstrate the gradual declining of the sampling areas (Mohiuddin *et al.* 2011). From the outcomes of PLI values (Table III) have finalized the conclusion that there was no contamination of the ten sampling sites in Patuakhali coastal regions. Because all of the individual sites displayed PLI values was below than 1. So, all of these sites are free from contamination for any individual metal.

from the sediment quality guidelines (SQG) to quantify the risk of marine organisms in coastal habitat. (MacDonald *et al.* 2000). The result appears in the Table IV: the percentage of samples with As, Cr did not surpass the TEC values, their concentration remained below the TEC value 100%. And the sample percentage of Hg 93%, Zn 60% and, Cu 23.33% concentration were computed without exceeding their TEC values. In other words, the percentage of samples with Hg exceeded 7%, Zn crossed 40% and Cu crossed concentrations 76.67%, respectively. Only the Ni percentage concentrations exceeded the PEC values by 100% and Zn showed that 6.66% of the samples crossed the limits of the PEC values. If the quantity of toxic metals surpasses the PEC standards of the SQG, the aquatic ecosystem would suffer as a result of the possibly hazardous influence on the sediments. (Voral and Sen, 2012: Pacle Decena *et al.* 2018).

Table III. Pollution load index values for selected Patuakhali coastal sampling sites

	Contamination Factor								
Point	Fe	Zn	Hg	Cu	Ni	Cr	Mn	PLI	Conditions
P-1	0.768	0.746	0.057	0.856	3.324	0.164	0.196	0.003	Below contamination
P-2	0.229	0.283	0.038	0.250	1.764	0.000	0.160	0.0002	Below contamination
P-3	0.321	0.692	0.069	0.672	2.659	0.060	0.180	0.0003	Below contamination
P-4	0.451	1.731	0.163	0.801	3.026	0.126	0.210	0.008	Below contamination
P-5	0.574	2.608	0.076	1.030	3.464	0.116	0.184	0.01	Below contamination
P-6	0.575	3.987	0.208	1.461	3.621	0.242	0.194	0.12	Below contamination
P-7	0.592	2.095	0.090	0.898	3.095	0.089	0.175	0.005	Below contamination
P-8	0.460	0.578	0.118	0.673	2.893	0.000	0.150	0.009	Below contamination
P-9	0.493	2.924	0.306	0.957	3.409	0.064	0.178	0.016	Below contamination
P-10	0.499	4.292	0.276	1.034	2.228	0.000	0.130	0.18	Below contamination

Table IV. Consensus-based sediment quality guideline values (mg/kg) for heavy metals of Patuakhali coastal sediments in Bangladesh

Metal	As	Hg	Cu	Zn	Ni	Cr
TEC	9.79	0.18	31.6	121	22.7	43.4
PEC	33.00	1.06	149	459	48.6	111.0
LEL	6.00	0.2	28	120	16	55.0
% of sample< TEC	100%	93%	23.33%	60%		100%
% of sample> PEC				6.66%	100%	

TFC= Threshold effect concentration
PEC= Probable effect concentration

Sediment quality guideline

In this study, the toxic metal concentrations were identified using consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC) values

Potential ecological risk index

The results of potential ecological risk factor E_r^i and the PER concise in Table V. The table was computed by the classification of ecological risk factor and the potential ecological risk index (PER). The ecological risk factor for all single metals in coastal sediments was Ni>As>Cu>Hg>Zn>Cr. When the prospective ecological risk index of individual metal E_r^i (Table V) was combined with its classifications, other metals exhibited low potential ecological risk without Ni. The individual ecological risk factor (Er^i) value of As, Cu, Hg, Zn, and Cr were remained below 40. However, only Ni was showed highest ecological risk in this research. The maximum probable ecological risk factor (E_r^i) of Ni was exhibited in P6 sampling sites which was 181.06. Ni was demonstrated as considerable ecological risk. The primary sources of nickel (Ni) in sediment are often the use of various types of fertilizers on agricultural fields adjacent to rivers and the disposal of municipal waste. (Chen and Lu, 2018). By calculating the overall integrated assessment, all sample sites were identified as having a moderate to high probable ecological risk. The PERI values for all sampling stations were shown in descending order of P2> P3>P8>P4>P7>P1>P10>P5>P9>P6. These station PERI values ranged from 90.03 to 241.021, indicating a substantial ecological threat in this coastline province. The second-highest level of pollution was discovered in P9 sampling locations, which were identified as the Kuakata sea beach area of the Patuakhali District and suggested a significant potential ecological danger due to anthropogenic inputs

Table V. Potential risk factors, risk index and pollution degree

Point	Potential ecological risk factor E_r^i						Potential ecological risk Index (PERI)	Pollution degree
	Zn	Hg	As	Cu	Ni	Cr		
P-1	0.75	2.28	-	4.28	166.21	0.33	173.84	Moderate
P-2	0.28	1.51	2.80	1.25	88.19	-	94.03	Moderate
P-3	0.69	2.76	6.90	3.36	132.93	0.12	146.77	Moderate
P-4	1.73	6.52	-	4.01	151.28	0.25	163.79	Moderate
P-5	2.61	3.04	-	5.15	173.19	0.23	184.22	Moderate
P-6	3.99	8.32	39.87	7.31	181.06	0.48	241.02	Considerable
P-7	2.09	3.58	-	4.49	154.74	0.18	165.08	Moderate
P-8	0.58	4.74	-	3.37	144.63	-	153.31	Moderate
P-9	2.92	12.24		4.79	170.47	0.13	190.55	Considerable
P-10	4.29	11.03	42.92	5.17	111.39	-	174.80	Moderate

The current study demonstrated that newly deposited sediments have the aptitude to adsorb toxic heavy metals that can enter the coastal biological system. Furthermore, the previous result of coastal studies had an emphasis on physical variables and a lack of understanding of chemical procedures that displayed contradictory outcomes. This would provide limited knowledge about the transmission and dispersion of heavy metals. Adsorption experiments provided a thorough understanding of how heavy metals bind with coastal sediments. Because of our improved understanding of adsorption mechanisms, now researchers can diagnose the mobility of inorganic pollutants in deposited sediments along coastlines. The application of chronological extraction techniques on environmental samples provides relevant data on potential toxicity that is released into the environment. Developing future remediation measures and pollution prevention programs for coastal sediments, especially in the Patuakhali regions that were the main focus of this topic inquiry, requires a knowledge of the mobility of potentially harmful components and how they might be transmitted in human-induced circumstances.

Conclusion

Heavy metals have a significant detrimental impact on marine resources due to their persuasiveness and aggregation capability in coastal areas. The overall findings of this research were to quantify the concentration of ten targeted toxic metals (Fe, Mn, Ni, As, Cd, Pb, Hg, Cu, Cr, and Zn) and visualized their imposing ecological risk. The concentration of these metals was well-arranged in the following order based on their mobility and bioavailability: Fe>Ni> Zn>Mn> Cu> Cr> Hg> As. The distribution results were revealed that Fe, Zn, Ni, and Mn are more bioavailable and transportable than Cu, Cr, Hg, and As. The ecological risk concluded that the sediment samples were highly contaminated with Fe, Cu, and Ni and moderately contaminated with Mn and Zn. The spatial distribution results highlighted the most hazardous zones that were enriched with excessive pollution loads. The CF, EF, PERI, and Igeo results will be utilized as reference data for ensuring human-induced consequences in the Patuakhali coastal zone of Bangladesh.

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Not applicable

Consent to participate

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Authors contributions

Niger Sultana: Investigation, Methodology, Formal analysis, data analysis, Writing - original draft and editing; M. Mahbubur Rahman: Supervision, review and editing and Shamima Akther Eti: Idea generation, Conceptualization, Supervision, Method Validation, Funding acquisition, Writing - review and editing.

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