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Research paper

Assessment of heavy metals with ecological risk of soils in the industrial vicinity of Tangail district, Bangladesh

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Abstract

This study was conducted to assess the ecological risk of heavy metals in soils collected from the industrial vicinity of Tangail district in Bangladesh. In this study, the levels of six heavy metals namely chromium (Cr), nickel (Ni), copper (Cu), arsenic (As), cadmium (Cd), and lead (Pb) in 15 sampling sites around the industrial vicinity of Tangail district in Bangladesh were assessed. The mean concentration of Cr, Ni, Cu, As, Cd and Pb in studied soils were 11.56, 23.92, 37.27, 6.11, 2.01, and 17.46 mg/kg, respectively. Certain indices, including the enrichment factor (EF), contamination factor (C^i_f), geoaccumulation index (I_{geo}), pollution load index (PLI), toxic unit analysis, and principal component analysis (PCA) were used to assess the ecological risk. The enrichment factor of all the studied metals for all sampling sites were in the descending order of Cd > Cu > As > Pb >Ni > Cr. The contamination factor values revealed that the studied soils were highly impacted by Cd. The pollution load index (PLI) values of Cd were higher than 1, indicating the progressive deterioration of soil due to Cd contamination. In the context of potential ecological risk (PER), soils from all sampling sites showed moderate to very high potential ecological risk.

Keywords: *Heavy Metal; Potential Ecological Risk; Industrial Vicinity; Bangladesh*

1. Introduction

For the survival of human life on the planet, soil act as a dynamic natural resource and regarded as the key receiver of the persistent pollutants like heavy metals (Luo et al. 2007, Karim et al. 2014, Islam et al. 2015, Proshad et al. 2018). Soil pollution by heavy metals is a global problem that is highly predisposed by human-induced activities (Han et al. 2002, Vare 2006, Islam et al. 2015). Nowadays, soil pollution by heavy metals has become an environmental issue in both developed and developing countries all over the world (Islam et al. 2015, Sun et al. 2010). Heavy metals such as nickel (Ni), chromium (Cr), copper (Cu), arsenic (As), cadmium (Cd), and lead (Pb) have been considered as the most toxic elements in the environment by the US Environment Protection Agency (EPA) (Luo et al. 2007, Lei et al. 2010, Proshad et al. 2017). In recent decades, there has been a major concern regarding soil pollution by various heavy metals due to rapid industrialization and urbanization, especially in developing countries (Islam et al. 2015, Sun et al. 2010, Chen et al. 2010, Islam et al. 2014, Ahmed et al. 2015). Heavy metals are of great concern due to their toxicity, non-biodegradable properties and accumulative behaviors (Islam et al. 2015, Islam et al. 2014). Heavy metals may initiate in soils around the industrial area from various sources of which are industrial activities, power generation, manufacturing, waste spills, or fossil fuel burning and waste disposal (Luo et al. 2007, Karim et al. 2014, Wei and Yang 2010, Li and Feng 2012, Rodriguez et al. 2014, Islam et al. 2015). The accumulation of heavy elements in soils is a great concern due to their potential environmental risk and harmful effects on soil ecosystems (Islam et al. 2015, Cui et al. 2004, Li et al. 2009, Yu et al. 2012, Yuan et al. 2014). To assess the ecological risks of heavy metals in soil different methods have been widely used, such as enrichment factor (EF), contamination factor (C^i_f), toxic unit analysis, and geoaccumulation load index (I_{geo}) (Islam et al. 2015, Rashed 2010). The enrichment factor of an area indicates the relative enrichment in any pollutant when compared to pre-industrial soils from the same environment (Islam et al. 2015, Sayadi and Sayyed 2011, Hower et al. 2013, Dias et al. 2014). As soil contamination arising from industry, the study area has raised attention due to its environmental pollution which is facing serious threats due to heavy metals pollution originated from the rapid development, congestion, and activities from industries (Islam et al. 2015, Islam et al. 2014). Several studies have stated the concentration of heavy metals in the industrial area soils in Bangladesh (Islam et al. 2015, Ahmad and Goni 2010, Rahman et al. 2012). Therefore, in this study, the variations of heavy metals in soils of different soil sampling sites were studied. The objective of this study was to assess the ecological risk of heavy metals in soil in the industrial vicinity of Tangail district in Bangladesh.

2. Materials and methods

2.1. Study area and sampling

The samples were collected from Tarutia, Tangail Sadar Upazila of Tangail district, Bangladesh (Figure 1). Tangail district area is 334.26 km² and situated at the middle part in Bangladesh. Tangail Sadar Upazila is highly densely area in Bangladesh and population density is 1,100/km2 in Tangail district. The study area is situated between Tangail Sadar is located at 24.2500°N to 89.9167°E. Tangail as an industrial vicinity of Bangladesh possesses highly vulnerable to environmental pollution nowadays. There are several types of industrial units including garments, packaging industry, dyeing, brick kiln, metal workshops, battery manufacturing industries, tanneries, textile industries, pesticide and fertilizer industries, different food processing industries and other factories produce huge volumes of effluents that contain trace metals. These industries are discharged untreated wastes randomly to river and canals. Then that wastes are mixed with soils and the soil is continuously polluted by toxic elements in the industrial areas of Tangail district in Bangladesh. Soil samples were collected during March- April, 2016. Tarutia was selected for sampling location situated near the industrial area of Tangail district, Bangladesh. Fifteen soil sampling sites were selected in the industrial areas of Tangail district. Agricultural field soil samples (samples were collected from the surface soil up to 10 cm) were taken and three subsamples collected which were used as composite sample by mixing it thoroughly. Samples were kept in air-dried at normal temperature for two weeks, then ground and homogenized. Soil was taken with the help of a percussion hammer corer (50–80 cm in length) for metal analysis and those samples were treated as pre-industrial sample (Schottler and Engstrom 2006). A porcelain mortar and pestle used to crumble all dried soil samples. Then the samples were sieved with 2 mm nylon sieve. The soil samples were stored in a clean Ziploc bag which was airtight and used for chemical analysis. Several researchers also followed the alike procedure for sampling and storing of soil samples (Oliveira et al. 2012a, Oliveira et al. 2012b, Arenas et al. 2014).

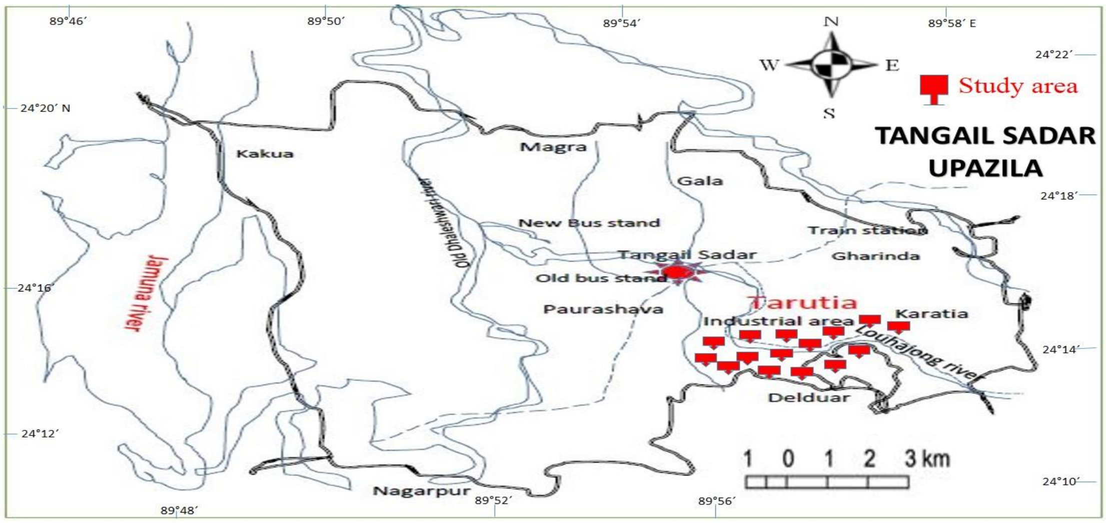

Fig. 1: Map Showing the Study Area of Soil Sample Collection in Tangail District (Industrial Vicinity), Bangladesh

2.2. Sample analysis

Analytical grade reagents were used for sample analysis and Milli-Q (Elix UV5 and MilliQ, Millipore, USA) water was used for the preparation of the solution. 4.5 mL 35% HCl (Kanto Chemical Co, Tokyo, Japan) in a closed Teflon vessel added with 1.5 mL 69% HNO3 (Kanto Chemical Co, Tokyo, Japan) which was mixed with 0.3 g of the soil sample and Microwave Digestion System (Berghof speedwave ®, Eningen, Germany) was used in metal analysis for soil sample. The digested solution was then filtered using a syringe filter (DISMIC®-25HP PTFE, pore size= 0.45 µm) (Arenas et al. 2014, Cerqueira et al. 2011, Cerqueira et al. 2012, Silva et al. 2012). Then the filtrate solution was used for storing (50 mL polypropylene tubes were used for storing).

2.3. Instrumental analysis and quality control

For hazardous elements, samples were analyzed using inductively coupled plasma mass spectrometer (ICP-MS, 7700 series). Multi element Standard XSTC-13 (SpexCertiPrep®, Metuchen, USA) solutions were used to prepare the calibration curve. Multi-element solution (Agilent Technologies, USA) 1.0 µg/L was used as tuning solution covering a wide range of masses of elements. All test batches were evaluated by applying internal quality system and validated if they satisfied the defined Internal Quality Controls (IQCs).

2.4. Ecological risk assessment for soil pollution

2.4.1. Enrichment factor (EF)

Enrichment factor assumed an impressive tool and used for determining hazardous element magnitude of environment (Franco et al. 2009). In soil, anthropogenic influences of toxic metals were assessed by enrichment factor and following formula was used (Selvaraj et al. 2004):

$$EF = (C_M/C_{Al})_{\text{sample}} / (C_M/C_{Al})_{\text{background}} \quad (1)$$

Where, $(C_M/C_{Al})_{\text{sample}}$ is assumed as ratio of hazardous element concentration of (C_M) to that of aluminum (C_{Al}) in the soil sample, and $(C_M/C_{Al})_{\text{background}}$ is the same reference ratio in the background sample. Enrichment factor value of toxic element is equal to 1 indicate that toxic elements arise due to natural weathering processes in the environment (Zhang and Liu 2002). When enrichment factor is higher than 1.5 resulting of human interference. Enrichment factor effects of metals known as minor, moderate, severe, and very severe modification when enrichment factor value are 1.5–3, 3–5, 5–10 and >10 respectively (Birch and Olmos 2008).

2.4.2. Contamination factor (C^i_f)

Contamination factor is the ratio of the metal concentration in the soil to that of baseline or background value:

$$(C^i_f) = C_{\text{heavy metal}} / C_{\text{background}} \quad (2)$$

The levels of contamination factor may be grouped into four classes ranged from 1 to 6 which are: low degree (C^i_f <1), moderate degree ($1 \le C^i_f < 3$), considerable degree ($3 \le C^i_f < 6$) and very high degree ($C^i_f \ge 6$) (Luo et al. 2007, Islam et al. 2015).

2.4.3. Geoaccumulation index (I_{geo})

Geoaccumulation index (I_{geo}) is assumed as an impressive tool to determine contamination degree from toxic metals. At present, geoaccumulation index is used globally to assess soil pollution (Santos et al. 2003). The most effective objective to determine geoaccumulation index (I_{geo}) is to identify pollution level in soil.

Geoaccumulation index (I_{geo}) may be assessed by applying equation given here by,

$$I_{geo} = \log_2 (C_n/1.5B_n) \quad (3)$$

Where, C_n is the determined element (n) concentration assessed from soil, B_n is the geochemical baseline value of element n in background sample (Yu et al. 2012). For decreasing possible variation in background values of element n, factor 1.5 is used to ascribe lithogenic effects.

2.4.4. Pollution load index (PLI)

Pollution load index is a compound system for determining the quality of soil. Pollution load index can be determined for six toxic metals like chromium, nickel, copper, arsenic, cadmium, and lead (Suresh et al. 2011). Pollution load index may be measured from a formula given here by:

$$PLI= (CF1 \times CF2 \times CF3 \times \ldots \times CF_n)^{1/n} \quad (4)$$

Pollution load index is the result of total toxicity level of hazardous metals in soil.

2.4.5. Potential ecological risk (PER)

The degrees of hazardous metals contamination in agricultural soils are determined by PER index. The equations which were used to calculate PER proposed by Guo and are as follows (Guo et al. 2010):

$$C_f^i = \frac{C^i}{C_n^i},\ C_d = \sum_{i=1}^{n} C_f^i \quad (5)$$

$$E_r^i = T_r^i \times C_f^i,\ PER = \sum_{i=1}^{m} E_r^i \quad (6)$$

Where, C_f^i is contamination factor of individual metal, C^i is element content in soils samples and C_n^i is metal baseline values. The baseline value of chromium, nickel, copper, arsenic, cadmium, and lead in soil samples were 45, 39, 33, 9.5, 0.95 and 27 mg/kg respectively. The integration of C_f^i for total elements represents the overall degree of pollution (C_d). E_r^i Represent potential ecological risk index and T_r^i is the biological toxic factor of single metal. The biological factors for chromium, nickel, copper, arsenic, cadmium, and lead were 2, 6, 5, 10, 30 and 5, respectively (Islam et al. 2014, Guo et al. 2010).

2.4.6. Toxic unit analysis

The sum of toxic units (ΣTUs) is considered as acute toxicity of toxic metals in agricultural soils. Toxic unit analysis is stated as the ratio of the assessed concentration of hazardous elements in soil to probable effect level (PELs) (Islam et al. 2014, Zheng et al. 2008). Moderate to serious toxicity of hazardous elements remain in soil when the sum of toxic units for all soil samples is more than 4 (Bai et al. 2011).

2.5. Statistical analysis

SPSS 20.0 (SPSS, USA) was used for statistical analysis for this study. Principal component analysis (PCA) was applied to address the sources of toxic element in soil. Microsoft Excel 2013 was used for other calculations.

3. Results and discussion

3.1. Physiochemical properties of soil

The physicochemical properties of soil are presented in Table 1. The studied soils pH values were ranged from 5.69 to 7.54 indicating that soils were slightly acidic to neutral excluding the S5, S6, S7, S8, S9, S10, and S13 site that were alkaline (Table 1) because of decomposition of organic matter and subsequent formation of carbonic acid. The highest values of soil pH were observed in S7 and S9 sites. Electrical conductivity (EC) value of the soil was non-saline (0-2 dS/m; SRDI soil salinity class) for all sampling sites which mean the salinity effect is negligible. The range of organic carbon (% C) was 0.149 to 3.113, where the highest value was observed in soil collected from the S3 site. According to the United States soil texture classification system, the textural analysis showed that the soil samples were loam, sandy loam, sandy clay loam, and silt loam (Table 1).

Table 1: Physiochemical Properties of Soils Collected from Industrial Vicinity of Tangail District, Bangladesh

Sampling sites	Sample no.	pH (1:2.5 H2O)	EC (dS/m)	Organic carbon (%)	Sand (% in <2 mm)	Silt	Clay	Soil type *
Tarutia,Tangail	S1	5.69	0.33	0.993	46.5	37.5	16	Loam
Tarutia,Tangail	S2	6.2	0.16	0.925	30.1	51.6	18.3	Silt loam
Tarutia,Tangail	S3	6.69	0.16	3.113	49.7	27.5	22.8	Sandy clay loam
Tarutia,Tangail	S4	6.78	0.7	0.725	63.5	22.5	14	Sandy loam
Tarutia,Tangail	S5	7.27	0.07	0.817	69	15	16	Sandy loam
Tarutia,Tangail	S6	7.01	0.13	0.713	74	9.1	16.9	Sandy loam
Tarutia,Tangail	S7	7.54	0.23	0.822	53.5	34.1	12.4	Sandy loam
Tarutia,Tangail	S8	7.18	0.36	1.874	51.5	29.1	19.4	Loam
Tarutia,Tangail	S9	7.4	0.2	0.699	53.5	31.6	14.9	Sandy loam
Tarutia,Tangail	S10	7.17	0.27	0.214	52.2	30	17.8	Sandy loam
Tarutia,Tangail	S11	6.85	0.54	0.217	63.5	25	11.5	Sandy loam
Tarutia,Tangail	S12	6.24	0.2	0.215	57.4	29.1	133	Sandy loam
Tarutia,Tangail	S13	7.23	0.36	0.149	71	19.1	99	Sandy loam
Tarutia,Tangail	S14	6.48	0.3	0.149	57.2	25	17.8	Sandy loam
Tarutia,Tangail	S15	6.64	0.22	1.152	47.4	37.5	15.1	Loam

* According to the United states Department of Agriculture soil classification system.

3.2. Heavy metal contamination in soil

The heavy metals concentrations of (Cr, Ni, Cu, As, Cd, and Pb) in soil samples are presented in (Table 2, Table 3, and Figure 2). The mean concentrations of Cr, Ni, Cu, As, Cd, and Pb in soil were found 11.56, 23.92, 37.27, 6.11, 2.01, and 17.46 mg/kg, respectively (Table 3). The maximum value of Cr, Ni, Cu, As, Cd, and Pb were observed in soil collected from the S3, S2, S5, and S1 site. Heavy metals in soils were compared with the other studies in Bangladesh and other countries. Cr, Ni, As, and Pb concentrations of the present study were higher than those of the study conducted in Bangladesh, Spain, Turkey, and India (Table 3). The mean concentrations of Cu were above the Dutch Soil Quality Standard (Table 3). The mean concentrations of Cd were above the Dutch Soil Quality Standard and Canadian Environmental Quality Guidelines value (Table 3). The Dutch Soil Quality Standard is considered as the most appropriate guideline indicating all possible exposure pathways for protecting humans, plants, and animals (Chen et al. 2011). The soil is considered clean, if any metal concentration in soil is below its respective Dutch Target Value. The soil is regarded to be slightly to moderately contaminated, if the concentration level lies between the target values and intervention values. In contrast, if the value is above the Dutch Intervention Value, the soil is considered detrimental to humans, plants, and animals. According to Table 3, Cu and Cd were in the worst situation among the studied metals as the mean concentration of Cu and Cd was higher than the Dutch Target Value.

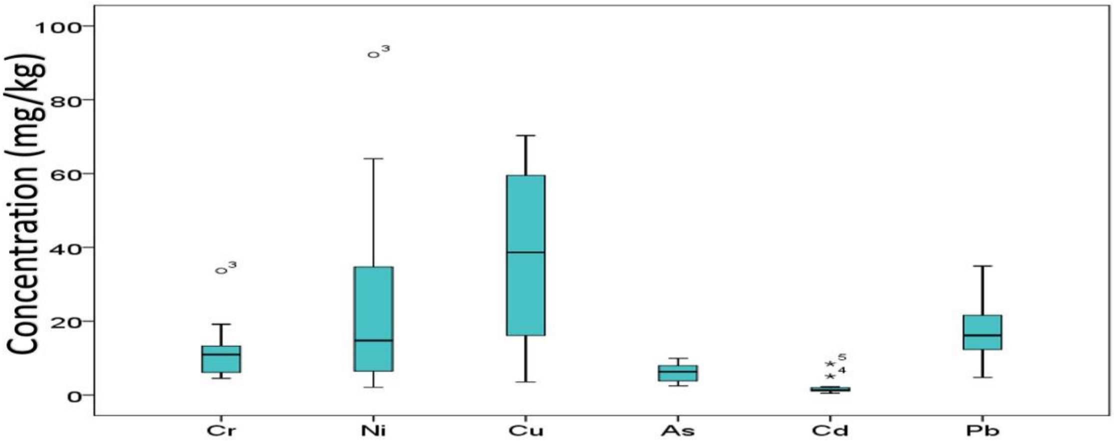

Fig. 2: Concentration of Heavy Metals (Cr, Ni, Cu, As, Cd, and Pb) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

Table 2: Metal Concentration (Mg/Kg) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh

Sampling sites	Sample no.	Cr	Ni	Cu	As	Cd	Pb
Tarutia,Tangail	S1	12.18	32.18	69.54	6.31	2.13	34.94
Tarutia,Tangail	S2	5.63	37.23	70.30	3.97	1.12	31.73
Tarutia,Tangail	S3	33.65	92.17	18.11	2.50	0.50	18.60
Tarutia,Tangail	S4	7.18	64.02	58.30	9.36	5.09	14.81
Tarutia,Tangail	S5	11.79	38.63	60.70	9.93	8.47	25.82
Tarutia,Tangail	S6	4.54	3.18	40.26	7.22	1.05	4.76
Tarutia,Tangail	S7	17.10	4.49	37.48	7.04	1.25	5.51
Tarutia,Tangail	S8	19.17	13.69	51.77	9.52	1.38	20.89
Tarutia,Tangail	S9	5.41	8.19	38.64	6.99	1.85	22.36
Tarutia,Tangail	S10	13.15	15.31	15.73	3.69	0.56	19.92
Tarutia,Tangail	S11	4.59	15.79	16.50	8.70	1.40	14.74
Tarutia,Tangail	S12	10.95	14.77	61.85	6.02	2.23	14.28
Tarutia,Tangail	S13	13.42	4.74	4.48	3.03	0.60	6.94
Tarutia,Tangail	S14	6.63	2.10	11.81	4.07	1.19	16.15
Tarutia,Tangail	S15	8.01	12.32	3.56	3.31	1.38	10.43
Dutch standard[a]		100	35	36	29	0.80	85
Canadian guidelines[b]		64	50	63	12	1.4	70
Australian guidelines[c]		50	60	60	20	3.0	300

A) VROM (2000). B) CCME (2003). C) DEP (2003).

Table 3: Comparison of Metal Concentration (Mg/Kg) in Soils of Present Study with Other Study and Guideline Values

District (Country)	Cr	Ni	Cu	As	Cd	Pb	References
Tangail, Bangladesh	11.56 (4.54-33.65)	23.92 (2.10-92.17)	37.27 (3.56-70.30)	6.11 (2.50-9.93)	2.01 (0.50-8.47)	17.46 (4.76-34.94)	Present study*
Tangail, Bangladesh	10.41	12.69	15.66	12.15	3.1	7.98	Proshad et al., 2017
Bogra (Bangladesh)	41	45	42	10	4.2	44	Islam et al., 2014
Maharashtra (India)	164	171	155	2.8	30	42	Bhagure and Mirgane (2011)
Murcia (Spain)	18	14	11	NA	0.22	49	Acosta et al. (2011)
Kayseri (Turkey)	29	45	37	NA	2.5	75	Tokalıoğlu and. Kartal (2006)
Dutch Soil Quality Standard (Target Value)	100	35	36	29	0.8	85	VROM (2000)
Dutch Soil Quality Standard (Intervention Value)	380	210	190	55	12	530	VROM (2000)
Canadian Environmental Quality Guidelines	64	50	63	12	1.4	70	CCME (2003)
Department of Environmental Protection, Australia	50	60	60	20	3	300	DEP (2003)

3.3. Source analysis of heavy metal in soil

To identify the source of heavy metals in soils of several sampling sites of the industrial area, a principal component analysis (PCA) was conducted, which has been considered to be an effective tool for source identification (Islam et al. 2015, Bai et al. 2011, Anju and Banerjee 2012). Due to source analysis of heavy metals, three principal components were obtained (Table 5), and those accounted for 96.96% of all the total variation. First principal component (PC1) explaining the largest variance (58.17%); second principal component (PC2) which explains 35.28% of the variance.

Table 4: Correlation Coefficient Matrix for Physiochemical Properties of Soils and Heavy Metals Collected from Industrial Vicinity of Tangail District, Bangladesh

	pH	EC	Organic carbon	Sand	Silt	Clay	Cr	Ni	Cu	As	Cd	Pb
pH	1											
EC	-0.62	1										
Organic carbon	0.46	0.18	1									
Sand	-0.43	-0.07	-0.95**	1								
Silt	-0.15	-0.07	0.22	-0.12	1							
Clay	-0.45	-0.22	-0.34	0.15	-0.29	1						
Cr	0.11	-0.19	-0.15	0.01	0.06	0.77**	1					
Ni	-0.26	0.10	-0.21	0.07	-0.17	0.67**	0.54*	1				
Cu	-0.34	-0.06	-0.23	0.21	0.12	0.06	-0.12	0.24	1			
As	0.27	0.31	0.38	-0.35	-0.24	-0.10	-0.25	-0.04	0.53*	1		
Cd	0.10	0.25	0.33	-0.33	-0.10	-0.08	-0.16	0.28	0.48	0.63*	1	
Pb	-0.47	-0.11	-0.58*	0.50	-0.25	0.19	0.22	0.36	0.57*	0.07	0.26	1

* = Correlation is significant at the 0.05 level (two-tailed).
** = Correlation is significant at the 0.01 level (two-tailed).

Table 5: Total Variance Explained and Component Matrices for the Heavy Metals in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	799.35	58.17	58.17	799.35	58.17	58.17	664.87	48.38	48.38
2	484.89	35.28	93.46	484.89	35.28	93.46	619.36	45.07	93.46
3	48.13	3.50	96.96						
4	34.97	2.54	99.51						
5	5.28	0.38	99.89						
6	1.45	0.10	100						

Elements	Component matrix			Rotated Component Matrix		
	PC1	PC2	PC3	PC1	PC2	PC3
Component matrix						
Cr	2.55	-4.23			4.87	
Ni	21.63	-13.04			24.28	
Cu	17.15	16.73		23.92		
As		1.28		1.32		
Cd	0.97			1.05		
Pb	5.40			5.6		

Extraction Method: principal component analysis.

3.4. Toxic unit analysis

Possible acute toxicity of heavy metals in soil samples can be estimated as the sum of toxic units (ΣTUs), defined as the ratio of the determined concentration of metal in soil to probable effect levels (PELs) (Islam et al. 2015, Ahmad and Goni 2010, Zheng et al. 2008). Toxic unit and sum of toxic units for heavy metals in different soil sampling sites of industrial areas of Tangail district are presented in Figure 7. The sum of toxic units for the studied metals for the sites S7, S2, and S9 was higher than the other sites, which were in the similar trends of metal concentrations in soils. If the sum of toxic units of soils was greater than 4, indicating a moderate to serious toxicity of heavy metals (Bai et al. 2011). In the studied soils, no samples were found which sum of toxic units was higher than 4.

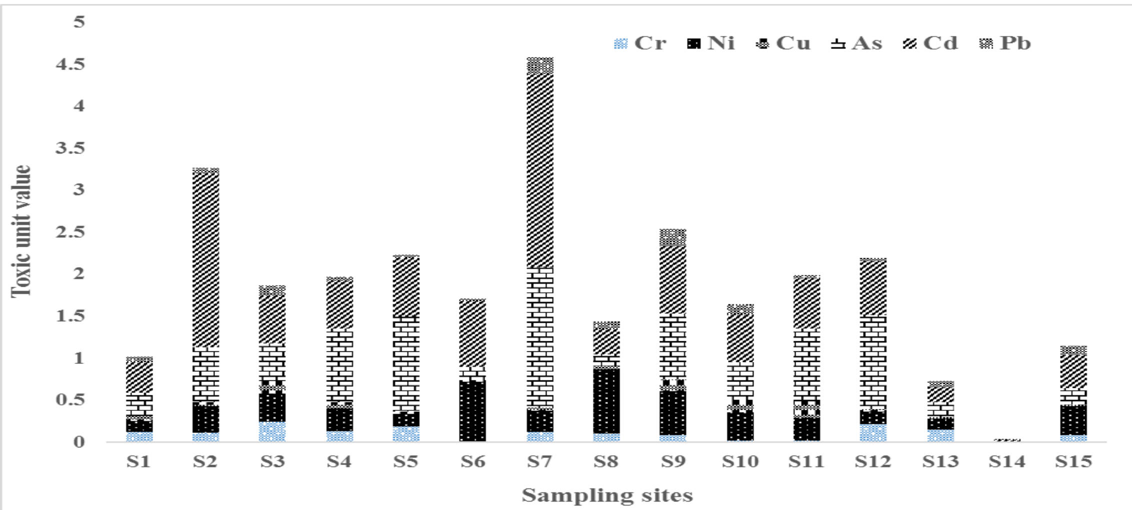

Fig. 7: Estimated Sum of the Toxic Unit (TU) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

3.5. Ecological risk assessment

In this study, the enrichment factor (EF), contamination factor (C^i_f), geoaccumulation index (I_{geo}) and pollution load index (PLI) were applied to assess the heavy metals contamination in soils. The enrichment factor values for studied soils are presented in Figure 3. Cd and Cu showed the highest enrichment factor value indicates the soil pollution for all the sampling sites. As a whole, the enrichment factor of all the studied metals for all sampling sites were in the descending order of Cd > Cu > As > Pb >Ni > Cr. Generally, studies have observed that little enrichment values indicate a great contribution for crusted source to the soil, while high enrichment factors indicate a substantial contribution from anthropogenic sources (Islam et al. 2015, Rashed 2010, Yadao and Rajamani 2006). Hakanson defines four types of contamination factors (CF) (Håkanson 1980), four types of degree of contamination (Cd), five types of E_r^i, and four types of PER are presented in Table 7. The contamination factor for individual metal was presented in Figure 4. In the studied area, contamination factor was higher for Cu and Cd. I_{geo} values of the present study are presented in Figure 5. For all heavy metals in the studied samples for different sampling sites, the I_{geo} values indicated the decreasing order of Cd>Cu>Pb>As>Ni>Cr. The mean of I_{geo} values for all the studied metals for all sampling sites indicating the soils were slowly contaminated with heavy metals. The value of pollution load index (PLI) equal to zero means perfection; a value of 1 indicates the presence of only baseline level of pollutants and values above 1 indicate progressive deterioration of soil by heavy metals (Islam et al. 2015, Proshad et al. 2017, Islam et al. 2014, Rashed 2010). As per above grade, studied soils were highly contaminated by Cd and it was observed that pollution load index (PLI) values of all others heavy metals for all sampling sites were not more than one (Figure 6). Combining the potential ecological risk index of individual metals (E_r^i) and the potential ecological risk index of the environment (PER) (Table 6) with their grade classifications (Table 7), soils from all sampling sites indicate the moderate to very high potential ecological risk in the studied area. PER represents the sensitivity of various biological communities, to toxic substances and illustrates the potential ecological risk caused by the heavy metals (Islam et al. 2015). The order of E_r^i in soils was in the following descending order of Cd> As> Cu> Ni> Pb>Cr.

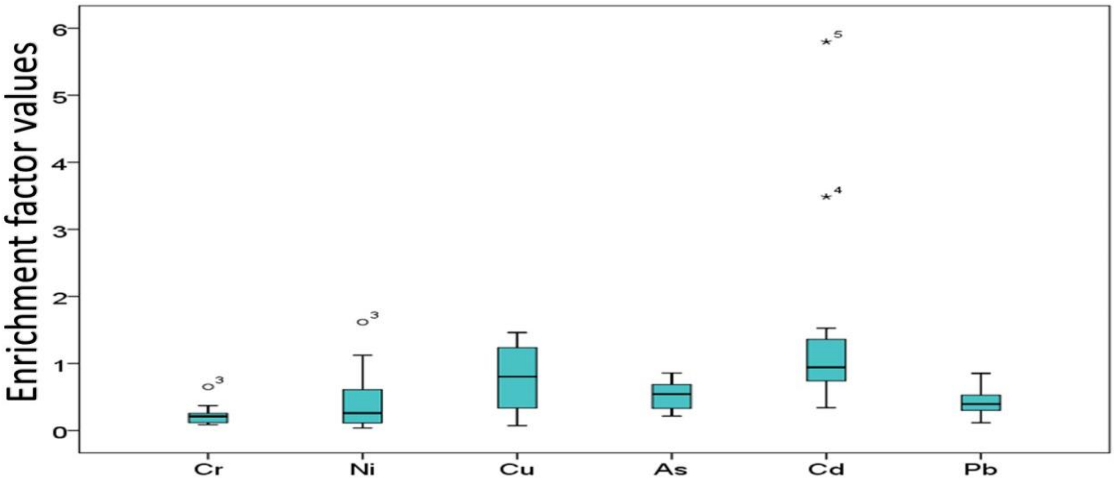

Fig. 3: Enrichment Factor (Cr, Ni, Cu, As, Cd, and Pb) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

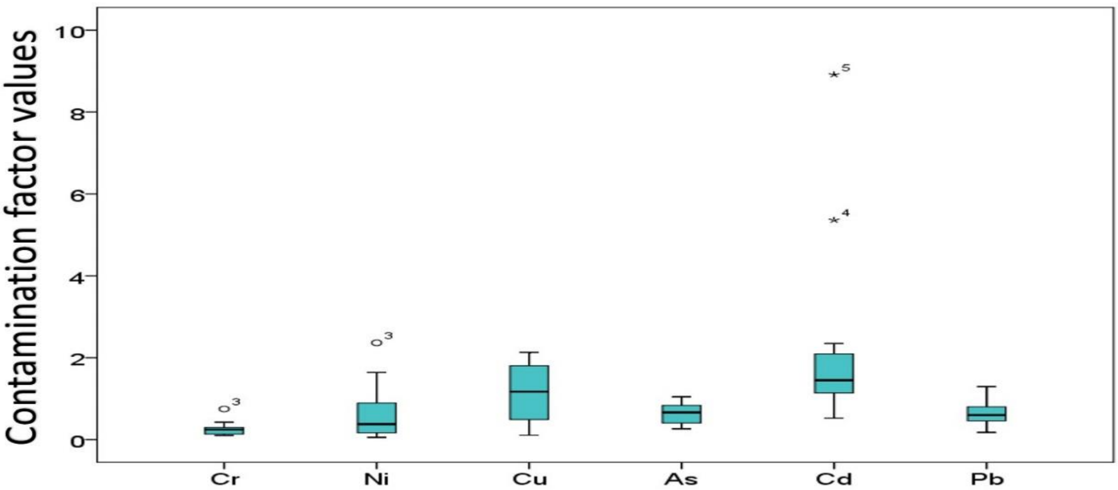

Fig. 4: Contamination Factor (Cr, Ni, Cu, As, Cd, and Pb) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

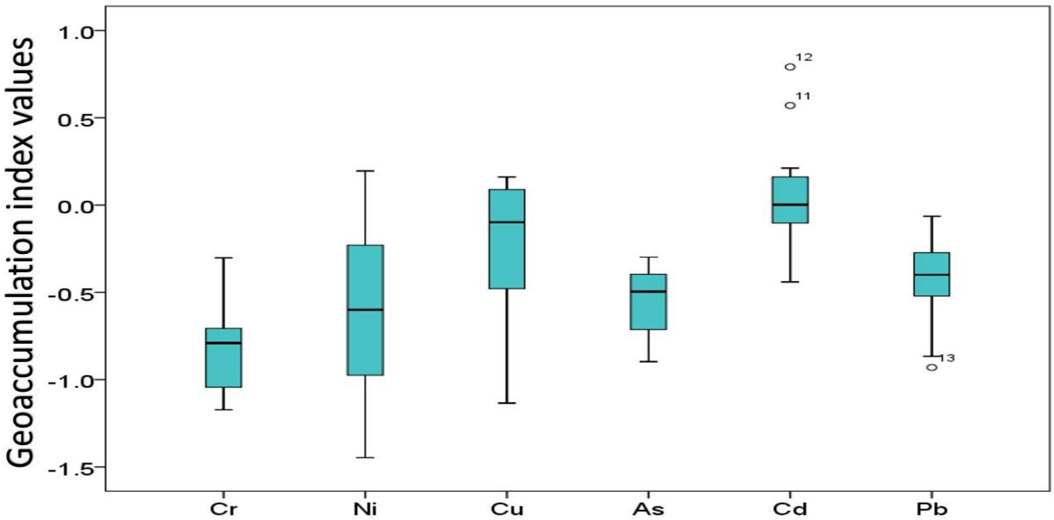

Fig. 5: Geoaccumulation Index Values (Cr, Ni, Cu, As, Cd, and Pb) in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

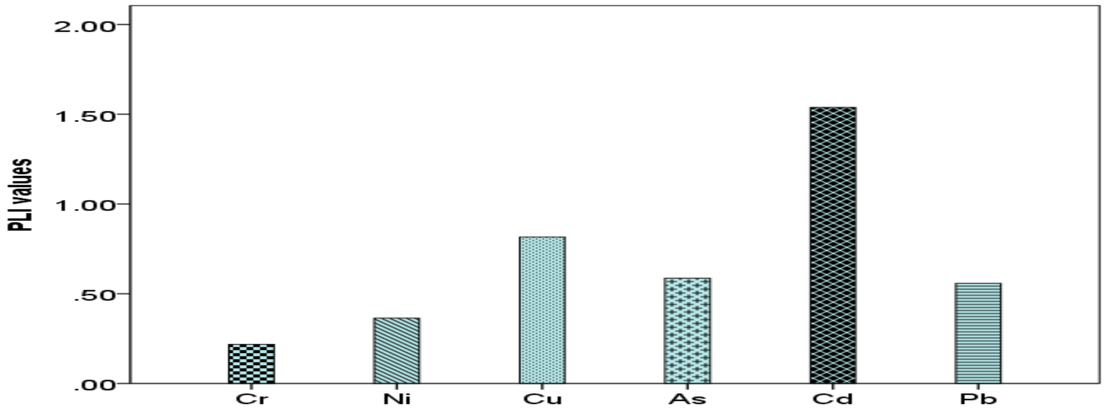

Fig. 6: Pollution Load Index (PLI) Values in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh.

Table 6: Potential Ecological Risk Factor, Risk Index and Pollution Degree of Heavy Metals in Soils Collected from Industrial Vicinity of Tangail District, Bangladesh

Sites	Potential ecological risk factor (E^i_r)						Potential Risk (PER)	Pollution degree
	Cr	Ni	Cu	As	Cd	Pb		
S1	2.17	19.80	42.14	26.55	268.69	25.88	385.2382	Very high risk
S2	1.00	22.91	42.60	16.69	141.20	23.50	247.9074	Considerable risk
S3	5.98	56.72	10.98	10.55	62.82	13.78	160.8233	Considerable risk
S4	1.28	39.40	35.34	39.42	643.39	10.97	769.7945	Very high risk
S5	2.10	23.77	36.79	41.80	1069.77	19.13	1193.354	Very high risk
S6	0.81	1.95	24.40	30.38	132.02	3.52	193.0811	Considerable risk
S7	3.04	2.76	22.72	29.64	157.35	4.08	219.5978	Considerable risk
S8	3.41	8.42	31.38	40.10	174.11	15.47	272.8823	Very high risk
S9	0.96	5.04	23.42	29.43	233.68	16.56	309.0982	Very high risk
S10	2.34	9.42	9.54	15.54	71.10	14.75	122.6902	Moderate risk
S11	0.82	9.72	10.00	36.62	176.66	10.92	244.7326	Considerable risk
S12	1.95	9.09	37.49	25.33	281.78	10.58	366.2122	Very high risk
S13	2.39	2.92	2.72	12.75	76.34	5.14	102.2505	Moderate risk
S14	1.18	1.29	7.15	17.15	150.40	11.96	189.1432	Considerable risk
S15	1.42	7.58	2.16	13.94	174.50	7.72	207.3333	Considerable risk

Table 7: Indices and Grades of Potential Ecological Risk of Heavy Metal Pollution (Luo et al. 2007).

Contamination factor (C^i_f)	Contamination degree of individual metal	Degree of contamination (Cd)	Contamination degree of the environment	E^i_r	Grade of ecological risk of individual metal	Risk index (PER)	
$C^i_f < 1$	Low	Cd<5	Low contamination	$E^i_r < 40$	Low risk	RI<65	Low risk
$1 \le C^i_f < 3$	Moderate	5≤Cd<10	Moderate contamination	$40 \le E^i_r < 80$	Moderate risk	65≤RI < 130	Moderate risk
$3 \le C^i_f < 6$	Considerable	10≤Cd<20	Considerable contamination	$80 \le E^i_r < 160$	Considerable risk	130 ≤RI < 260	Considerable risk
$C^i_f \ge 6$	High	Cd≥20	High contamination	$160 \le E^i_r < 320$	High risk	RI ≥ 260	Very high risk
				$E^i_r \ge 320$	Very high risk		

4. Conclusions

Contamination of heavy metals (Cr, Ni, Cu, As, Cd, and Pb) was investigated soils in the industrial vicinity of Tangail district in Bangladesh. This study revealed that all soil samples from different sites were heavily contaminated by heavy metals especially Cu and Cd (80% and 60% samples exceed the Dutch Soil Quality Target Value). The enrichment factor (EF), contamination factor (C^i_f), geoaccumulation index (I_{geo}), pollution load index (PLI), toxic unit (TU) analysis revealed that soils in this study were highly contaminated by the Cd. Heavy metals in soil for different sampling sites showed moderate to very high degree of contamination. For individual heavy metal, only Cd had very severe ecological risk for most of the sites, whereas, the study area comprises high potential ecological risk according to the ecological risk indexes of heavy metals. However, it is necessary to further study to explain the reasons for the higher potential ecological risk caused mainly by Cd in different industrial area soils of Tangail district in Bangladesh.

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References

[1] Luo W, Lu Y, Gisey JP, Wang T, Shi Y, Wang G & Xing Y (2007), Effects of land use on concentrations of metals in surface soils and ecological risk around Guanting Reservoir, China. Environmental Geochemistry and Health 29, 459-471. https://doi.org/10.1007/s10653-007-9115-z.

[2] Karim Z, Qureshi BA, Mumtaz M & Qureshi S (2014), Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi—a multivariate spatio-temporal analysis. Ecological Indicators 42, 20-31. https://doi.org/10.1016/j.ecolind.2013.07.020.

[3] Islam MS, Ahmed MK, Al-mamun MH & Masunaga S (2015), Potential ecological risk of hazardous elements in different land-use urban soils of Bangladesh. Science of the Total Environment 512, 94-102. https://doi.org/10.1016/j.scitotenv.2014.12.100.

[4] Proshad R, Kormoker T, Mursheed N, Islam MM, Bhuyan Mi, Islam MS & Mithu TN (2018), Heavy metal toxicity in agricultural soil due to rapid industrialization in Bangladesh: a review. International Journal of Advanced Geosciences 6(1), 83-88. https://doi.org/10.14419/ijag.v6i1.9174.

[5] Han FX, Banin A, Su Y, Monts DL, Plodinec MJ, Kingery WL & Triplett GE (2002), Industrial age anthropogenic inputs of heavy metals into the pedosphere. Naturwissenschaften 89, 497-504. https://doi.org/10.1007/s00114-002-0373-4.

[6] Vare L (2006), Anthropogenic inputs of heavy metals to the Kongsfjord area. Geophysical Research Abstracts 8, 06079.

[7] Islam MS, Ahmed MK, Al-Mamun MH & Raknuzzaman M (2015), Trace elements in different land use soils of Bangladesh and potential ecological risks. Environmental Monitoring and Assessment 187, 587-598. https://doi.org/10.1007/s10661-015-4803-0.

[8] Sun YB, Zhou QX, Xie XK & Liu R (2010), Spatial, sources and risk assessment of heavy metal contamination of urban soils in typical regions of Shenyang, China. Journal of Hazardous Materials 174, 455-462. https://doi.org/10.1016/j.jhazmat.2009.09.074.

[9] Lei M, Zhang Y, Khan S, Qin PF & Liao BH (2010), Pollution, fractionation and mobility of Pb, Cd, Cu, and Zn in garden and paddy soils from a Pb/Zn mining area. Environmental Monitoring and Assessment 168, 215-222. https://doi.org/10.1007/s10661-009-1105-4.

[10] Proshad R, Ahmed S, Rahman M & Kumar T (2017), Apportionment of Hazardous Elements in Agricultural Soils Around the Vicinity of Brick Kiln in Bangladesh. Journal Environmental Analytical Toxicology 7, 1-6. https://doi.org/10.4172/2161-0525.1000439.

[11] Chen X, Xia XH, Zhao Y & Zhang P (2010), Heavy metal concentrations in roadside soils and correlation with urban traffic in Beijing, China. Journal of Hazardous Materials 181, 640-646. https://doi.org/10.1016/j.jhazmat.2010.05.060.

[12] Islam MS, Ahmed MK, Al-mamun MH & Masunaga S (2014), Trace metals in soil and vegetables and associated health risk assessment. Environmental Monitoring and Assessment 186, 8727-8739. https://doi.org/10.1007/s10661-014-4040-y.

[13] Ahmed MK, Shaheen N, Islam MS, Al-Mamun MH, Islam S & Banu CP (2015), Trace elements in two staple cereals (rice and wheat) and associated health risk implications in Bangladesh. Environmental Monitoring and Assessment 187, 326-336. https://doi.org/10.1007/s10661-015-4576-5.

[14] Islam MS, Shuping HA, Ahmed MK & Masunaga S (2014), Assessment of trace metal contamination in water and sediment of some rivers in Bangladesh. Water and Environment Technology 12, 109-121. https://doi.org/10.2965/jwet.2014.109.

[15] Wei BG & Yang LS (2010), A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchemical Journal 94, 99-107. https://doi.org/10.1016/j.microc.2009.09.014.

[16] Li X & Feng L (2012), Multivariate and geostatistical analyzes of metals in urban soil of Weinan industrial areas, Northwest of China. Atmospheric Environment 47, 58-65. https://doi.org/10.1016/j.atmosenv.2011.11.041.

[17] Rodríguez Martín JA, Gutiérrez C, Escuer M, García- González MT, Campos-Herrera R & Águila N (2014), Effect of mine tailing on the spatial variability of soil nematodes from lead pollution in La Union (Spain). Science of the Total Environment 473, 518–529. https://doi.org/10.1016/j.scitotenv.2013.12.075.

[18] Islam MS, Ahmed MK & Al-Mamun MH (2015), Metal speciation in soil and health risk due to vegetables consumption in Bangladesh. Environmental Monitoring and Assessment 187, 288–303. https://doi.org/10.1007/s10661-015-4533-3.

[19] Cui Y, Zhu Y, Zhai R, Chen D, Huang Y & Qiu Y (2004), Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China. Environment International 30, 785-791. https://doi.org/10.1016/j.envint.2004.01.003.

[20] Li JH, Lu Y, Yin W, Gan HH, Zhang C, Deng XL & Lian J (2009), Distribution of heavy metals in agricultural soils near a petrochemical complex in Guangzhou, China. Environmental Monitoring and Assessment 153, 365-375. https://doi.org/10.1007/s10661-008-0363-x.

[21] Yu J, Huang Z, Chen T, Qin D, Zeng X & Huang Y (2012), Evaluation of ecological risk and source of heavy metals in vegetable-growing soils in Fujian province, China. Environmental Earth Science 65, 29-37. https://doi.org/10.1007/s12665-011-1062-4.

[22] Yuan GL, Sun TH, Han P, Li J & Lang XX (2014), Source identification and ecological risk assessment of heavy metals in topsoil using environmental geochemical mapping: typical urban renewal area in Beijing, China. Journal of Geochemical Exploration 136, 40-67. https://doi.org/10.1016/j.gexplo.2013.10.002.

[23] Rashed MN (2010), Monitoring of contaminated toxic and heavy metals, from mine tailings through age accumulation, in soil and some wild plants at Southeast Egypt. Journal of Hazardous Materials 178, 739–746. https://doi.org/10.1016/j.jhazmat.2010.01.147.

[24] Sayadi MH & Sayyed MRG (2011), Comparative assessment of baseline concentration of the heavy metals in the soils of Tehran (Iran) with the comprisable reference data. Environmental Earth Science 63, 1179-1188. https://doi.org/10.1007/s12665-010-0792-z.

[25] Hower JC, O'Keefe JMK, Henke KR, Wagner NJ, Copley G, Blake DR, Garrison T, Oliveira MLS, Kautzmann RM & Silva LFO (2013), Gaseous emissions and sublimates from the Truman Shepherd coal fire, Floyd County, Kentucky: a re-investigation following attempted mitigation of the fire. International Journal of Coal Geology 116, 63-74. https://doi.org/10.1016/j.coal.2013.06.007.

[26] Dias CL, Oliveira MLS, Hower JC, Taffarel SR, Kautzmann RM & Silva LFO (2014), Nanominerals and ultrafine particles from coal fires from Santa Catarina, South Brazil. International Journal of Coal Geology 122, 50-60. https://doi.org/10.1016/j.coal.2013.12.011.

[27] Islam MS, Ahmed MK, Al-Mamun MH & Hoque MF (2014), Preliminary assessment of heavy metal contamination in surface sediments from a river in Bangladesh. Environmental Earth Science 73, 1837-1848. https://doi.org/10.1007/s12665-014-3538-5.

[28] Ahmad JU & Goni MA (2010), Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. Environmental Monitoring and Assessment 166, 347-357. https://doi.org/10.1007/s10661-009-1006-6.

[29] Rahman SH, Khanam D, Adyel TM, Islam MS, Ahsan MA & Akbor MA (2012), Assessment of heavy metal contamination of agri-

cultural soil around Dhaka Export Processing Zone (DEPZ), Bangladesh, implication of seasonal variation and indices. Applied Science 2, 584-601. https://doi.org/10.3390/app2030584.
[30] Schottler SP & Engstrom DR (2006), A chronological assessment of Lake Okeechobee (Florida) sediments using multiple dating markers. Journal of Paleolimnology 36, 19-36. https://doi.org/10.1007/s10933-006-0007-5.
[31] Oliveira MLS, Ward CR, French D, Hower JC, Querol X & Silva LFO (2012), Mineralogy and leaching characteristics of beneficiated coal products from Santa Catarina, Brazil. International Journal of Coal Geology 94, 314-325. https://doi.org/10.1016/j.coal.2011.10.004.
[32] Oliveira MLS, Ward CR, Izquierdo M, Sampaio CH, de Brum IAS, Kautzmann RM, Sabedot S, Querol X & Silva LFO (2012), Chemical composition and minerals in pyrite ash of an abandoned sulphuric acid production plant. Science of the Total Environment 430, 34-47. https://doi.org/10.1016/j.scitotenv.2012.04.046.
[33] Arenas-Lago D, Vega FA, Silva LFO & Andrade ML (2014), Copper distribution in surface and subsurface soil horizons. Environmental Science and Pollution Research International 21, 10997-11008. https://doi.org/10.1007/s11356-014-3084-4.
[34] Cerqueira B, Vega FA, Serra C, Silva LFO & Andrade ML (2011), Time of flight secondary ion mass spectrometry and high-resolution transmission electron microscopy/energy dispersive spectroscopy: a preliminary study of the distribution of Cu2+ and Cu2+/ Pb2+ on a Bt horizon surfaces. Journal of Hazardous Materials 195, 422-431. https://doi.org/10.1016/j.jhazmat.2011.08.059.
[35] Cerqueira B, Vega FA, Silva LFO & Andrade L (2012), Effects of vegetation on chemical and mineralogical characteristics of soils developed on a decantation bank from a copper mine. Science of the Total Environment 421, 220-229. https://doi.org/10.1016/j.scitotenv.2012.01.055.
[36] Silva LFO, Sampaio CH, Guedes A, Fdez-Ortiz de Vallejuelo S & Madariaga JM (2012), Multi analytical approaches to the characterisation of minerals associated with coals and the diagnosis of their potential risk by using combined instrumental micro spectroscopic techniques and thermodynamic speciation. Fuel Journal 94, 52-63. https://doi.org/10.1016/j.fuel.2011.11.007.
[37] Franco-Uria A, Lopez-Mateo C, Roca E & Fernandez-Marcos ML (2009), Source identification of heavy metals in pasture land by multivariate analysis in NW Spain. Journal of Hazardous Materials 165, 1008-1015. https://doi.org/10.1016/j.jhazmat.2008.10.118.
[38] Selvaraj K, Mohan VR & Szefer P (2004), Evaluation of metal contamination in coastal sediments of the Bay of Bengal, India: geochemical and statistical approaches. Marine Pollution Bulletin 49, 174-185. https://doi.org/10.1016/j.marpolbul.2004.02.006.
[39] Zhang J & Liu CL (2002), Riverine composition and estuarine geochemistry of particulate metals in China-weathering features, anthropogenic impact and chemical fluxes. Estuarine, Coastal and Shelf Science 54, 1051-1070. https://doi.org/10.1006/ecss.2001.0879.
[40] Birch GF & Olmos MA (2008), Sediment-bound heavy metals as indicators of human influence and biological risk in coastal water bodies. ICES Journal of Marine Science 65, 1407-1413. https://doi.org/10.1093/icesjms/fsn139.
[41] Santos Bermejo JC, Beltrán R & Gómez Ariza JL (2003), Spatial variations of heavy metals contamination in sediments from Odiel River (Southwest Spain). Environment International 29, 69-77. https://doi.org/10.1016/S0160-4120(02)00147-2.
[42] Suresh G, Ramasamy V, Meenakshisundaram V, Venkatachalapathy R & Ponnusamy V (2011), Influence of mineralogical and heavy metal composition on natural radionuclide contents in the river sediments. Applied Radiation and Isotopes 69, 1466–1474. https://doi.org/10.1016/j.apradiso.2011.05.020.
[43] Guo W, Liu X, Liu Z & Li G (2010), Pollution and potential ecological risk evaluation of heavy metals in the sediments around Dongjiang Harbor, Tianjin. Proceeding of Environmental Science 2, 729-736. https://doi.org/10.1016/j.proenv.2010.10.084.
[44] Zheng N, Wang Q, Liang Z & Zheng D (2008), Characterization of heavy metal concentrations in the sediments of three freshwater rivers in Huludao City, Northeast China. Environmental Pollution 154, 135-142. https://doi.org/10.1016/j.envpol.2008.01.001.
[45] Bai J, Xiao R, Cui B, Zhang K, Wang Q, Liu X, Gao H & Huang L (2011), Assessment of heavy metal pollution in wetland soils from the young and old reclaimed regions in the Pearl River Estuary, South China. Environmental Pollution 159, 817-824. https://doi.org/10.1016/j.envpol.2010.11.004.
[46] Anju M & Banerjee DK (2012), Multivariate statistical analysis of heavy metals in soils of a Pb-Zn mining area, India. Environmental Monitoring and Assessment 184, 4191-4206. https://doi.org/10.1007/s10661-011-2255-8.
[47] Yadao S & Rajamani V (2006), Air quality and trace metal chemistry of different size fractions of aerosols in N–NW India—implications for source diversity, Atmospheric Environment 40, 698-712. https://doi.org/10.1016/j.atmosenv.2005.10.005.
[48] Håkanson L (1980), an ecological risk index for aquatic pollution control: a sedimentological approach. Water Research 14, 975–1001. https://doi.org/10.1016/0043-1354(80)90143-8.