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ORIGINAL ARTICLE

Characterizing Changes of Heavy Metals in the Soils from Different Urban Location of Borujerd, Lorestan Province, Iran

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KEYWORDS

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ABSTRACT: As more people live in cities and urban areas, evaluation of urban environmental quality is nowadays an unavoidable necessity. Urbanization gives off heavy metals into urban soils and threatens the human health. In this study, urban soil samples were acquired from different locations (Public parks, streets, and squares) from Borujerd, Iran. The levels of Cd and Pb in the soils, along with soil pH, electrical conductivity (EC), and particle size distribution (texture), were analyzed. Kriging method by Surfer software was employed to create the spatial distribution maps of Cd, Pb, and geoaccumulation index (Igeo). The average Cd and Pb concentrations in the surface soil samples were 2.50±1.14, and 50.37±34.77 mg/kg dry weight, respectively. The highest mean concentration of Cd was found in street soils and as for Pb in square soils. The interpolation maps illustrated the same behavior for Cd and Pb with elevated concentrations located in the southeast. The mean values of geoaccumulation index (Igeo) showed that soils are moderately/strongly contaminated with Cd and moderately contaminated with Pb. In this study, traffic emission, textile industries and probably released untreated municipal wastewater into the soil are anthropogenic sources of Pb and Cd.

INTRODUCTION

Rapid urbanization and industrialization have significant effects on soil potentially toxic elements (PTE) concentrations [1]. In addition, urbanization processes not only deposited toxic substances such as metals in the soils but also changed intrinsic properties of the affected soils, such as their pH, texture, cation exchange capacity, and bulk density [2]. Therefore, soil, as the key components of urban ecosystems, plays a fundamental role in the maintenance of urban ecosystem services, such as biodiversity conservation, protection of water resources;

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regulate the microclimate, sequestering carbon from the atmosphere, food production, and cultural and recreational infrastructure [3]. Heavy metals persist for long periods in the soil and may act as a source of further pollution in vegetation, surface, and groundwater and pose a potential threat to urban residents [4]. Howbeit urban soils are not applied for crop planting; metals in urban soils can be easily taken into human bodies through different routes such as ingestion, inhalation, or dermal penetration, etc. [5]. Anthropogenic sources of heavy metals contamination in urban soils are traffic (vehicle exhaust particles, brake wear, tyre wear, road surface wear), industrial activity (coal and fuel combustion, power plants, auto repair shop, chemical plants, metallurgical industry, etc.), household and industrial (toxic) waste, weathering of building and pavement surface, atmospheric deposited and so on [6-9]. These processes released heavy metals into the atmosphere and the heavy metals subsequently are deposited into urban soil as the metal-containing dust falls. Heavy metals in the urban soils can also produce airborne particles and dust, which may affect the urban air quality [10, 11]. Traffic emission is a significant and increasing source of air and soil pollution in urban ecosystems [12].

Lead and cadmium are the most common pollutants that may occur in urban soils. The main sources of Pb and Cd are the leaded gasoline in the form of tetraethyl lead from the early 1920's and the wear of tires respectively [13]. Many adverse health effects of heavy metals in high concentrations have been recognized for a long exposure to these pollutants [14]. The toxic metals may accumulate inside the human body in tissue such as fat, bone, and affects different organs such as central nervous system, causing heavy metal poisoning and acting as cofactors in many other diseases. Therefore, particularly dangerous lead and cadmium, so-called "metals of death", with capability accumulation in organisms and food chains must be investigated [15]. Because of the importance of this issue, in the recent decades, numerous researches were done in different cities of the world to evaluate heavy metals contamination in urban soils [9-10, 16-24].

There are no published data on the soil pollution in urban areas of Borujerd. However, it is necessary to design a study on the occurrence of metal contaminants in urban soils of Borujerd. Thereby, the objectives of this research were to 1) determine the concentrations and distribution of heavy metals (Cd and Pb) in surface soils collected from Borujerd, 2) identify possible sources of these metals, 3) assess contamination level of the studied heavy metals.

MATERIALS AND METHODS

The area studied in this research was the metropolitan area of Borujerd City (western Iran). Borujerd is in the northeast part of Lorestan Province, Iran, the geographical position is 33° 53' 50" N, 48° 45' 5" E. The city's elevation from sea level is approximately 1670 meters with cold winters. The average annual temperature is 14.6 °C and the mean annual rainfall is about 480 mm [25]. Scope of the soil sampling was confined to the urban area of Borujerd, Iran. Altogether 40 composite urban topsoils (0-5 cm), including 19 urban parks (19 samples), 11 streets (11 samples) and 10 squares (10 samples) soils were gathered from an area about 30 km^2 in some part of Borujerd city (Figure 1).

All the soil sample locations were registered by GPS during the completely sampling period. Samples of almost 0.5 kg of surface soil consisting of 5 subsamples collected in every sampling point were taken and then mixed thoroughly to obtain a bulk sample. After air-drying of soil samples, the sample was gently crushed and passed through a 10-mesh sieve to remove extraneous materials and finally was again sieved with 0.15 mm mesh. 0.5 gram of soil sample was put into the digestion vessels along with 7.5 mL hydrochloric acid, 2.5 mL concentrated nitric acid and 2.5 mL perchloric acid. The filtered residues were diluted with deionized water to 25 ml in a volumetric flask and applied directly for analysis by atomic absorption analysis. In order to correct the measurements, a blank was run throughout the entire extraction procedure for each batch of sample preparation. The concentrations of Cd and Pb in the digestion solution were measured by atomic absorption spectrometry (AAS). Pb concentrations were determined by flame atomic absorption spectroscopy (FAAS). Due to low levels of Cd in the soil and that was not in detection limit of FAAS, concentration of Cd was analyzed by graphite furnace atomic absorption spectroscopy (GFAAS).

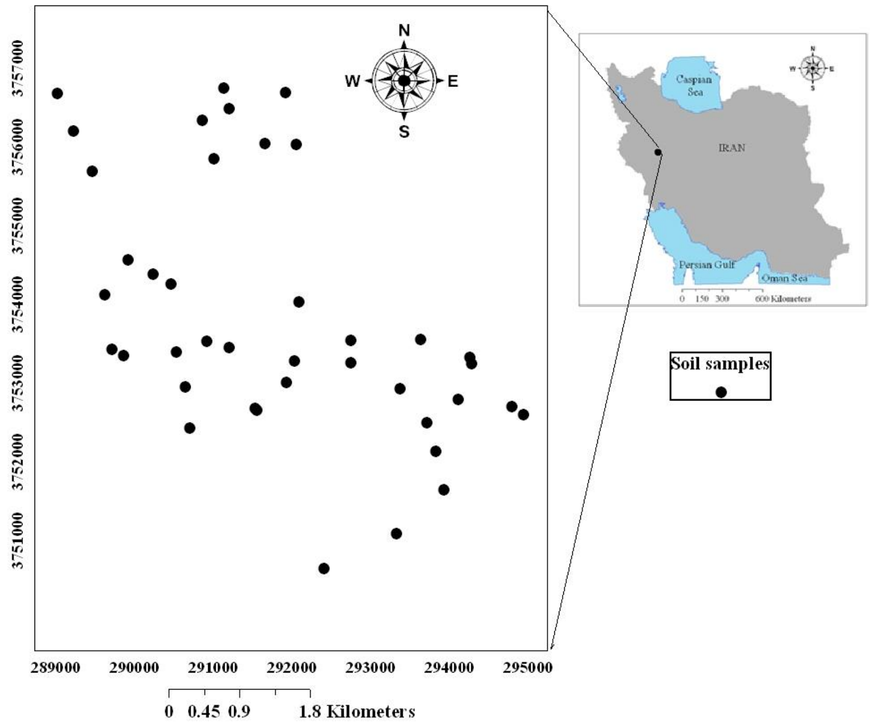

Figure 1. Map of the location of Borujerd City in Iran and the sampling points

Statistical analyses were carried out using SPSS version 18.0 (Chicago, IL, USA). Descriptive statistics include maximum, minimum, median, mean, standard deviation (SD) were calculated for the heavy metals in the soil samples. The data were assessed for normal distribution with the Shapiro-Wilk test, which indicated that most of the variables were not normally distributed (except EC). Spearman correlation coefficients were obtained using the bivariate procedure in SPSS. We applied Spearman correlation analysis to assess the relationships between the heavy metal concentrations and soil properties. A two-tailed *P*-value of <0.05 was regarded to show statistical significance. The Kruskal-Wallis test was applied to test the differences in Cd and Pb levels between different locations. Kriging method was used and spatial distribution contour maps were made by using Golden Software Surfer 9.0.

RESULTS AND DISCUSSION

The contamination of urban surface soils with heavy metals generally presents urban environmental quality. Table 1 shows the analytical results of cadmium and leads in surface soil samples from the Borujerd city. A wide range of values for these metal concentrations was seen for the soils in the study area. We obtained the concentration ranges of metals in urban soils for Cd (1.20– 7.60 mg/kg), and Pb (5.65–117.46 mg/kg), with mean concentrations of 2.50, and 50.37 mg/kg, respectively. This considerable variation suggests the effect of anthropogenic activity on the content and distribution of soil metals in the city. The comparison with mean concentrations of Cd and Pb of urban soils reported for other cities (Table 2) in the world [26-33] indicates that the mean value of Pb in Borujerd urban soils was within the normal range of Pb in urban soils with the exception of NewYork (USA), Baltimore (USA) and Seri Kembangan (Malaysia). Besides, in this table, comparing average Cd level (2.50 mg/kg) in surface soil of the Borujerd city with that existing from previous studies in Iran (e.g. Asadabad and Birjand) [34, 35], Cd showed higher concentrations than the average values. In addition, for Pb (average 50.37 mg/kg) levels were higher than those obtained by other Iranian studies, such as [34] (mean 20.72 mg/kg), [35] (mean 46.59 mg/kg) and [36] (mean 12 mg/kg).

Table 1. Cd and Pb concentrations (mg/kg), pH and EC in Borujerd at 40 soil sample sites and corresponding descriptive statistics

	Cd	Pb	pH	EC
N	40	40	40	40
Minimum	1.20	5.65	6.91	0.04
Maximum	7.60	117.46	8.50	1.82
Mean	2.50	50.37	7.72	0.29
Std. Error	0.18	5.45	0.07	0.05
Std. Deviation	1.14	34.77	0.43	0.32
Skewness	2.6	0.80	-0.12	3.14
Kurtosis	9.51	-0.63	-1.08	12.79

Table 2. Mean Cd and Pb concentrations (mg/kg) in urban soils in different cities

City, Country	Cd	Pb	Data sources
Changsha, China	0.74	50.14	[26]
Las Tunas, Cuba	-	42	[27]
Guiyang, China	0.98	79.5	[28]
Lithgow, Australia	-	20.8	[29]
Annaba, Algeria	0.44	53.1	[30]
NewYork, USA	0.4	221	[31]
Baltimore, USA	1.06	231	[32]
Seri Kembangan, Malaysia	47.5	2801.8	[33]
Asadabad, Iran	0.18	20.72	[34]
Birjand, Iran	1.53	46.59	[35]
Masjed Soleyman, Iran	-	12	[36]
Borujerd, Iran	2.50	50.37	This study

The mean value of Cd in this research was higher than soils in most cities except for Seri Kembangan (Malaysia) which probably may be caused to the high background content [5] of Cd in Borujerd verified by study of the background values of heavy metal concentrations in soils. Urban soils in this research ranged in pH from

6.91 to 8.50 (mean 7.72). As shown in Table 1, pH of 30% of the soil samples was neutral soils (pH of 6.5–7.5) and 70% of the soil samples was alkaline soils (pH>7.5). The EC (electrical conductivity) values of the soil samples (0-5cm) in the study area ranged from 0.04 to 1.82 dS/m with a mean value of 0.29 dS/m. Soil texture plays a very important role in the mobility of heavy metals in soil. The soil texture reflects the distribution of soil particle size and thus the content of fine particles like oxides and clay. Clay size fraction retains high amount of heavy metals when compared to sand size fraction [37]. Based on the findings of particle size, 40% of soils exhibited loamy sand and 60% of soils showed sandy loam texture.

Land use is projected to have impact on soil pollution and public health [38]. Therefore, study of heavy metal levels in different locations of urban soils would be useful. Examination of Cd and Pb concentrations in different locations (Park, Street, and Square) disclosed different accumulations of Cd and Pb. Findings of Cd and Pb concentrations in different locations are shown in Table 3 along with relevant main statistical parameters. Although two metals had no significant differences among locations (Figure 2), higher values of lead concentrations higher values of lead were found in square while Cd dominated in street soils. The mean Cd concentration with different locations followed the sequence: Street > Square > Park, and Pb level follows the sequence: Square > Street > Park. Among different land uses, parks and road greenbelts had lower soil Pb, primarily because of soil restoration [3]. The spatial distribution of metal in soils is a useful aid to evaluate the possible sources of metal and to identify the pollution hotspots of metals [39, 40]. The results of spatial distribution patterns of cadmium and lead in surface soil sample are presented in Figure 3 using kriging method. Maps of these metals indicated approximately similar spatial distribution patterns, showing they may have been affected by the same sources that the presence of elevated metals in soils of the study area is due to anthropogenic sources. The spatial distribution of Cd and Pb in soil indicated a center-to-southeast trend with elevated concentrations located in the southeast (Figure 3). The reason for high concentrations of Cd and Pb in the soil of the southeast part of the study area could be attributed to the impact of textile industries. Textile industries are one of the main sources of the heavy metal pollution in the environment [41] and emissions of metals such as Cd and Pb in the textile dying industrial sites resulted in contamination of soils in close proximity to these areas [42]. Strong positive correlation was obtained among some of the heavy metals contractions in industrial area soils and their decreasing contents with distance in the textile dying industrial areas [42]. In addition, notable levels of metals had been released into the surrounding soil from textile industries [41]. Values of 56.4 and 164mg/kg were obtained for Pb and Cd respectively. Since the observed distribution, trends for Cd and Pb had many hot-spot areas and their mean concentrations were high, Cd and Pb in urban soils were defined polluted and were probably originated from human activities. High levels of lead might be related to the use of petrol with Pb additives. Although lead in petrol has dramatically declined and banned over the last decades, the level of Pb in the urban soils may show long-term accumulation of historical Pb contamination from traffic emissions [43]. Another increasing trend was observed for Cd from the center to north. In the studied area, the high Cd concentration in the soil may be attributed to releases large quantities of untreated municipal wastewater into the soil and groundwater, and it has been reported that absorbing wells are used for disposal of 70% wastewater.

Table 3. Urban soil Cd and Pb concentrations in different locations of Borujerd city

	Parks		Squares		Streets	
	Cd	**Pb**	**Cd**	**Pb**	**Cd**	**Pb**
N	19	19	11	11	10	10
Minimum	1.20	5.65	1.69	7.65	1.75	19.46
Maximum	7.60	117.46	4.87	117.12	4.34	111.42
Mean	2.4	43.64	2.47	56.48	2.74	56.42
Std. Error	0.33	7.65	0.29	11.32	0.22	11.26
Std. Deviation	1.42	33.34	0.97	37.53	0.71	35.62
Skewness	2.97	1.15	1.78	0.6	1.01	0.78
Kurtosis	10.49	0.66	3.14	-1.24	2.59	-1.12

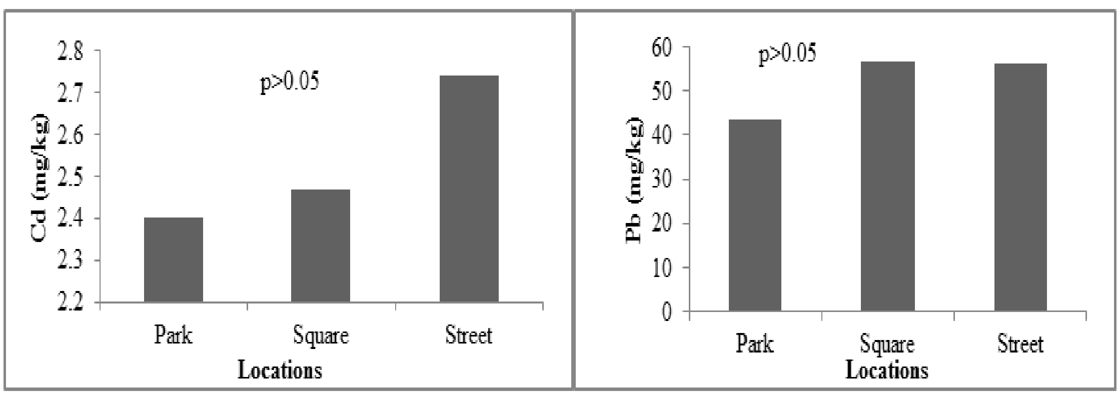

Figure 2. Kruskal-Wallis test for comparison of Cd and Pb concentrations in soil samples from three locations

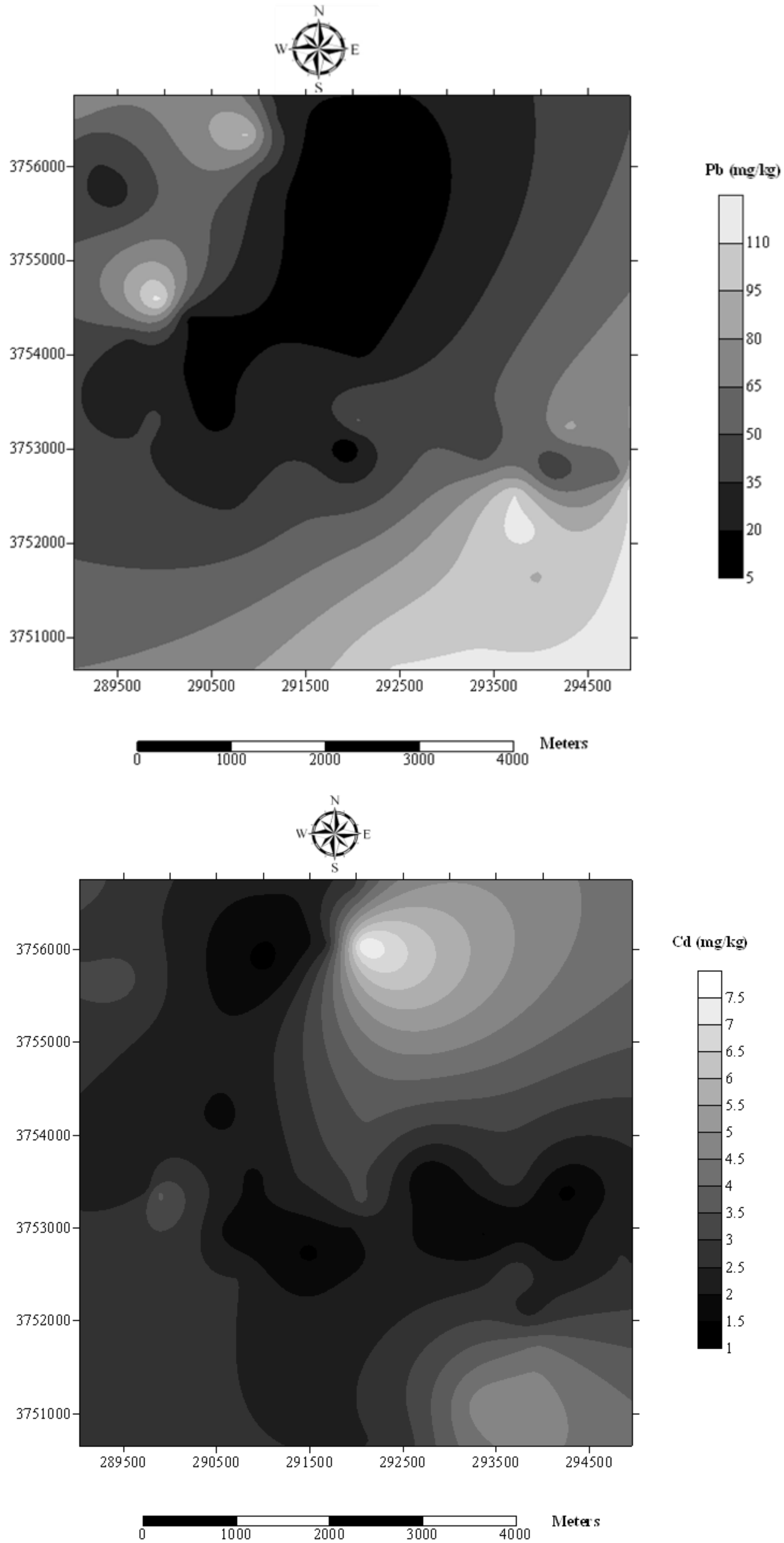

Figure 3. Spatial distribution map of Cd and Pb in Borujerd urban soil

Heavy metals accumulate in urban soils originated from various sources such as atmospheric deposition vehicle emissions, industrial wastes, fuel combustion, and other activities [44]. Also in the study area, high levels of Pb and Cd may be related to_urban trash and waste that contributed to the concentrations of these heavy metals in urban soils of Borujerd.

In this research, geoaccumulation index (Igeo), was computed to determine the level of soil contamination by Cd and Pb. This index was introduced [45] that evaluates soil contamination comparing the measured and pre-industrial concentrations of heavy metals in the Earth's crust [45, 46]. The geoaccumulation index (Igeo) values were calculated using the following equation: Igeo= $\log_2 C_n/1.5B_n$. Where Cn is the concentration of n-th metal in the soil samples**,** and Bn is the background value of metal, which in the present study is represented with Earth's crust, based on Taylor [47]. The constant factor 1.5 in this equation is added to minimize the possible fluctuations in the background values due to lithogenic variations in soils. Seven classes of Igeo values were listed as shown in Table 4 [45]. The calculated results of Igeo values indicate the order of Igeo is Cd > Pb. The high Igeo for Pb and Cd in the urban soils indicate that there is remarkable Pb and Cd pollution, which mainly derives from human activities. The Igeo values ranges from 2 to 4.66 with a mean value of 2.95 for Cd, and -1.73 to 2.64 with a mean value of 1.04 for Pb. According to the Igeo data and Muller's classifications presented in Table 3, the mean Igeo values for Cd were in class 3 (moderately/strongly contaminated), while the mean Igeo values of Pb were in class 2 (moderately contaminated). High concentrations of Pb and Cd show that the urban soils in the parks, squares, and street in the Borujerd city have been considerably impacted metals originated from anthropogenic activities. In addition, the spatial distribution of the Igeo in different sampling sites is given in Figure 4.

Table 4. Geo-accumulation index (Igeo) for contamination levels in soil

Contamination Level	Igeo Value	Igeo Class
Practically uncontaminated	Igeo ≤ 0	0
Uncontaminated/moderately contaminated	0 < Igeo < 1	1
Moderately contaminated	1 < Igeo < 2	2
Moderately/strongly contaminated	2 < Igeo < 3	3
Strongly contaminated	3 < Igeo < 4	4
Strongly/extremely contaminated	4 < Igeo < 5	5
Extremely contaminated	5 < Igeo	6

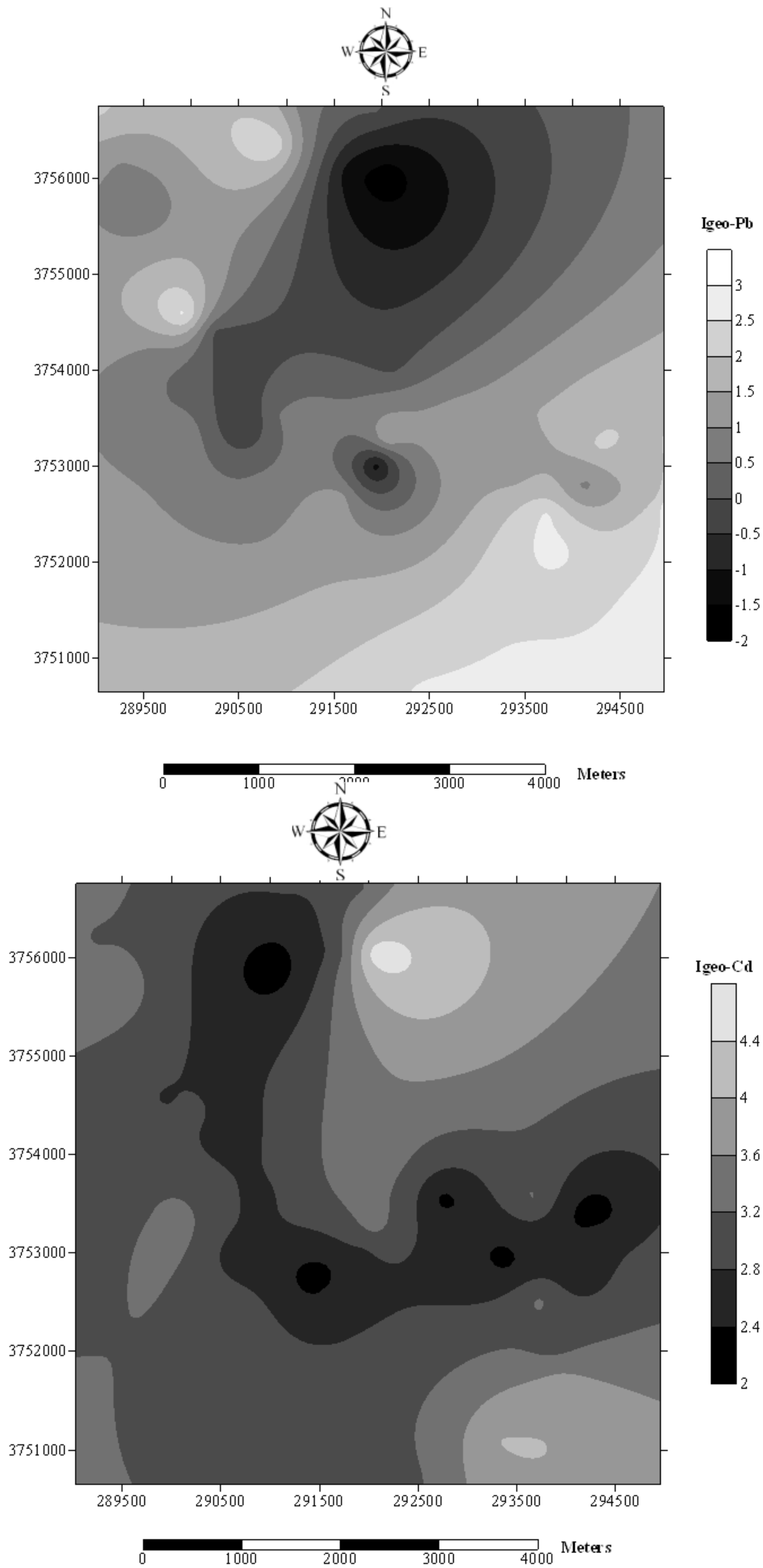

Figure 4. Spatial distribution map of the Igeo of Cd and Pb in Borujerd urban soil

Correlation analysis as an effective way has been widely used to disclose the relationships among metals in soil and have been useful for understanding the influencing factors. In order to evaluate the interrelationships between metals and soil properties, Spearman correlation coefficients were computed and correlation matrix is presented in Table 5. The relationships between Cd and Pb are not significantly correlated. In addition, no clear correlations are observed between soil pH and heavy metals (P>0.05). In addition, the correlation coefficients indicated that EC was correlated significantly negatively with Cd. In addition, the results show a significant negative correlation between EC and pH. The salts accumulation can be caused significant decrease of the soil pH values [48]. There is a poor correlation of soil Pb with Cd that may be due to the facts that besides traffic is the common source of Pb and Cd in urban soils, urban soils can also absorb Cd and Pb from other sources.

Table 5. Pearson correlation coefficients matrix between soil properties and metals of Borujerd city

	Cd	**Pb**	**pH**	**EC**
Cd	1.00	0.04	0.13	-0.32*
Pb	0.04	1.00	-0.01	0.03
pH	.134	-.014	1.00	-0.59**
EC	-0.32*	0.03	-0.59**	1.00

Level of significance: * P<0.01; ** P<0.05

CONCLUSIONS

The concentration of Cd in soils of different locations follows the order of Street > Square > Park, and Pb level follows the sequence: Square > Street > Park. High values of Cd and Pb were present in the urban soils of Borujerd and levels of individual metals had an increasing trend toward industry. Thus, high values of these metals also showed that main source of contamination are the wastewater and textile industries and mainly derived from traffic sources. The geoaccumulation index (Igeo) confirmed that urban soils of Borujerd are moderate to high contaminated by Cd, and Pb. The obtained results from this study will widen our knowledge of the soil remediation, and provide scientific basis for policy-maker to protect soils from degradation due to heavy metal accumulation.

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The authors declare that there is no conflict of interest.

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