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Apportionment of Hazardous Elements in Agricultural Soils Around the Industrial Vicinity of Bangladesh

Proshad R[1], Islam Md. S[1,2], Haque MA[1], Hoque Md. F[1], Ahmed S[1]*

[1]Department of Soil Science, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

[2]Environment and Information Sciences, Yokohama National University, 79-7 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa, 240-8501, Japan

Abstract

Tangail district is an industrial growing site of Bangladesh and highly sensitive to environmental pollution which is the result of natural and anthropogenic factors that expressively decrease environmental quality. In present study, three different sampling locations were selected around industrial vicinity and level of hazardous elements (Cr, Ni, Cu, As, Cd and Pb) were assessed from agricultural soils. The ranges of Cr, Ni, Cu, As, Cd and Pb in studied soils were 0.46–25.07, 2.82– 69.18, 2.34–66.25, 1.49–22.82, 0.45–8.52 and 1.73–47.51mg/kg, respectively. The presence of these hazardous elements in soils indicating a potential risk to the environment. Certain indices, including the enrichment factor (EF), pollution load index (PLI) and contamination factor (C^i_f), and geoaccumulation index (I_{geo}) were used to assess the ecological risk posed by hazardous elements in soils. Geoaccumulation index (I_{geo}) and contamination factor (C^i_f) indicated that most of the agricultural soils were moderately to highly contaminated by hazardous elements. Pollution load index values of soils for all selected location were less than 1 indicating minor deterioration of soil due to metal contamination. In context of potential ecological risk (PER), agricultural soils around industrial vicinity indicated considerable to very high ecological risk.

Keywords: Bangladesh; Ecological risk; Hazardous materials; Soil

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***Correspondence:**
Md. Saiful Islam, Department of Soil Science, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh; Environment and Information Sciences, Yokohama National University, 79-7 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa, 240-8501, Japan.
Tel: +8801717372057
E-mail: islam-md.saiful-nj@ynu.jp

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Introduction

Soil is known as inborn action of forces for living being and considered as key receiver of the merciless pollutants as hazardous elements [1]. Agricultural soil contamination by hazardous elements around industrial vicinity have a chief concern in the developing as well as developed countries in the world which assume as environmental consequences at present [2]. Hazardous elements are of great concern due to their wide sources, toxicity, non-biodegradable properties and accumulative behaviors [3]. Hazardous elements such as Cr, Ni, As, Cd and Pb have been considered as the most toxic elements in the environment by the US Environment Protection Agency (EPA) [4,5]. Agricultural crops along with soils have potential negative effect due to the contamination by hazardous elements. Plant metabolic dysfunction, inhibition of photosynthesis, respiration, and degeneration of main cell organelles, crop growth reduction, even leading to death of plants and produce other ecological hazard due to presence high concentration of hazardous elements. Agricultural soils become toxic due to high exposure duration as these hazardous elements are being continuously deposited in the soils [6,7]. Deposition of these hazardous elements damage soil ecosystem cause potential risk to agricultural soils [8,9]. Agricultural soil pollution by several hazardous elements become a precious issue now a days due to heavy industrialization and many research have already been conducted in many areas in the world [2,10,11] as well as in Bangladesh [3,5,12]. Due to rapid industrialization, agricultural soil pollution by hazardous elements is a great concern which causes potential ecological risk in soils developing countries like Bangladesh [2,5,10,13-15].

Various procedures have been used to determine the pollution status of hazardous materials in soils like contamination factor (CF), enrichment factor (EF), potential ecological risk (PER), geoaccumulation index (I_{geo}) etc. [16]. Natural and human-related metal enrichment in soils should be differentiated prior to the assessment of metal contamination processes by enrichment factor (EF) [17]. EF of any agricultural soils assumes the Relative enrichment in any pollutant when compared to pre-industrial soils from the same environment [18]. When data from pre-industrial agricultural soils may be found than this proposal is true. Again, allocation with source association

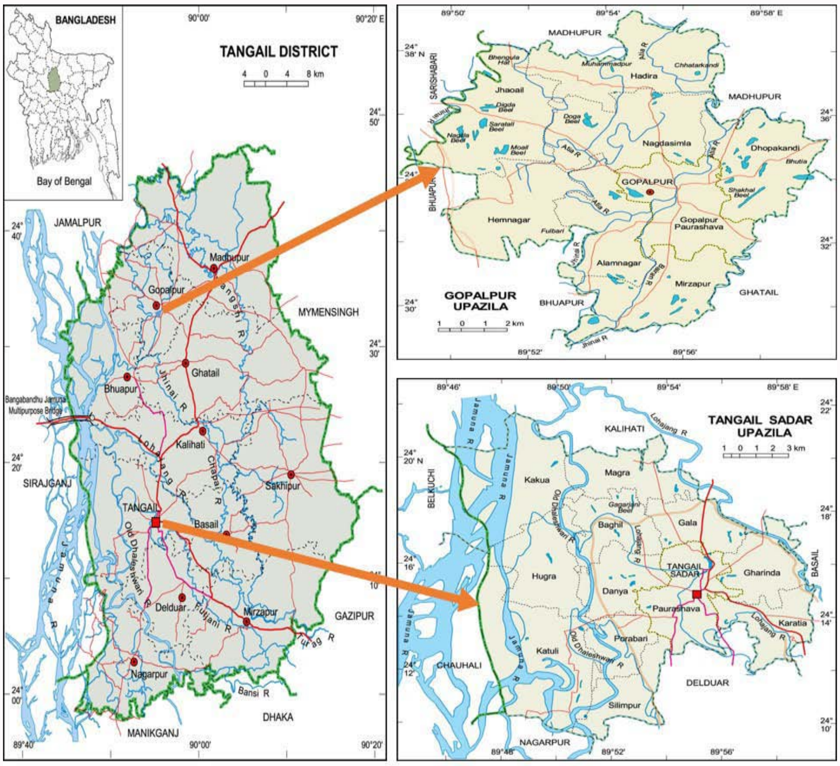

Figure 1: Map showing the study area of Tangail District, Bangladesh.

of hazardous elements in several agricultural soils is most significant to get ecological risk and pollution status of soils [19,20]. Bangladesh, as a study area have raised attention due to severe environmental pollution through rapid industrialization and facing thoughtful threats cause elemental pollution created from the district's speedy congestion, expansion and activities from industries [13,14]. The concentration of hazardous elements has reported in different studies conducted industrial vicinity agricultural soils in Bangladesh [5,21]. In present study, the variations of hazardous elements in agricultural soils were investigated. The objectives of this study are to address the problem of Cr, Ni, Cu, As, Cd, and Pb in soils and to assess the ecological risk of hazardous elements in agricultural soils around industrial vicinity in Bangladesh.

Materials and Methods

Study area and sampling

This study was conducted in three different sampling location in Tangail district, Bangladesh (Figure 1). The area of Tangail district is 3414.28km^2 and located at the center point in Bangladesh. Tangail district is one of the most densely polluted area in Bangladesh where the density of population is 1,100/km^2. The study area is situated between 24° 01′ and 24° 47′ north latitudes and between 89° 44′ and 90° 18′ east longitudes. Soil samples were collected during March-April, 2016. Three sampling locations (Makulla, Pankata and Tarutia) were selected near the industrial area of Tangail district, Bangladesh. At each sampling location, agricultural soil samples (up to 10 cm) were collected in the form of three subsamples. These sub-samples were thoroughly mixed to form a composite sample. Samples were air-dried at room temperature for two weeks, then ground and homogenized. The dried soil samples were crumbled with a porcelain mortar and pestle and sieved through 2 mm nylon sieve and stored in an airtight clean Ziploc bag and kept frozen until chemical analysis.

Sample analysis

For sample analysis, analytical grade reagents were used and for solution preparation Milli-Q (Elix UV5 and MilliQ, Millipore, USA) water was used. 0.5 g of the soil sample was mixed with 1.5mL 69% HNO_3 (Kanto Chemical Co, Tokyo, Japan) and 4.5mL 35% HCl (Kanto Chemical Co, Tokyo, Japan) in a closed Teflon vessel and was digested in a Microwave Digestion System (Berghofspeedwave®, Eningen, Germany) for metal analysis. By using a syringe filter (DISMIC®-25HP PTFE, pore size = 0.45μm) Toyo Roshi Kaisha, Ltd., Tokyo, Japan the solution was digested and 50 mL polypropylene tubes (Nalgene, New York) were used for storing.

Quality control and instrumental analysis

Inductively coupled plasma mass spectrometer (ICP-MS, 7700 series) was used for sample analysis. To prepare calibration curve, Multi-element Standard XSTC-13 (SpexCertiPrep®, Metuchen, USA) solutions were used. Due to cover more range of masses of elements, 1.0μg/L multi-element standard solution was used as tuning solution. An internal quality system was used for evaluation every test batches. Once defined Internal Quality Controls (IQCs) was satisfied than it was validated.

Ecological risk assessment

Enrichment factor (EF): For assessing the magnitude of hazardous elements in the environment, enrichment factor is assumed impressive tool [22]. For determination anthropogenic influences of hazardous elements in soil, enrichment factor was calculated using the following formula [23]:

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

where, $(C_M/C_{Al})_{sample}$ is assumed as ratio of hazardous element concentration of (C_M) to that of aluminum (C_{Al}) in the soil sample,

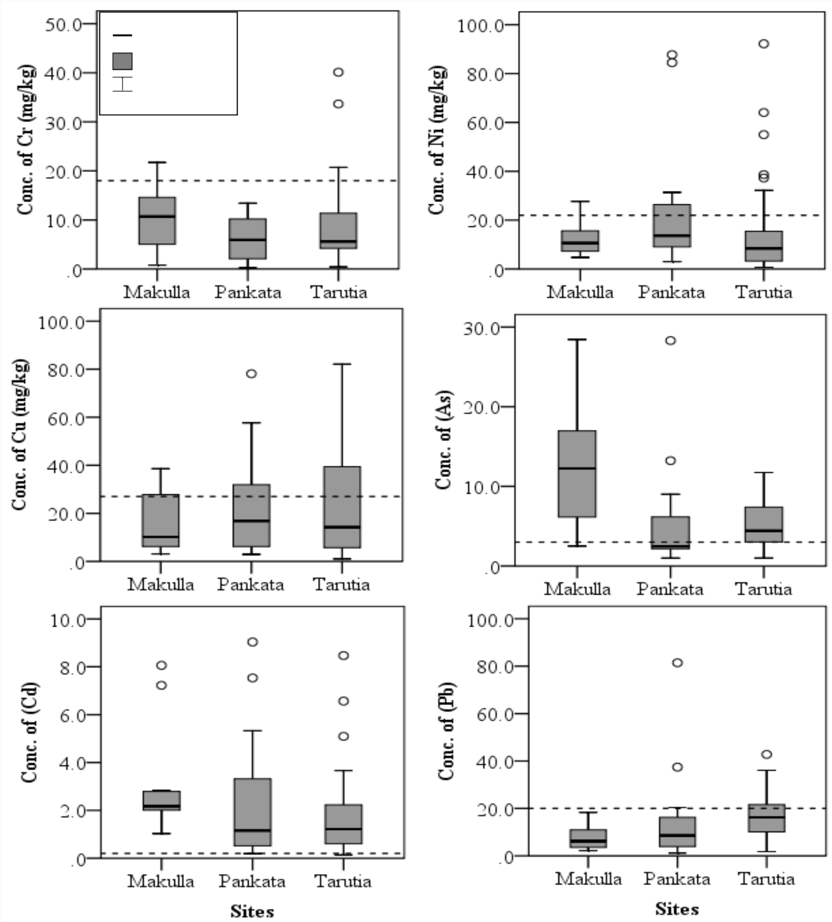

Figure 2: Concentration of hazardous elements in soil (mg/kg) collected from Tangail industrial area, Bangladesh (Horizontal dot line indicates Background value of trace metals in soil of Bangladesh, Islam et al., 2015. Circle (O) indicates outlier).

Table 1: Physicochemical properties of soil collected from the industrial area of Tangail district, Bangladesh.

Sampling sites		pH	EC (dS/m)	OC (%)	OM (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
Makulla (n=12)	Mean±SD	6.66±0.50	0.17±0.14	1.68±1.30	2.9±2.24	40.2±5.3	43.7±41.0	16.1±33.0	Loam
	Range	6.02-7.87	0.06-0.47	0.54-3.65	0.93-6.31	34.0-48.5	37.5-49.1	9.9-20.3	
Pankata (n=19)	Mean±SD	6.19±0.31	0.12±0.07	1.54±1.42	2.66±2.45	39.6±3.9	44.1±36.3	16.3±2.9	Loam
	Range	5.58-6.87	0.06-0.33	0.50-4.31	0.86-7.45	31.5-46.5	36.5-47.5	11.5-21.9	
Tarutia (n=44)	Mean±SD	6.85±0.63	0.47±0.44	1.11±0.75	1.92±1.29	50.6±9.4	33.7±9.0	15.8±3.0	Silt loam
	Range	5.48-8.01	0.07-2.11	0.15-3.33	0.25-5.76	30.1-74.0	9.1-51.6	9.9-22.8	

and $(C_M/C_{Al}))_{background}$ is the same reference ratio in the background sample. If the EF value of hazardous materials is 1, it means that metal may be entirely from crustal materials or natural weathering processes [24]. It is stating a fact of human interference if enrichment factor of samples is more than1.5. An EF of 1.5–3, 3–5, 5–10 and >10 is considered the evidence of minor, moderate, severe, and very severe modification [25].

Contamination factor (C^i_f): The (C^i_f) may be defined as the ratio of the metal concentration in the soil to that of baseline or background value (background value is considered as toxic elements in the pre-industrial soil around research vicinity):

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

According to the intensities of contamination, the levels of contamination may be divided on six categories which range from 1 to 6: very high degree ($C^i_f \geq 6$), considerable degree ($3 \leq C^i_f < 6$), moderate degree ($1 \leq C^i_f < 3$) and low degree ($C^i_f < 1$) [14,26,27]. Thus, the enrichment of each metal may be monitored by C^i_f values over a long time in soils.

Geo accumulation index (I_{geo}): Geo accumulation index (I_{geo}) may be considered as an effective tool for assessing degree of contamination from hazardous element. It use universally for determination of soil concentration now a days [28]. One of the most important purposes for assessing geo accumulation index (I_{geo}) is to characterize the level of pollution from soil. Geo accumulation index (I_{geo}) can be determined adopting following equation,

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

Where, C_n is the assessed metal (n) concentration in the soil and B_n is considered as the geochemical baseline value of metal n in

Table 2: Concentration of heavy metals in soil (mg/kg, dw) collected from the industrial area of Tangail district, Bangladesh.

Sites		Cr	Ni	Cu	As	Cd	Pb
Makulla (n=12)	Mean	10.41	12.69	15.66	12.15	3	7.98
	SD	6.82	7.58	11.95	7.72	2.24	5.57
	Min.	0.77	4.74	3.08	2.5	1.03	2.23
	Max.	21.7	27.67	38.56	28.44	8.06	18.32
Pankata (n=19)	Mean	6.31	21.9	21.92	5.21	2.41	14.14
	SD	4.52	24.16	20.46	6.39	2.61	18.48
	Min.	0.22	3.01	2.91	0.99	0.19	1.19
	Max.	13.41	87.72	78.11	28.3	9.04	81.43
Tarutia (n=44)	Mean	8.65	14.38	24.67	5.25	1.66	16.93
	SD	7.98	18.41	24.31	2.97	1.64	9.9
	Min.	0.41	0.71	1.03	1	0.14	1.79
	Max.	40.11	92.17	82.08	11.74	8.47	42.78

the baseline sample [29,30]. For reducing the probable variations in the baseline values of metal n, factor 1.5 is used that can be ascribed to lithogenic effects. Geo accumulation index (I_{geo}) values were categorized as: 5 <I_{geo} – extremely contaminated; 4 ≤ I_{geo} ≤ 5 – heavily to extremely contaminated; 3 ≤ I_{geo} ≤ 4 – heavily contaminated; 2 ≤ I_{geo} ≤ 3 – moderately to heavily contaminated; 1 ≤ I_{geo} ≤ 2 – moderately contaminated; 0 ≤ I_{geo} ≤ 1 – uncontaminated to moderately contaminated; and I_{geo} ≤ 0 – practically uncontaminated.

Pollution load index (PLI): Pollution load index act as an integrated approach which assess soil quality of the six metals is calculated according to Suresh et al. [31]. The PLI can be calculated by using following formula:

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

The overall toxicity status of hazardous materials in soils may be assessed from Pollution load index (PLI) calculation. PLI is the share of conclusion of six hazardous materials.

Potential ecological risk (PER): The degree of hazardous elements contamination in agricultural soils is determined by PER index. Guo et al. [32] proposed equations which were used to calculate PER and are as follows:

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

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

where, C_f^i is the single element contamination factor, C^i is the content of the element in samples and C_n^i is the background value of the element. The background value of Cr, Ni, Cu, As, Cd and Pb in soils were 4.5, 29, 13, 2.5, 0.45 and 7.7 mg/kg (pre-industrial samples of the study area). The sum of C_f^i for all metals represent the integrated pollution degree (C_d) of the environment. E_r^i is the potential ecological risk index and T_r^i is the biological toxic factor of an individual element. The toxic-response factors for Cr, Ni, Cu, As, Cd and Pb were 2, 6, 5, 10, 30 and 5, respectively [3,32,33]. *PER* is the comprehensive potential ecological risk index, which is the sum of E_r^i. Sensitivity of the biological community is represented by it to the toxic substance and indicates the potential ecological risk caused by the overall contamination.

Statistical analysis

The data were statistically analysed using the statistical package, SPSS 20.0 (SPSS, USA).The means of the hazardous element concentrations in soils were calculated. Multivariate methods in terms of principal component analysis (PCA) were used to interpret the potential sources of hazardous element in soil. Other calculations were performed by Microsoft Excel 2010.

Results and Discussion

Physicochemical properties and hazardous elements in soil

The physicochemical properties of soil are shown in Table 1. Physiochemical properties such as pH and organic matter are considered as most impressive factors that mobility and concentration of hazardous elements in soil. The studied soils were slightly acidic to neutral because of decomposition of organic matter and subsequent formation of carbonic acid [3,13,14]. In low pH soil (pH<5), solubility of hazardous elements are increased and indirect effect was observed. Hydrogen ion remains in soil as hydrated protons and act like toxicant [34]. 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 effects is negligible on crop plants. Organic carbon (%C) ranged from 0.50-4.31and the highest organic carbon was found in Pankata soils in Tangail district, Bangladesh. High organic carbon content is an indication that metals are more likely to be bound to organic matter to form metal chelate complexes and

Table 3: Comparison of hazardous elements concentration (mg/kg) [mean (range)] in soil of present study with other study and guideline values.

District (Country)	Cr	Ni	Cu	As	Cd	Pb	References
Tangail, Bangladesh	8.34(0.22-40.1)	16.0 (0.71-92.2)	22.5 (1.03-82.1)	6.35 (0.99-28.4)	2.07 (0.14-9.04)	14.8 (1.19-81.4)	Present study
Bogra (Bangladesh)	41 (6.6-87)	45 (15-95)	42 (6.4-107)	10 (2.0-36)	4.2 (0.7-10)	44 (13-96)	Islam et al., 2014b
Noakhali (Bangladesh)	29 (18-46)	64 (37-93)	22 (13-63)	3.3 (1.5-9.2)	0.07 (0.03-0.2)	13 (8-22)	Rahman et al. (2013)
Dhaka (Bangladesh)	54 (34-68)	58 (36-74)	39 (31-45)	NA	11 (6-16)	50 (44-52)	Ahmad and Goni (2010)
Guandong (China)	12.3 (9.66-19)	8.83 (7.04-10.3)	324 (210-450)	NA	0.9 (0.26-1.17)	96 (73-134)	Luo et al. (2011)
Maharashtra (India)	164 (66-279)	171 (69-465)	155 (52-373)	2.8 (NA-11.2)	30 (22-39)	42 (36-49)	Bhagure and Mirgane (2011)
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)

NA; not available

Table 4: Total variance explained and component matrices for the heavy metals in surface soils collected from Tangail, 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	2.1	35.5	35.5	2.1	35.5	35.5	1.7	27.7	27.7
2	1.3	21.5	57	1.3	21.5	57	1.5	25	52.7
3	1.06	17.7	74.7	1.06	17.7	74.7	1.3	21.9	74.7
4	0.68	11.3	86						
5	0.52	8.7	94.7						
6	0.32	5.3	100						
Elements	Component matrix				Rotated Component Matrix				
	PC1	PC2	PC3		PC1	PC2	PC3		
Component Matrix									
Cr	0.41	0.281	0.76		0.13	-0.11	0.889		
Ni	0.55	0.613	0.19		-0.07	0.5	0.68		
Cu	0.78	0.15	-0.282		0.39	0.72	0.2		
As	0.66	-0.58	0.18		0.89	0.004	0.146		
Cd	0.63	-0.57	-0.07		0.84	0.16	-0.05		
Pb	0.47	0.39	-0.58		-0.02	0.84	-0.06		

Table 5: Enrichment factor (EF) of heavy metals in soil collected from different area of Tangail district, Bangladesh.

Sampling location	Cr	Ni	Cu	As	Cd	Pb
Makulla	0.20±0.13	0.22±0.13	0.33±0.25	1.05±0.67	2.05±1.53	0.19±0.14
Pankata	0.11±0.08	0.35±0.38	0.41±0.38	0.41±0.50	1.49±1.61	0.31±0.41
Tarutia	0.15±0.14	0.23±0.29	0.46±0.46	0.41±0.23	1.03±1.02	0.37±0.22

Table 6: Contamination factor, degree of contamination and contamination level of heavy metals in soils collected from Tangail district, Bangladesh.

Sites	Contamination factor (CF)						Degree of contamination	Contamination level
	Cr	Ni	Cu	As	Cd	Pb		
Makulla	0.12	0.19	0.35	0.93	10	0.4	12	Considerable
Pankata	0.07	0.32	0.49	0.4	8.03	0.71	10	Moderate
Tarutia	0.1	0.21	0.55	0.4	5.55	0.85	7.7	Moderate

this would also result in less availability of metals to plants [35]. The textural class of the soil was loam, and silt loam (Table 1) according to the United States soil texture classification.

The concentrations of hazardous elements (Cr, Ni, Cu, As, Cd and Pb) were presented in Table 2 and Figure 2. Among the sampling sites, levels of trace elements were varied over wide ranges in soil samples with following the descending order of Ni> Cu>Pb> Cr> As> Cd. The ranges of mean concentrations were 0.46-25.07, 2.82-69.18, 2.34-66.25, 1.49-22.82, 0.45-8.52 and 1.73-47.51 mg/kg for Cr, Ni, Cu, As, Cd and Pb, respectively (Table 2). From Table 2 it was distinct that hazardous elements contamination of agricultural soils in three sampling sites around industrial vicinity in Tangail district were not equal. According to Hahm et al. [36], unequal concentration of hazardous materials in soils may be the result of bed rock presence in study area. Several agricultural management like application of fertilizers, manure and pesticides may change hazardous element concentration in soils. The highest mean concentrations of Cr (10.41±6.82mg/kg), As (12.15± 7.72mg/kg) and Cd (3.0±2.24mg/kg) were found in Makulla, Tangail. The notable industrial activities observed at the sites of Makulla were tanneries, lead melting, battery manufacturing, metal processing, etc. Solid and liquid wastes emanating from the tanning industries contain Cr, As, and Cd [5]. During our sampling, we observed huge amount of Ni-Cd batteries, Cd plated items, casting lead, and lead products manufacturing activities at these sites. The highest mean concentration of Ni (21.9±24.14mg/kg) was obtained in Pankata, Tangail and the highest mean concentration of Cu (24.67±24.31mg/kg) and Pb (16.93±9.9mg/kg) were found in Tarutia, Tangail. Li and Huang [37] found an elevated level of Pb (268mg/kg) near battery manufacturing industries of Baoji city, China. It was also noted that Ni, Cd, and Pb are the main primary raw materials used for battery manufacturing [37]. Earlier studies reported that huge amount of Cu is released from steel manufacturing industry [38], Cr from tannery industry [39,40], and Pb from smelting, motor-vehicle exhaust fumes, and from corrosion of lead pipe work. In the present study, different industrial activities were observed which might be the dominant source of metals in soil. High levels of trace metals in soil were consistent with the patterns observed at the industrial area of Dhaka Export Processing Zones by Rahman et al. [21].

Comparison of hazardous elements in soil with other study

Metals in soils were compared with the other studies in Bangladesh and other countries with guideline values. Chromium

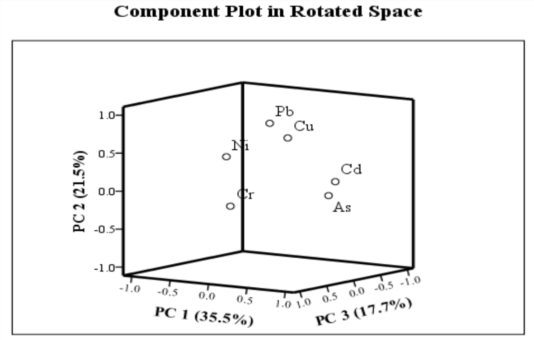

Figure 3: Principal component analysis (PCA) of heavy metals in soils collected from different agricultural fields of Tangail, Bangladesh.

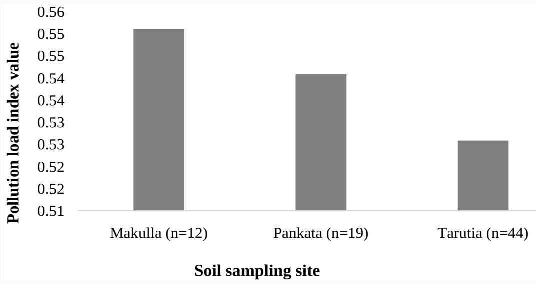

Figure 4: Pollution load index (PLI) of heavy metals in soil collected from different area of Tangail district, Bangladesh.

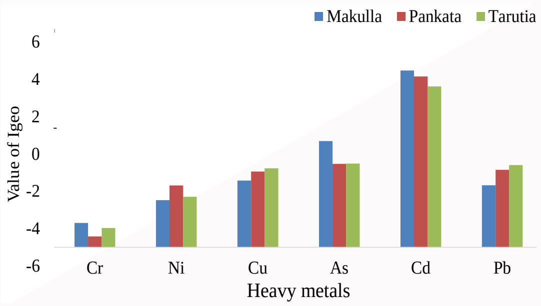

Figure 5: Geoaccumulation index (I_{geo}) of heavy metals in soil collected from different area of Tangail district, Bangladesh (Horizontal dot line indicates the baseline level of metals).

concentrations of the present study were less than those of the study conducted in China, India and study conducted in Bangladesh (Table 3), indicating that soils were less contaminated by Cr. In Bangladesh, the main sources of Cr in agricultural soils where the farmers grow cereals and pulses are the repeated uses of untreated or poorly treated wastewater from industrial establishments (e.g., textile and tannery sludge) and the application of chemical fertilizers and pesticides. This is why studied metals were slightly higher than found in the other studies conducted in Bangladesh and other countries. This can be ascribed to the fact that metal processing, battery manufacturing, and smelting industries responsible for severe metal pollution have been reported from many countries. The mean concentrations of Ni, Cu, and Cd in the present study were less than the Dutch soil quality standard (Table 3). The functional properties of these soils such as nutrients and contaminants storage, transformation and biomass production, etc. were less seriously hampered or threatened, which could potentially cause an adverse effect on humans, plants, and animals. Therefore, the contaminations of these agricultural fields' soils are a major concern because foods are still being grown on these soils. The Dutch soil quality standard is regarded as the most comprehensive guideline considering all possible exposure pathways for protecting humans, plants, and animals. If any metal concentration in soil is below its respective Dutch Target Value, the soil is considered clean. If the concentration level lies between the target values and intervention values, the soil is regarded to be slightly too moderately contaminated. 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, Cd was the worst situation among the studied metals as the mean concentration of Cd was 3 times higher than the Dutch Target value.

Sources of hazardous elements in soil

Principal component analysis (PCA) has commonly been used for investigating metal sources, anthropogenic activities, or soil parent materials [41,42,43]. Three principal components were obtained (Table 4 and Figure 3), and those accounted for 74.7% for soil of all the total variation. In the PCA analysis, first three components were computed and the variance explained by them was 35.5, 21.5 and 17.7 % for soil. PCA revealed three major groups of the metals for soil. First group comprised of Ni, Pb and Cu for soil which were predominantly contributed by lithogenic sources [44]. Second group showed mutual association of As and Cd in soil which were mostly contributed by the industrial emissions in the vicinity of the sampling sites [14,45]. Third group revealed similar loadings of Cr in soil indicated that it was mostly contributed by anthropogenic activities. The depositions of atmospheric particulates released by automobile emissions were believed to contribute these metals in the industrial areas, from where the soil samples were collected [45-48]. PCA analysis revealed that the apportionment of same kind of hazardous materials in soil were not similar, which might be due to the emission behavior of hazardous materials from the source to the environment.

Ecological risk assessment

In present study enrichment factors (EF), pollution load index (PLI), contamination factor (C_f^i) and degree of contaminations (C_d) were determined to know the agricultural soil pollution around the vicinity of Tangail district, Bangladesh. Enrichment factors of soil collected from different locations in Tangail district were presented in Table 5. Among the sites, the descending order of EFs were as Makulla> Pankata>Tarutia. The enrichment factors of hazardous elements of all locations were in the decreasing order of Cd>As>Cu>Pb>Ni>Cr. In regard of all sampling locations, the enrichment factors were less than 1.5 for all hazardous elements (Table 5) assuming less human interference from several industrial activities of Tangail district [27]. Usually in different research have found crusted source to the soil for low enrichment factors which is considered important contribution for agricultural soils and anthropogenic sources for high enrichment factors value [27,49].

The contamination factor (C_f^i) for individual metal and degree of contamination (C_d) are presented in Table 6. Among three sites, Makulla and Pankata showed very high contamination ($C_f^i > 6$) for Cd in soil (Table 6), indicating Cd may pose potential risk to the surrounding ecosystems [27]. Overall, the C_f^i for studied metals were the descending order: Cd >Pb> As > Cu > Ni > Cr. The assessment of soil contamination was based on the degree of contamination (C_d) showed moderate to considerable degree of metal contamination (Table 6). Pollution load index (PLI) value equal to zero indicates perfection; value of one indicates the presence of only baseline

Table 7: Indices and grades of potential ecological risk of heavy metal pollution (Luo et al., 2007).

Contamination factor (Cif)	Contamination degree of individual metal	Degree of contamination (Cd)	Contamination degree of the environment	Eir	Grade of ecological risk of individual metal	Risk index (PER)	
Cif<1	Low	Cd<5	Low contamination	Eir<40	Low risk	RI<65	Low risk
1≤Cf<3	Moderate	5≤Cd<10	Moderate contamination	40≤Eir<80	Moderate risk	65≤RI < 130	Moderate risk
3≤Cf<6	Considerable	10≤Cd<20	Considerable contamination	80≤Eir<160	Considerable risk	130 ≤RI < 260	Considerable risk
Cf≥6	High	Cd≥20	High contamination	160≤Eir<320	High risk	RI ≥ 260	Very high risk
				Eir≥320	Very high risk		

Table 8: Potential ecological risk factor, risk index and pollution degree of heavy metals in soils collected from Tangail district, Bangladesh.

Sites	Potential ecological risk factor (Eir)						Potential Risk (PER)	Pollution degree
	Cr	Ni	Cu	As	Cd	Pb		
Makulla (n=12)	0.2	1.1	1.7	9.3	300	2	314.5	Very high risk
Pankata (n=19)	0.1	1.9	2.4	4	240.8	3.5	252.9	Considerable risk
Tarutia (n=44)	0.2	1.3	2.7	4	166.5	4.2	179	Considerable risk

level of contaminants and values above one indicates progressive deterioration of soil due to metal contamination [14,27]. Extent of pollution increases with the increase of numerical PLI value. As per above grade, present soils were not polluted, since PLI of most lands were lower than one (Figure 4).

Håkanson [50] defines four categories of C_f^i, four categories of C_d, five categories of E_r^i, and four categories of PER, as shown in Table 7. Combining the potential ecological risk index of individual metals (E_r^i) and the potential ecological risk index (*PER*) (Table 8) with their grades (Table 7), soils from three sampling sites were classified at considerable to very high ecological risk by Cd and low potential ecological risk by the remaining hazardous materials. PER represents the sensitivity of various biological communities to different toxic substances and illustrates the potential ecological risk caused by hazardous materials. According to other authors [51,52], Cd contributes significantly to the PER of the environment and may originate from anthropogenic activities. The maximum value of PER (314.5 in soil at Makulla site) denotes very high potential ecological risk for land receiving waste from coal burning power station.

Conclusions

Contamination of hazardous materials (Cr, Ni, Cu, As, Cd and Pb) wasinvestigated in the surface soils from Makulla, Pankata and Tarutia, Tangail district of Bangladesh. Some metals group indicates that they have the same origin, whereas, the distribution of Ni, Pb and Cu in the studied soils confirmed that these metals are derived from the parent material. Metals in soils of three studied sites showed considerable to very high degree of contamination. Considering the individual metal, only Cd showed high ecological risk for all sites, whereas, the potential ecological risk indexes of other metals were low to moderate potential ecological risks. Therefore, a long-term risk assessment needs to be carried out on the leach ability and migration potential of these hazardous elements at the contaminated sites. Moreover, different remediation measures (phyto-remediation or bio-remediation) should be taken promptly to remove or reduce excising metal contamination in the study areas.

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