International Journal of Plant & Soil Science
7(6): 362-372, 2015; Article no.IJPSS.2015.163
ISSN: 2320-7035

SCIENCEDOMAIN
SCIENCEDOMAIN *international*
www.sciencedomain.org

Assessment of Heavy Metal Contamination in Urban Soils of Chittagong City, Bangladesh

M. Alamgir[1*], M. Islam[1], N. Hossain[1], M. G. Kibria[1] and M. M. Rahman[2]

[1]Department of Soil Science, University of Chittagong, Chittagong 4331, Bangladesh.
[2]Department of Physics, University of Chittagong, Chittagong 4331, Bangladesh.

Authors' contributions

Author MA performed the statistical analysis and data interpretation, wrote the protocol, and wrote the first draft of the manuscript. Authors MI and NH managed the analyses of the study. Author MGK designed the study and evaluated manuscript. Author MMR collected samples and recorded data. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2015/18424
Editor(s):
(1) Marco Trevisan, Institute of Agricultural Chemistry and Environmental Research Centre BIOMASS, Faculty of Agriculture, Catholic University of the Sacred Heart, Italy.
(2) Dionisios Gasparatos, Soil Science Laboratory, Faculty of Agriculture, Aristotle University of Thessaloniki, Greece.
Reviewers:
(1) Raul S. Lavado, University of Buenos Aires, National Research Council, Argentina.
(2) Anonymous, Spain.
(3) Zakka Israila Yashim, Department of Chemistry, Ahmadu Bello University Zaria, Nigeria.
(4) Peiyue Li, School of Environmental Science and Engineering, Chang'an University, China.
Complete Peer review History: http://sciencedomain.org/review-history/9895

Original Research Article

Received 20th April 2015
Accepted 4th June 2015
Published 20th June 2015

ABSTRACT

In order to assess the distribution of heavy metals in the urban environment; concentrations of Cd, Cu, Pb, Mn, Ni and Zn were measured on 21 topsoil samples collected from roadside soils of Chittagong city. The heavy metal concentrations were determined by flame atomic absorption spectrometry after digesting the soils with nitric acid–perchloric acid. Mean Cd, Cu, Pb, Mn, Ni and Zn concentrations of the investigated urban soils are 2.43, 32.63, 7.33, 160.79, 860.33, 139.30 mg kg^{-1} respectively. Compared to urban soils of some other cities in the world Cu, Cd, Pb, Mn and Zn concentrations were somewhat similar. Ni concentration largely exceeded the maximum allowable concentration (60 mg kg^{-1}) indicating high contamination. Stepwise multiple regression indicated that soil properties was responsible for 37 to 42% variation in Cd, Cu and Pb content and in case of Ni it was only 16%. The main sources of Ni contamination in Chittagong city can be considered as anthropogenic sources.

**Corresponding author: E-mail: mdalamgir@cu.ac.bd*

Keywords: Metal contamination; roadside soil; pollution index; soil pollution; Chittagong city corporation.

1. INTRODUCTION

Heavy metal pollution of soils is now observed on local, regional and global scales. It has been shown that heavy metal concentrations in surface soil are likely to increase worldwide, with growing industrial and agricultural activities [1]. Heavy metal in urban soils has recently become a subject of many studies and it is shown to be a very useful tracer of environmental pollution [2-8]. Urban soils are generally less well characterized than agricultural soils and are known to have peculiar characteristics such as unpredictable layering, poor structure, and high concentrations of heavy metals [9]. The properties of urban soils can be modified in an unpredictable manner due to diverse human activities including addition of waste materials, pollution from numerous point and diffuse sources, landscaping, and rapid changes of land-use [10]. Due to the high population density and intensive anthropogenic activities, urban soils have been severely disturbed and heavy metal pollution remains as a major issue. The influence of traffic on pollution in top soils near highways is well documented [11]. Heavy metals may originate and reach urban soils in a variety of ways such as vehicle wear (including tyres, brakes and engine) as well as to leaking oil and corrosion, chemical industry, coal combustion, municipal solid waste, the sedimentation of dust and suspended substances in the atmosphere and other activities [11-13]. Roadside soil is also affected by contaminated wastewater from the surface of the road, which is partly accumulated in the soil adjacent to the road [11].

Metals associated with urban soils are of environmental concern because of their direct and indirect effects on human health, persist in soils for a very long time and they may enter the food chain in significantly elevated amounts [14]. Although, many studies have been conducted on urban soils compared with those on agricultural and forest soils, the uniform national approaches for soil environmental quality and clean-up criteria seem rare [9]. Furthermore, urban pollution of cities is specific and varies with local condition [1]. Therefore, more investigations on urban soil pollution should be conducted [15].

In Bangladesh several studies confirmed the presence of elevated concentrations of different heavy metals in soils, water and sediments in the industrial areas. It has been reported that concentration of Cu, Fe, and Cd in irrigation water and Cd content in soil of the industrial areas of Dhaka were much above the recommended level [16] and concentrations of Mn, Zn, Cr, Cu and Pb in water and sediments of Turag River at Tongi area in Bangladesh [17]. Only few studies have evaluated the accumulation of heavy metals in soils of Chittagong city area [18,19]. In these studies soils from industrial and municipal wastes and contaminated sites were investigated but no systematic study has been conducted to evaluate the heavy metal status of urban roadside soils of Chittagong City Corporation (CCC) area. Therefore the objective of the study was to perform a quantitative determination Cd, Cu, Pb, Mn, Ni and Zn in surface soils of the Chittagong city. These metals were chosen because of their abundance and toxic effects in the urban environment.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling

The study area (Chittagong) is located in the south-eastern region of Bangladesh which is the second largest city of Bangladesh. Chittagong is also known as port city of Bangladesh. Chittagong City Corporation (CCC) is one of the 11 City Corporations of Bangladesh and currently it is divided into 41 wards. Major industries in CCC area include garments, fertilizer, chemical, cement clinker, steel mill, paper and jute industries. CCC has an area of 185 Sq. km with a population of 3.56 million [20]. A total of 21 topsoil samples (depth = 0–10 cm) were collected within Chittagong City Corporation (CCC) area (Fig. 1). The GPS coordinates and elevation of soil sampling locations are presented in Table 1. Most of the sampling locations were besides the major roads and are thus likely to be affected by urban environments (traffic, industry, natural substrate, etc).

2.2 Analytical Methods

The soil samples were air-dried and passed through a 2 mm sieve to remove any roots, debris and stones. The samples were then stored in plastic containers for further analyses. The samples were analyzed for pH, texture, organic carbon and metal contents. Soil pH was measured in a soil water suspension in the 1:2.5 soil:water ratio (w:v), by a glass electrode pH meter. Soil texture was determined by hydrometer method and organic carbon by Walkley and Black wet oxidation method. Organic matter content was calculated by multiplying organic carbon values with 1.724. The bulk density of the soil was calculated using bulk-density calculator based on the U.S. Texture Triangle [21]. The concentrations of Cu, Cd, Pb, Mn, Ni, and Zn were determined by atomic absorption spectrometry using a Aligent 240 Atomic Absorption Spectrophotometer (AAS) after digesting the soils with nitric acid–perchloric acid [22].

2.3 Statistical Analysis

All statistical analyses were carried out using PASW Statistics 18, Rel. 18.0.2 (SPSS Inc., 2010, Chicago, USA). Pearson's correlation coefficient and stepwise multiple regression analyses were used to evaluate the relationships between soil properties and metal contents.

3. RESULTS AND DISCUSSION

3.1 Soil Properties

The properties of urban soils are known to differ greatly from agricultural soils of a particular area. Some properties of the soils investigated are given in Tables 2. The soils studied are loamy sand or sandy loam with sand percentage ranging from 53% to 83% except soil from Boro Dighir Par that has relatively low sand content (33%). High sand content of the soils in this region may be explained by their origin from sandstone parent materials [23]. Most sites were homogeneous in terms of their pH and organic matter content. pH of the soil samples ranged from 5.42 to 8.41. Soils from Ishpahani Hall had lower average pH values than other sites. According to Staff [24] most of soil samples can be classified as slightly acid to moderately alkaline (>6.1 to <8.4). Samples from location 2, 16 and 21 represent strongly to moderately acid soil (pH 5.42 to 6). Among the sites OM content was highest in West Bakalia. Average OM content of the soils ranged from 0.13 to 1.85% and according to FRG [25] the soils are very low in OM content (<1% OM) except West Bakalia with low OM content (1.1-1.7).

3.2 Heavy Metals in the Soil

The average concentrations of Cd, Cu, Pb, Mn, Ni and Zn in surface soils of Chittagong city are presented in Table 3. There was marked variability in levels of Ni and Zn in the soils studied, with frequent outlier data but levels of Cd, Cu, Pb, Mn, were normally distributed (Fig. 2).

Table 1. The sampling location and their corresponding geographical positions

Sample No.	Location	Latitude	Longitude	Elevation (m)
1	Nandir Dighi	22.4516389	91.8172778	7.92
2	Boro Dighir Par	22.4353611	91.8175278	7.62
3	Natunpara	22.4181111	91.8186111	10.67
4	Kulgong	22.4008611	91.8174722	21.03
5	Kuaish	22.4013333	91.8338889	7.01
6	Saheed Nagar	22.4005833	91.8508889	2.44
7	Bayezeed	22.3840000	91.8175556	35.05
8	Kalurghat	22.3844722	91.8337500	4.57
9	Bohaddar Hat	22.3842778	91.8511111	3.96
10	Sulokbahar	22.3836944	91.8672778	5.49
11	Foy's Lake	22.3672500	91.8008889	32.31
12	Sholoshahar	22.3685000	91.8183611	11.89
13	Al-Falah Mosque	22.3673611	91.8338056	9.75
14	Chawk Bazar Road	22.3680833	91.8506944	7.01
15	Uttar Kattli	22.3505833	91.8003611	14.94
16	Ishpahani Hall	22.3508611	91.8170000	31.70
17	West Bakalia	22.3509444	91.8339167	36.58
18	South Kattli	22.3336389	91.7839444	7.01
19	Sarai Para	22.3339722	91.8003056	8.23
20	Eidgah Kacha Rasta	22.3341944	91.8172778	13.11
21	Station Polo Ground	22.3339167	91.8336667	19.81

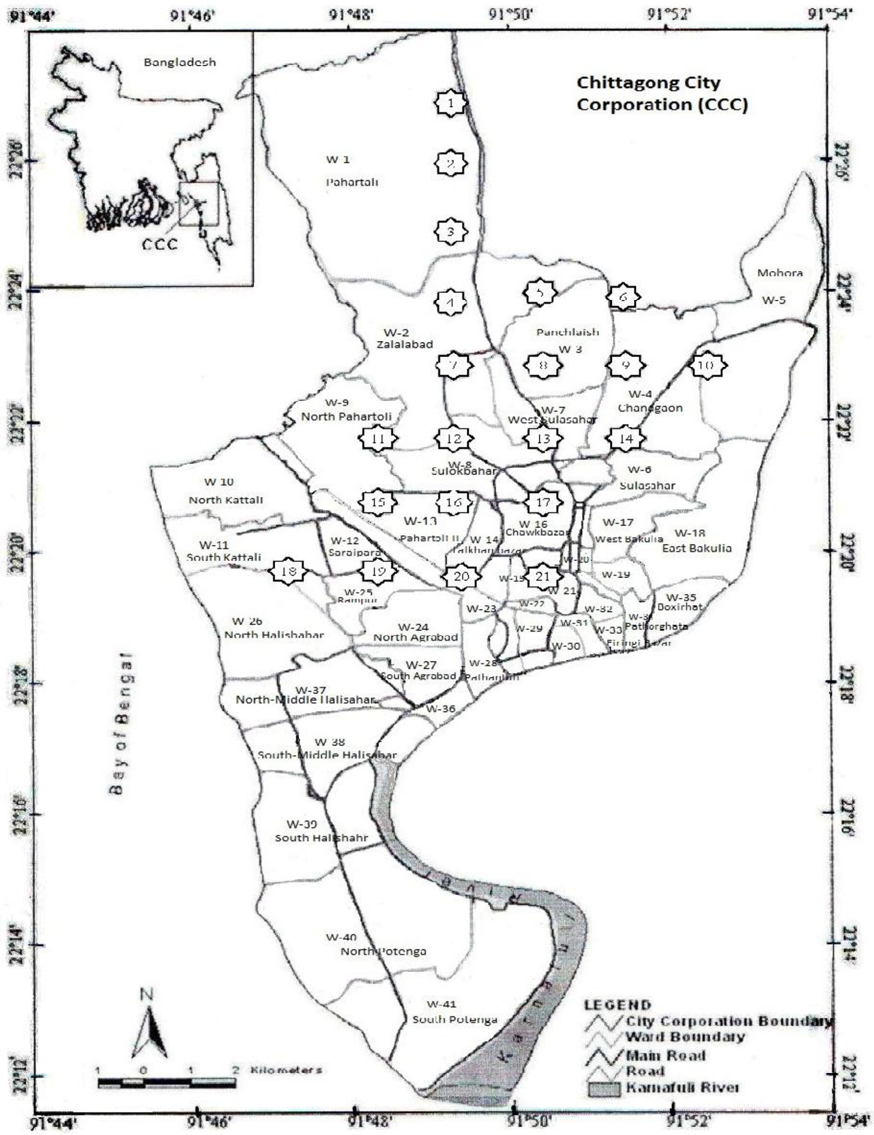

Fig. 1. Location of sample collection in chittagong city corporation

The ranges of the metals were 0.49 - 4.89 mg kg^{-1} for Cd, 4.00-76.00 mg kg^{-1} for Cu, 3.46-13.51 mg kg^{-1} for Pb, 8.80-504.00 mg kg^{-1} for Mn, 12.89-2598.00 mg kg^{-1} for Ni and 21.68-418.00 mg kg^{-1} for Zn. The lowest concentration of Cd was found at Station Polo Ground and the highest at Sulokbahar. For Cu the average is 32.63 mg kg^{-1}, with the lowest concentration occurring at two sites (Bayezeed and Chawk Bazar Road) and the highest for Natunpara. Pb content was highest at Boro Dighir Par and lowest at Foy's lake. Nickel is considered more phytotoxic to plants than other heavy metals, and Ni concentration in all samples except Kuaish was higher than the typical threshold level (60 mg kg^{-1}) for agricultural soil [26]. Of the 21 soils studied, two (Natunpara and Uttar Kattli) were contaminated with Zn (>300 mg kg^{-1}), whereas the remaining nineteen soils were not contaminated with Zn. Compared to results of other studies regarding metals in urban soils in the world (Table 4), those of the present one seem to be comparable. Cu, Cd, Pb, Mn and Zn concentrations are generally similar to those reported for other cities, while Ni content is generally higher indicating soil pollution by this element.

Table 2. Properties of soil collected from Chittagong City, Bangladesh

Location	% Sand	% Clay	Texture	Bulk density	pH	OM (%)
1	75	7	Sandy Loam	1.62	6.35	0.96
2	33	15	Silt Loam	1.44	5.84	0.56
3	58	10	Sandy Loam	1.55	6.48	0.86
4	70	7	Sandy Loam	1.61	8.19	0.16
5	78	5	Loamy Sand	1.68	8.01	0.69
6	78	10	Sandy Loam	1.59	6.75	0.40
7	78	10	Sandy Loam	1.59	6.33	0.20
8	53	5	Sandy Loam	1.64	7.83	0.99
9	75	10	Sandy Loam	1.58	6.26	0.49
10	78	5	Loamy Sand	1.68	8.41	0.13
11	80	7	Loamy Sand	1.63	6.72	0.30
12	75	7	Sandy Loam	1.62	7.46	0.53
13	80	7	Loamy Sand	1.63	7.03	0.53
14	80	7	Loamy Sand	1.63	7.91	0.13
15	80	7	Loamy Sand	1.63	8.39	0.20
16	83	7	Loamy Sand	1.64	5.39	0.53
17	78	7	Loamy Sand	1.63	7.81	1.85
18	65	10	Sandy Loam	1.56	6.17	0.69
19	83	7	Loamy Sand	1.64	6.60	0.49
20	83	5	Loamy Sand	1.69	6.28	0.79
21	68	10	Sandy Loam	1.57	6.02	0.89

Table 3. Average heavy metals concentrations (mean±SEM) in the soils from different locations of Chittagong, Bangladesh and ranges of maximum allowable concentrations (MAC) in agricultural soils (mg kg^{-1})

Loca-tion	Cd	Cu	Pb	Mn	Ni	Zn
1	2.09±0.04	53.78±1.17	7.36±0.05	131.78±1.31	909.67±7.12	114.45±0.99
2	4.24±0.02	50.67±0.44	13.40±0.05	154.35±1.30	1204.84±7.80	23.20±0.80
3	3.45±0.03	74.33±0.88	9.26±0.08	343.82±1.96	2363.22±69.48	402.95±8.04
4	4.62±0.03	72.86±0.58	8.86±0.05	332.61±2.37	2551.96±27.92	71.79±1.34
5	1.16±0.01	34.71±1.05	5.25±0.06	20.07±0.58	13.17±0.18	125.11±3.85
6	2.38±0.02	43.25±0.52	4.22±0.04	112.04±1.12	953.84±10.07	112.07±1.09
7	3.48±0.01	4.68±0.46	3.91±0.03	73.07±0.81	496.10±5.13	61.68±1.38
8	1.75±0.02	22.71±1.17	3.85±0.07	242.08±3.50	686.64±4.71	143.46±1.82
9	2.34±0.03	63.82±0.43	5.55±0.05	500.31±1.87	780.10±5.89	217.21±3.21
10	4.84±0.03	9.03±0.55	4.53±0.19	48.88±1.21	64.37±1.13	69.41±1.83
11	0.77±0.01	11.04±0.29	3.63±0.16	54.55±1.85	748.61±4.20	172.36±2.86
12	2.75±0.02	51.48±0.78	6.33±0.09	275.09±2.71	1251.21±25.22	154.59±1.84
13	1.81±0.04	20.14±0.32	5.58±0.10	14.77±0.79	682.89±1.74	124.62±1.09
14	3.87±0.02	4.68±1.32	13.35±0.11	12.90±0.38	816.60±0.87	84.16±1.07
15	0.89±0.01	42.31±1.23	6.40±0.04	356.25±10.09	149.92±1.54	356.08±12.28
16	1.09±0.04	8.50±0.50	8.38±0.14	60.65±0.68	751.25±4.41	62.50±0.95
17	4.26±0.05	53.08±4.40	12.26±0.03	415.64±4.22	2184.76±52.32	83.91±1.43
18	2.34±0.03	22.71±1.46	10.30±0.08	118.04±1.77	452.98±1.03	224.75±10.39
19	1.34±0.02	10.70±0.35	5.66±0.09	39.61±0.70	160.92±0.98	85.96±1.76
20	1.02±0.01	19.10±0.36	4.46±0.18	9.10±0.21	748.36±3.63	202.90±3.05
21	0.52±0.02	11.57±0.61	11.33±0.16	61.05±2.51	95.56±0.56	32.15±0.54
Total	2.43±0.17	32.63±2.87	7.33±0.40	160.79±18.77	860.33±89.85	139.30±12.18
MAC*	1–5	60-150	20–300	1500-3000	20–60	100-300

**[26]*

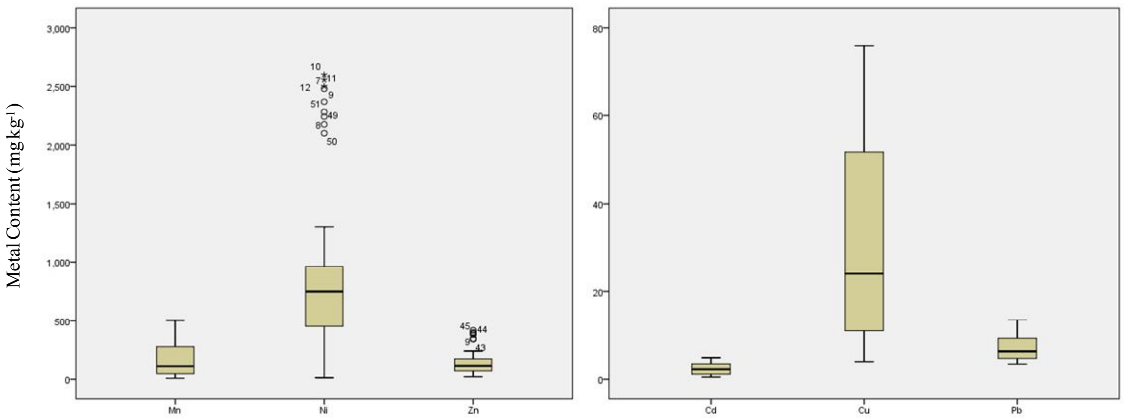

Fig. 2. Boxplot of HM contents in the urban soils of Chittagong, Bangladesh showing the values of the maximal, minimal, median, upper and lower quartiles and outliers

Table 4. Comparison of heavy metal concentrations in urban soils in different cities (mg kg^{-1})

City	Cd	Cu	Pb	Mn	Ni	Zn	Reference
Beijing	0.19	34.43	39.50	-	25.87	89.63	[12]
Manila	0.57	98.70	213.60	1999.00	20.90	440.00	[27]
Bangkok	0.29	41.70	47.80	340.00	24.80	118.00	[28]
Palermo	0.68	63.00	202.00	519	17.80	138	[8]
Chittagong	2.43	32.63	7.33	160.79	860.33	139.30	This Study

In order to determine the influence of the soil properties on the distribution of HM, simple correlations between total HM contents and the soil parameters were calculated. Cu, Ni, and Pb significantly correlated with OM but among the HMs only Cd showed significant correlation with pH (Table 5). Due to high specific surface area OM can form complexes with HM and consequently influence their distribution. Sand showed negative correlation with most of the metals studied, while silt showed positive correlations. Cu and Pb were found to be correlated with clay content. McLean and Bledsoe [29] found that adsorption of metal cations has been correlated with such soil properties as pH, redox potential, clay, soil organic matter, Fe and Mn oxides, and calcium carbonate content. Zn and Mn were not correlated with any soil properties. The lack of correlations of Zn and Mn with the soil properties could be due to the fact that they are deposited onto the polluted sites and is not clearly incorporated into soil dynamics. Inter element correlations show that Cu, Ni and Zn and Cd are correlated with Mn which suggests their affinities for soil Mn-phases. It has been reported that the affinity of trace elements for Mn oxide was usually much greater than that for Fe or Al oxides [30]. Highly significant correlations between Cu, Mn and Ni indicate that these polluting elements could originate from the same source. The negative correlations are may be due to less combined physiological effect of two or more elements than the sum of their independent effects [31].

The results of linear multiple regressions are presented in Table 6. Stepwise multiple regression indicate that 37 to 42% variation in Cd, Cu and Pb can be explained by the variation in clay, pH sand, silt and OM content of the soils. OM was the dominant factor for Cu, Pb and Ni. In addition pH, sand and silt also contributed to the prediction of metal concentrations in some cases. Clay played an important role for the content Pb only in the studied sites. Soriano-Disla et al. [32] also confirmed the importance of pH as well as other soil properties such as texture, electrical conductivity and organic matter or carbonates on the behavior of heavy metals through multiple regression analyses.

Heavy metal dynamics in soils are complex and metal bioavailability depends on a variety of factors including the properties of both the metal and the soil environment such as the pH, soil organic matter, soil texture, redox potential, temperature etc. [33-35]. Season and climatic conditions can also cause an enhanced or reduced mobility [1].

Table 5. Pearson correlation coefficients between soil properties and metals

	Sand	Clay	Silt	pH	OM	Mn	Cu	Ni	Zn	Pb
Clay	-.619**									
Silt	-.984**	.470**								
pH	.190	-.574**	-.084							
OM	-.032	.081	.017	-.224						
Mn	-.238	.180	.227	.215	.241					
Cu	-.354**	.273*	.337**	.118	.307*	.784**				
Ni	-.281*	.186	.274*	.062	.337**	.569**	.710**			
Zn	.007	-.052	.004	.090	.029	.442**	.382**	.135		
Pb	-.415**	.464**	.362**	-.126	.404**	.150	.199	.376**	-.181	
Cd	-.317*	.241	.301*	.314*	-.020	.294*	.343**	.560**	-.225	.381**

**. Correlation is significant at the 0.05 level (2-tailed), **. correlation is significant at the 0.01 level (2-tailed)*

Table 6. Results of stepwise linear multiple regression analysis

Metal	Multiple regression equation	R^2
Cd	1.01(pH) – 0.36 (sand) – 0.31 (silt) + 25.38	0.37
Cu	22.22 (OM) – 4.09 (sand) – 3.70 (silt) +12.91(pH) +309.58	0.38
Pb	3.49 (OM) + 0.82 (clay) + 1.14 (pH) – 8.89	0.42
Ni	619.37 (OM) – 16.15 (sand) + 1705.62	0.16

The soil pH is generally the most important factor controlling partitioning behavior of heavy metals in soil. Generally, metal sorption to soil is low at low pH (<5.0) and increases as soil pH increases due to the effects of pH on variable-charged sorption sites [36,37]. Soil pH had significant positive correlation with concentrations of As, Cd, Cr, Cu, Mn, Se, and Zn [38].

The presence of heavy metals may be a result of natural processes but could also be related to metal corrosion from vehicles and highway infrastructure. It is known that the main sources of some heavy metals such as cadmium, copper, lead, nickel and zinc are the traffic, domestic heating and long-range transport [11,39,40]. The dispersion of metals is influenced by meteorological conditions like wind, rainfall and traffic intensity.

The soils studied had a relatively low OM with a sandy texture. Due to their sandy texture and low organic matter content these soils have a low sorption capacity for metal ions. Chittagong city has a high daily traffic density of roads but most of vehicles running within city use compressed natural gas (CNG) as fuel. Due to government subsidy and low price of CNG most of the cars and other small vehicles have been converted in a way that both CNG and octane/disel can be used as fuel. Furthermore leaded Octane/Disel has been banned in Bangladesh almost a decade ago. Almost every year during monsoon heavy downpour causes unprecedented inundation in Chittagong city and consequently a significant portion of surface soils are removed through runoff. Thus, the low HM contents in Chittagong city can be predicted in a way that greater quantity of heavy metals might have leached and dispersed downstream by water and wind than the atmospheric depositions. Similar was reported by Page, Chang, and El-Amamy [41] in highly weathered US soils. The pollution due to Ni in soils from Chittagong may be the consequence of the impact of traffic but may also derive from other anthropogenic sources of pollution.

3.3 Soil Pollution Indices

Soil Pollution Index (SPI) may be used to quantify the degree of pollution of urban soil. The geo-accumulation Index (Igeo) and Single Element Pollution Index (SEPI) were employed to assess the pollution of metals in urban soils of Chittagong, Bangladesh.

3.3.1 Geo-accumulation Index (Igeo)

Geo-accumulation Index (Igeo), which was proposed to assess the degree of pollution in aquatic sediments by Müller in 1969 [42], can also be used to the assessment of soil pollution [43]. Igeo is computed by the following equation:

$$Igeo = \log_2(Cn/1.5Bn)$$

where, Cn is the measured concentration of the examined metal (n) in the soil, Bn is the geochemical background concentration of the metal (n), and factor 1.5 is the background matrix correction factor due to lithogenic effects. Igeo was classified into seven grades ranging from unpolluted to extremely polluted: Igeo ≤0 (grade 0), unpolluted; 0< Igeo ≤1(grade 1), slightly polluted; 1< Igeo ≤2 (grade 2), moderately polluted; 2< Igeo ≤3 (grade 3), moderately severely polluted; 3< Igeo ≤4 (grade 4), severely polluted; 4< Igeo ≤5 (grade 5), severely extremely polluted; Igeo >5 (grade 6), extremely polluted.

In this study, we did not obtain the background values of heavy metals in soils of Chittagong region. Therefore, Igeo has been calculated by using background values according to Jiménez-Ballesta, et al. [44] and Al Obaidy and Al Mashhadi [45]. The distribution of heavy metal enrichment based on Igeo in different sampling locations has been shown in Fig. 3. The negative Igeo values in the figure are the results of relatively low levels of contamination and the background variability factor (1.5) in the Igeo equation.

The Igeo values indicate that Ni can be considered as a strong pollutant at most of the study locations except locations 5 and 10. Mn showed moderate pollution in 5 locations. Based on geo-accumulation index the studied locations are considered unpolluted from Cd and Pb. Cu and Zn showed uncontaminated to slight pollution in most locations.

3.3.2 Single Element Pollution Index (SEPI)

SEPI is a simple and well known index [46]. Single pollution index in this study was calculated as follows:

SEPI= metal content in soils/ permissible level of metal

The permissible level of metals in soil suggested by [47] was used for calculation and each heavy metal was classified as low contamination (SEPI ≤ 1), moderate contamination (1 < SEPI ≤ 3) or high contamination (SEPI > 3) [48].

The SEPI value of Cd, Cu, Mn, Pb and Zn varied from 0.02 to 0.49 (Table 7) which indicated low contamination level. The studied soils were highly contaminated by Ni with SEPI value of 14.33.

Table 7. Single element pollution index values

Metals	SEPI
Cd	0.49
Cu	0.22
Mn	0.05
Ni	14.33
Pb	0.02
Zn	0.46

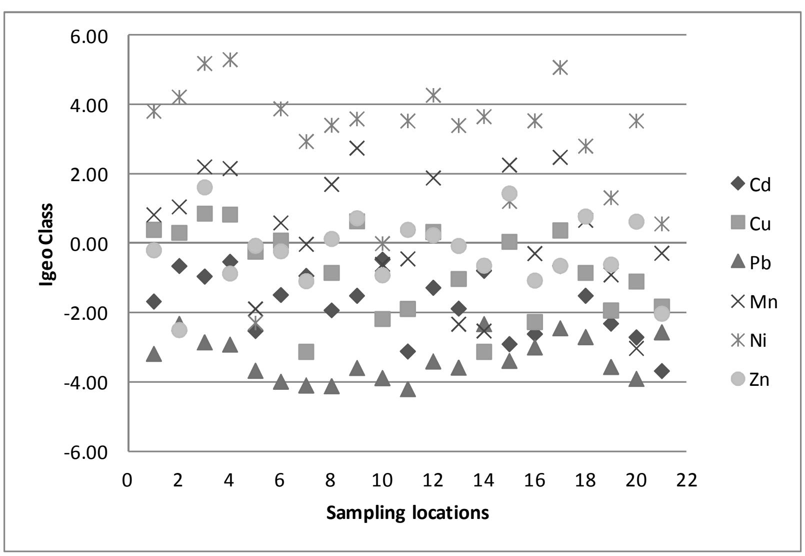

Fig. 3. Distribution of heavy metal enrichment based on Igeo

4. CONCLUSIONS

The present study carried out to understand levels of metal pollution in Chittagong city indicate that the samples studied can be considered to be polluted by Ni to a greater extent. Based on the single element pollution index, the studied area is not contaminated with respect to Cd, Cu, Mn, Pb and Zn but based on geo-accumulation index the area is slightly to moderately polluted with regards to Cu, Mn and Zn. The linear regression equations obtained can be helpful to obtain approximated concentrations of Cd, Cu, Pb and Zn in soil samples of Chittagong region based on pH, OM, sand, silt and clay contents. For better understanding of HM dynamics further research is necessary to evaluate HM contents in unpolluted natural soils of Chittagong city.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kabata-Pendias A. Trace elements in soils and plants. Fourth Edition. CRC press; 2010.
2. Davies BE, Houghton NJ. Distance—Decline patterns in heavy metal contamination of soils and plants in Birmingham, England. Urban Ecology. 1984;8(4):285-294.
3. Burguera J, Burguera M, Rondon C. Lead in roadside soils of Merida City, Venezuela. Science of the Total Environment. 1988;77(1):45-49.
4. Sanchez-Martin M, Sánchez-Camazano M, Lorenzo L. Cadmium and lead contents in suburban and urban soils from two medium-sized cities of Spain: Influence of traffic intensity. Bulletin of Environmental Contamination and Toxicology. 2000; 64(2):250-257.
5. Curran-Courname F, et al. Heavy metal soil pollution is influenced by the location of green spaces within urban settings. Soil Research; 2015.
6. Karim Z, et al. 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. 2014;42:20-31.
7. Luo X.-S, et al. Source identification and apportionment of heavy metals in urban soil profiles. Chemosphere. 2015;127(0): 152-157.
8. Manta DS, et al. Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. Sci. Total Environ. 2002; 300(1):229-243.
9. Tiller K. Urban soil contamination in Australia. Soil Research. 1992;30(6):937-957.
10. Madrid L, et al. Variability in concentrations of potentially toxic elements in urban parks from six European cities. Journal of Environmental Monitoring. 2006;8(11): 1158-1165.
11. Dobsa J, et al. Evaluation of spatial and temporal variation in water contamination along croatian highways by multivariate exploratory analysis. Water, Air, Soil Pollut. 2014;225(10):1-15.
12. Xia X, et al. Heavy metals in urban soils with various types of land use in Beijing, China. J. Hazard. Mater. 2011;186(2): 2043-2050.
13. Manta DS, et al. Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. The Science of the Total Environment. 2002;300(1-3):229-43.
14. Ciesla GL, Komisarek J, Potarzycki J. Geochemical Assessment of Heavy Metals Pollution of Urban Soils. Polish Journal of Environmental Studies. 2002;11(5).
15. Pouyat RV, McDonnell MJ, Pickett S. Soil characteristics of oak stands along an urban-rural land-use gradient. Journal of Environmental Quality. 1995;24(3):516-526.
16. Ahmad J, Goni MA. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. Environ Monit Assess. 2010;166(1-4):347-357.
17. Zakir H, Sharmin S, Shikazono N. Heavy metal pollution assessment in water and sediments of Turag River at Tongi area in Bangladesh. International Journal of Lakes & Rivers. 2006;1(1).
18. Alam SS, Osman KT, Kibria MG. Heavy metal pollution of soil from industrial and municipal wastes in Chittagong,

Bangladesh. Archives of Agronomy and Soil Science. 2011;58(12):1427-1438.

19. Kibria M, et al. Dynamics of cadmium and lead in some soils of Chittagong, Bangladesh. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2013;64-71.
20. BBS, Bangladesh Bureau of Statistics (BBS); 2000.
21. Pedosphere.ca. Bulk Density Calculator based on the Canadian Texture Triangle; 2012. Available:http://www.pedosphere.com/resources/bulkdensity/worktable_us.cfm
22. Olsen S, Sommers L, Page A. Methods of soil analysis. Part 2. Chemical and Microbiological properties. 1982;9.
23. Brammer H. Bangladesh Land Resources Technical Report-3. AGL: SF, Pak-6, FAO, Rome; 1971.
24. Staff SSD. Soil Survey Manual. Soil Conservation Service. U.S. Department of Agriculture Handbook. 1993;18.
25. FRG. Fertilizer Recommendation Guide, Farmgate, Dhaka, Bangladesh: Bangladesh Agriculture Research Council; 2012.
26. Kabata Pendias A, Sadurski W. Trace elements and compounds in soil. Elements and Their Compounds in the Environment: Occurrence, Analysis and Biological Relevance, Second Edition. 2004;79-99.
27. Pfeiffer E-M, et al. Trace elements and heavy metals in soils and plants of the Southeast Asian metropolis Metro Manila and of some rice cultivation provinces in Luzon, Philippines; 1988. Verein zur Förderung d. Bodenkunde in Hamburg.
28. Wilcke W, et al. Urban soil contamination in Bangkok: heavy metal and aluminium partitioning in topsoils. Geoderma. 1998; 86(3):211-228.
29. McLean J, Bledsoe B. Behaviour of metals in soils (EPA Ground Water Issue, EPA 540-S-92-018: 25 pp). Washington, USA: Environmental Protection Agency; 1992.
30. Violante A, et al. Mobility and bioavailability of heavy metals and metalloids in soil environments. Journal of Soil Science and Plant Nutrition. 2010;10(3):268-292.
31. Olsen S. Micronutrient interactions, in Micronutrients in agriculture, Mortvedt J, Giordano P, Lindsay W. Editors. Soil Science Society of America: Madison. WI. 1972;243-264.
32. Soriano-Disla J, et al. Edaphic factors related to heavy metals and nutrients behaviour following a single sewage sludge application. Geoph. Res. Abs. 2008;10:00769.
33. Adriano D, et al. Role of assisted natural remediation in environmental cleanup. Geoderma. 2004;122(2):121-142.
34. Naidu R, Bolan N. Contaminant chemistry in soils: key concepts and bioavailability. Chemical Bioavailability in Terrestrial Environment. 2008;9:38.
35. Alloway BJ. Heavy metals in soils: trace metals and metalloids in soils and their bioavailability. Springer; 2012.
36. McBride M. Reactions controlling heavy metal solubility in soils, in Advances in soil science. Springer. 1989;1-56.
37. Schindler PW. The regulation of heavy metal concentrations in natural aquatic systems. Heavy Metals in the Environment. 1991;1:95-123.
38. Chen M, Ma LQ, Harris WG. Baseline concentrations of 15 trace elements in Florida surface soils. Journal of Environmental Quality. 1999;28(4):1173-1181.
39. Viard B, et al. Integrated assessment of heavy metal (Pb, Zn, Cd) highway pollution: bioaccumulation in soil, Graminaceae and land snails. Chemosphere. 2004;55(10):1349-1359.
40. Bakirdere S, Yaman M. Determination of lead, cadmium and copper in roadside soil and plants in Elazig, Turkey. Environ. Monit. Assess. 2008;136(1-3):401-410.
41. Page A, Chang A, El-Amamy M. Cadmium levels in soils and crops in the United States. Lead, Mercury, Cadmium and Arsenic in the Environment. 1987;119-146.
42. Muller G. Index of geoaccumulation in sediments of the Rhine River. GeoJournal. 1969;2:108-118.
43. Zhiyuan W, et al. Assessment of soil heavy metal pollution with principal component analysis and geoaccumulation index. Procedia Environmental Sciences. 2011; 10:1946-1952.
44. Jiménez-Ballesta, et al. Pedo-geochemical baseline content levels and soil quality reference values of trace elements in soils from the Mediterranean (Castilla La

Mancha, Spain). Central Euro. J. Geoscience. 2010;2(4):441-454.

45. Fadigas FS, et al. Background levels of some trace elements in weathered soils from the Brazilian Northern region. Scientia Agricola. 2010;67(1):53-59.

46. Al Obaidy AHM, Al Mashhadi AA. Heavy metal contaminations in urban soil within Baghdad city, Iraq. Journal of Environmental Protection. 2013;4:72.

47. Kabata-Pendias A. Soil–plant transfer of trace elements—an environmental issue. Geoderma. 2004;122(2):143-149.

48. Chen T-B, et al. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. Chemosphere. 2005;60(4):542-551.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/9895