RESEARCH ARTICLE

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Contamination of Two Heavy Metals in Topsoils of the Urban Parks Asadabad, Iran 2013

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Background & Aims of the Study: Heavy metals are the most important contaminants in the soil. Due to their non-biodegradable property, heavy metals can persist in the ecosystem for a long time. Therefore, this research focuses on heavy metal contamination in urban park soils in Asadabad, Hamedan, Iran.

Materials & Methods: Altogether 18 composite soil samples were collected at depths 0-20 cm from urban parks. The urban soil samples were digested in aqua regia according to 11466 ISO standard methods. Total concentrations of Cd and Pb were measured by Atomic Absorption Spectrometer.

Results: Concentrations of Cd and Pb varied in the range of 0.15-0.22 and 7.5-27.5 mg/kg, with mean values of 0.18 and 20.72, respectively. The mean values of geo-accumulation index (Igeo) were (-0.70) and (0.04) for Cd and Pb respectively. The urban soils in Asadabad, Iran, were uncontaminated by Cd and uncontaminated until moderately contaminate with Pb. There was no significant correlation between Pb and Cd (r^2=0.16), it seems that these metals may have derived from different sources.

Conclusions: Findings showed that Cd was usually associated with parent material in the soils, while Pb was controlled by anthropogenic activities such as traffic and residential wastes. Also the results indicated that urban park's location affects the total metal contents of the analyzed soils.

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Background

Urban soils, as an important part of ecosystem, have direct and indirect effects on the quality of life and can be the most important reservoir or sink of heavy metals and other pollutants in urban areas (1,2). Therefore, excessive input of metals into urban soils by human activity can impose a long term burden on the biogeochemical cycle in the urban ecosystem by cause effects such as the soil function deterioration, changes in the soil properties and other environmental problems. (3,4). Also urban soils were known to have peculiar characteristics such as poor structure, unpredictable layering and high concentration of metals (5,6). On the other hand, the soil can be considered as a medium with the capacity to transfer pollutants to the groundwater, into the food chain and the human body (7). Generally, metals are characterized by their particular properties such as enrichment, toxicity, bioaccumulation and concealment (8) which pose serious threats to human health and urban ecosystems on a global scale. These are some reasons for using the urban soils as a good indicator of the level and extent of metal accumulation in the environment (9). Thus, metals are used as tracers of environmental pollution (10). In urban soils and road dusts, the anthropogenic sources of heavy metals are include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical industry, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposited and so on. Consequently soil pollution by heavy metals is the most critical environmental problems (11) and one of the fastest growing types of environmental pollution around the world due to the human activities. There are many research studies that have been done to identify the scope of this problem. In the recent decades, there are several studies on heavy metals contamination of the urban soils around the world (12-19) and Iran (20-22). The above studies are indicating the high accumulation of heavy metals in the urban top soils. In contrast with the soils of agricultural areas, soils in urban environment, particularly in parks and gardens have a direct influence on public health not related with the production of food. This is due to the easy contact with humans and are transferred to them, either as suspended dust or direct contact (23). The study of heavy metal content in urban soils provides baseline information about the anthropogenic sources of pollution (identify the point and non-point sources), behavior of heavy metals in different soils, basis for planning management strategy to achieve a better environment quality and substantial development of the city. Thus with regard to the importance of parks and green areas, special attention has been paid to study the heavy metal contamination in urban parks. Also parks and playgrounds are places where urban children spend most of their free time out of the home and are also where they most frequently are in contact with the soil. Children who exposed to the contaminated soils, dust and air particulates may ingest a significant amount of toxic elements by putting dirty hands in their mouth (24). Most of the studies which had been carried out in urban soils of small and big cities had been neglected.

Aims of the study:

The main objective of this study is to investigate the concentrations of cadmium (Cd) and lead (Pb) in the surface soils of urban parks throughout the Asadabad, Hamedan, Iran and to evaluate the soil environment quality in terms of metal contamination and identify their possible sources.

Materials & Methods

Study site

In this study, the urban areas of Asadabad, Iran were considered for soil sampling. Asadabad is a small city that is located in the west of Hamedan province, Iran, between 34◦°35' and 34◦°58' of the northern latitude and 47◦°50' and 48◦°18' of the eastern longitude. The average height above the sea level for the whole town is 1607 meters. Asadabad has a semi coldweather, but warmer than the centre of province and urban areas, the rainfall regime has a Mediterranean climate type. The annual rainfall is between 350-500 mm and the annual temperature is between -29 and 37 ºC. The area is limited to the geographical longitude 235614 to 238183 E and the latitude 3851694 to 3853847 N. The green spaces cover an area of 40 ha in this city approximately.

Before sampling, a primary field survey of the study area was conducted. During the research, 11 urban parks (10 urban parks and 1 Forest Park) in total were selected from different parts of the city.

Sampling techniques and preparation

A total of 18 soil samples (depths 0–20 cm) were collected, using random sampling method. Soil samples were taken from 11 locations of urban parks of Asadabad, Iran (Fig. 1) in January and February 2013. One to three samples per park were collected (depend on area size). Also at each sampling point, five sub-samples from top 20 cm layer, within a 20×20 cm surface were collected and mixed to obtain a bulk composite sample. The collected soil samples were stored in a polyethylene bag for transportation and storage. The sample locations were registered at a Global Positioning System (GPS) receiver in a Universal Transverse Mercator (UTM) coordinate system. Air-dried samples sieved through a 2 mm nylon to remove coarse debris and stones, then ground in an agate grinder until fine particles (<200 µm) were obtained. The ground soil samples were stored in the polyethylene bags and placed in a desiccators before the analysis.

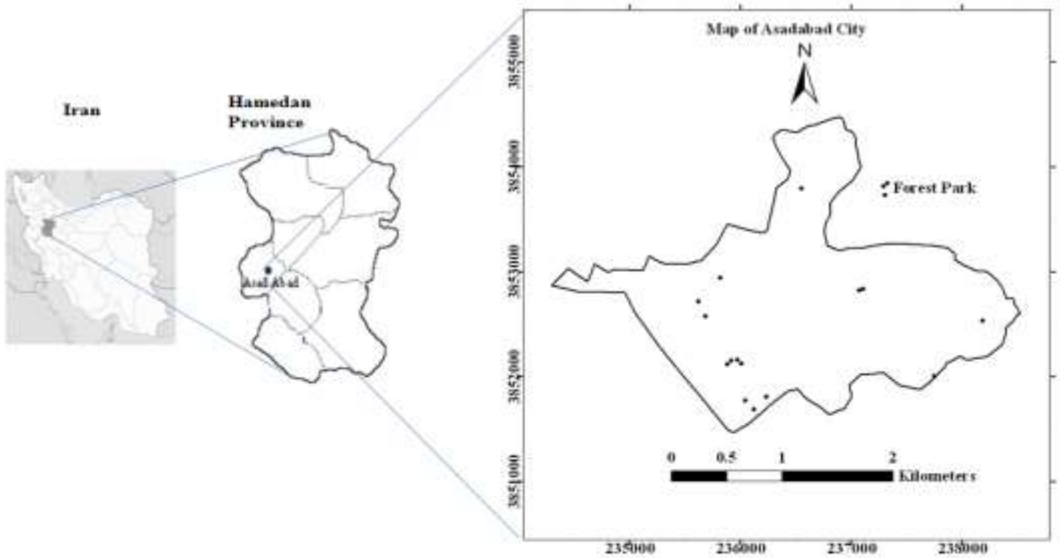

Figure 1) Location of soil sampling sites in urban parks of Asadabad city

Chemical analysis

An acid digestion with aqua regia according to the ISO 11466 (25) was used to extract the total cadmium and lead concentrations from the soil. The total concentrations of Pb were analyzed by Flame Atomic Absorption Spectrometry (F-AAS 8020), whereas Cd was measured by Graphite Furnace Atomic Absorption Spectrometry (GF-AAS 8020). For the quality control, replicates have been measured and blanks were included in the batches. Each sample was analyzed in triplicate and also blank samples without soil were prepared in the same manner to monitor analytical precision. The analytical precision was between 5% and 6%, with a maximum of 10%. For the soil pH and EC, 25 mL of deionized water was added to 5 g (soil: deionized water=1:5) of ground soil and the mixture was stirred well for 2 hours. The pH and EC values were determined by a pH meter and an EC meter, respectively.

Index of Geo-accumulation (Igeo)

The Geo-accumulation Index (Igeo), which was introduced by Muller (26), widely employed to assess the contamination level or degree in terrestrial, aquatic as well as marine environments (27-31) by comparing the levels of heavy metal obtained from background levels of soil or bottom sediments. It is calculated, using the equation:

$$Igeo = \log_2 [C_n/1.5B_n]$$

Where C_n is the measured concentration of the element in the soil, B_n is the geochemical background value in the soil. The factor 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to the lithologic variations (30). In our calculation of Igeo, the background concentration of trace metals in the earth's crust was used as a reference value (32). According to Muller (26), the Igeo for each metal is calculated and classified as: uncontaminated (Igeo<0), uncontaminated to moderately contaminated (0<Igeo<1), moderately contaminated (1<Igeo<≤2), moderately to heavily contaminated (2<Igeo<3), heavily contaminated (3<Igeo<4), heavily to extremely contaminated (4<Igeo<5) and extremely contaminated (Igeo< 5).

Data processing

The range, mean, median, standard deviation (SD) and variation coefficient (VC) of the data collected were analyzed in this study. The normality of data was tested with the Shapiro–Wilk statistical method ($p<0.05$. Pearson correlation was used to evaluate the association between heavy metals and other soil properties (pH and EC). All statistical treatments were done by SPSS (version 18.0) and Microsoft Office Excel 2007.

Results

The descriptive statistical parameters of soil pH, soil Electrical conductivity (EC) and metal concentrations (Pb and Cd) of urban soils from the location are shown in Table 1. The variation of pH was relatively low, ranging from 7.63 to 8.17 with a mean value of 8.54, which implies the neutral to sub alkaline conditions for all urban samples. The chemical analysis of samples show that, metals were detected in allof them. In urban soils, the average concentrations of Cd and Pb were 0.18 and 20.72 mg/kg, respectively. Also the concentrations of Cd and Pb at various sampling points from all parks are in ranged from 0.15-0.22 to 7.5-27.5 mg/kg respectively. Also the mean values of heavy metals in the surface soils from the other park of the Asadabad, Iran, are presented in Table 1. The accumulated Cadmium in the park soils followed the sequence of Laleh mahmoudbaygi>Shahidghandi>Farhangian>Shahidrajaei>Melat>Bahonar>Rezvan>Mahalei-Mahmoudbaygi>Azadegan>Daneshjo>Shahid-Madani and lead had a pattern of Lalehmahmoudbaygi>Azadegan>Rezvan>Daneshjo>Shahidghandi>Bahonar>Farhangian>Shahidmadani>Melat>Shahidrajaei>Mahalei-Mahmoudbaygi.

Table1) Descriptive statistics of metal concentrations (mg/kg) and soil properties in urban soils

		Pb			Cd			pH			EC		
Urban park	number	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	3	7.50	27.50	18.33	0.18	0.19	0.18	7.63	8.10	7.85	0.34	1.69	1.09
2	3	17.50	22.50	19.16	0.15	0.18	0.17	8.21	8.54	8.34	0.17	0.45	0.32
3	1	20	20	20	0.19	0.19	0.19	7.97	7.97	7.97	0.53	0.53	0.52
4	2	15	20	17.5	0.18	0.20	0.19	8.31	8.35	8.33	0.30	0.32	0.31
5	2	20	27.5	23.75	0.18	0.19	0.186	8.12	8.40	8.26	0.24	0.35	0.30
6	1	20	20.	20.	0.20	0.20	0.20	8.36	8.36	8.36	0.25	0.25	0.25
7	1	12.5	12.5	12.5	0.19	0.19	0.19	7.83	7.83	7.83	0.27	0.27	0.27
8	1	22.5	22.5	22.5	0.18	0.18	0.18	8.10	8.10	8.10	0.19	0.19	0.19
9	2	26	27.5	26.75	0.18	0.19	0.182	8.40	8.40	8.40	0.20	0.24	0.22
10	1	27	27	27	0.22	0.22	0.22	8.18	8.18	8.18	0.40	0.40	0.40
11	1	22.5	22.5	22.5	0.21	0.21	0.21	8.18	8.18	8.18	0.54	0.54	0.54
Total	18	7.50	27.5	20.72	0.15	0.22	0.18	7.63	8.54	8.17	0.17	1.69	0.45

Urban park: 1=melat, 2=madani, 3=Bahonar, 4=Shahidrajaei, 5=Rezvan, 6=Farhangian, 7=Mahalemahmodbaygi, 9=Azadegan, 10=Lalehmahmod, 11=Ghandi

Typically the content of heavy metal originated from the same source tend to have a significant correlation, so the correlation between the heavy metal content in soil can be regarded as an indicator of whether the source of heavy metal was the same or not. A correlation analysis is a tool for detecting the linear relationship between the soil variables and has been broadly used in pollution studies. For this purpose, the association between the soil properties and heavy metal concentrations were determined by Pearson's correlation coefficient. The correlation analysis results based on Pearson's correlation coefficients are presented in Table 2. The analysis showed no significant correlations between heavy metals and other parameters except for EC and pH that have a significant correlation statistically but negative was obtained. The obtained results of the Geo-accumulation Index (Igeo) in urban soils are presented in Table 3. Results of the Geo-accumulation Index (Igeo) in urban soils showed low levels of contamination for cadmium and lead, ranging from -1.02 to -0.43 and from -1.32 to 0.55, respectively.

Table2) Pearson correlation coefficients between metals and soil properties

	Cd	Pb	pH	EC
Cd	1	0.16	-0.03	0.01
Pb	0.16	1	0.10	0.13
pH	-0.03	0.10	1	-0.71**
EC	0.01	0.13	-0.71**	1

Table 3) Igeo values calculated of metals in the urban soil of Asadabad, Iran

	Statistical values		
Metals	Minimum	Maximum	Mean
Cd	-1.02	-0.43	-0.70
Pb	-1.32	0.55	0.04

Discussion

The soils of Asadabad, Iran exhibited an alkaline range of pH (7.63–8.54). The study results of other researchers show that the urban soils are typically sub alkaline or alkaline (17-18,23,33-35), because of the excessive entry of sub-alkaline building materials (e.g. bricks, cement, construction debris and calcareous material), carbonate, ash and cinders of anthropogenic origin into the urban soils can be related to the soil alkalization (1,18,36). Also the atmospheric deposition of the alkali components in the ground affects the soil pH (18). The soil pH and organic matter are of the most important parameters for controlling the accumulation and availability of heavy metals in soil (37). Generally, the soil pH seems to have the greatest impact on the solubility or retention of metals in soils, with a greater retention and lower solubility of metal cations, occurring at high soil pH (38,39).

The values of the average and standard deviation for Cd and Pb in urban soils of Asadabad, Iran, show that the Pb has more variability than Cd. Naturally, cadmium concentration occurred in ranges of 0.03 to 0.30 mg/kg in soils (40). Many of guidelines have been developed to evaluate the level of total metal contamination in soils. The Polish soil classification system developed by Kabata-Pendias et al. (41) was used for assessing the metal contamination of soils. Based on this classification, the mean soil concentrations of Pb and Cd obtained in this study placed into the classification of "natural (background content)" (Table 4).

Table 4) Metals contamination levels (mg/kg) based on Polish soil classification system (36)

Metal	O	I	II	III	IV	V
Pb	0 - 30	30 - 70	70 - 100	100 - 500	500 - 2500	> 2500
Cd	0 - 0.3	0.3 - 1	1 - 2	2 - 3	3 - 5	> 5

O = natural (background content), I = slightly elevated content, II = weak pollution, III = medium heavy pollution, V = heavy pollution, V = very heavy pollution (and should be remediated).

The natural ranges of the concentration of the Cd and Pb in the soil are 0-1 mg/kg and 0-500 mg/kg, respectively. The Maximum Allowable Concentrations (MAC) in agricultural soils that have been reported for Pb and Cd are 20-300 mg/kg and 1 to 5 mg/kg, respectively (42). Metal concentrations in Asadabad urban soils, Iran, (Table 1) were below these values. Lack of significant correlations between cadmium and lead indicate that these metals in the Asadabad soils, Iran, have a different source which originates from the urban activities in agreement with those of Odewande et al., (12) and Zhai et al., (43). Several studies by Albeit indicated that a significant correlation between Pb and Cd in urban soils (1,44,45).

Table 5) Cadmium and Lead concentrations (mg/kg) in urban soils from different cities in the world

City	Pb	Cd	Reference
Asadabad (Iran)	20.72	0.18	Present study
Masjed-i-Soleiman (Iran)	12	-	(20)
Isfahan (Iran)	16.02	1.27	(21)
Birjand (Iran)	46.59	1.53	(22)
Fallujah (Iraq)	3.82	0.64	(56)
Shenyang (China)	116.76	1.1	(53)
Wien (Austria)	54	0.3	(49)
Beijing (China)	23.3	0.13	(46)
Islamabad (Pakistan)	212.34	3.54	(50)
Havana (Cuba)	101	NA	(15)
Beijing (China)	35.4	0.21	(19)
Teresina (Brazil)	7.7	NA	(57)
Talcahuano (Chile)	25.7	NA	(13)
Xuzhou (China)	43.3	0.54	(51)
Poznan (Poland)	30.59	0.75	(52)
Baghdad (Iraq)	113.98	0.54	(18)
Baghdad (Iraq)	8.34	1.58	(58)
Bangkok, Thailand	47.8	0.29	(53)
Seoul, Korea	240	3.1	(54)
Beijing, China	39.50	0.192	(17)
Sanya, China	28.53	0.09	(55)
Madrid	22	0.14	(47)
Mymensingh, Bangladesh	20.93	0.37	(42)

NA: Not Available

The results of Asadabad research, Iran,were compared with other cities around the world (Table 5). The Cd and the Pb recorded in current study were comparable to the urban soils in Beijing, China (46), Madrid, Spain (47) and were lower than reported in Shenyang ,China (48), Wien, Austria (49), Islamabad, Pakistan (50), Xuzhou, China (51), Poznan, Poland (52), Baghdad, Iraq (18), Bangkok, Thailand (53), Seoul, Korea (54). The Cd and the Pb from urban parks soil of Asadabad, Iran, were higher in comparison to some studies. In the case of Cd, it was higher than Sanya, China (55). Pb values were higher than those reported from Fallujah, Iraq (56), Teresina, Brazil (57), Baghdad, Iraq (58), Masjed-i-Soleiman (20) and Isfahan, Iran (21). This variation of the soil metal concentrations in the different cities reflects the influence of different agents such as type of a parent material, population, traffic volume, industrial activities, microclimatic condition and thev nature of anthropogenic inputs (59).

The Cd in all eighteen locations had the Igeo which was less than zero, with a mean value of -0.70, indicated that the concentrations of Cd in the urban soil samples were comparable with the earth crust values and there was no obvious pollution of Cd in the park soil samples. The mean Igeo for Pb was 0.04. This indicated that the urban soils in Asadabad, Iran, are uncontaminated to slightly contaminate by Pb as a result of anthropogenic activities. Based on the calculated Igeo values, Asadabad urban soils, Iran, are moderately contaminate by lead but not by cadmium. This index shows that there is a moderate contribution of anthropogenic sources to their levels in urban soil. The most likely source of additions to the natural soil of these elements is vehicular emissions.

As can be seen from these trends, the highest concentrations of cadmium and lead have been occurred in Laleh-mahmoudbaygi park city. With regard to this park which is far from the center of the city, it seems that the urban soils are influenced by residential wastes that are seen in this area. The arrival of waste to soil systems may lead to the accumulation of heavy metals in the soil. Many measures such as burial of waste that contains metals, engine oil leaks, leakage from landfills or pipelines carrying sewage are the most common ways to pollute the urban soil with metals directly. Another source of direct pollution with metals is the use of fertilizers, fungicides substances and incompletely treated compost for the maintenance of green spaces and gardens in residential areas (60). Rapid urbanization and industrial developments along with non-normative waste management and improper disposal procedures have lead to the high levels of metals in the urban soils of developing countries (61).

A small amount of cadmium in shahid-madani forestry park, Asadabad, Iran, may be because of far from the city and human activities, this may reflects the role of location of parks in heavy metal accumulation in urban soils. Chen et al (4) in their study of surface soils of Beijing urban parks (China) concluded that heavy metal pollution in the urban park soils may be associated with the location and the history of the parks. In fact in different locations there are differences in the density of traffic and human activities. Although traffic is one of the main sources of these metals, but the influence of other sources cannot be excluded in these areas. Atmospheric deposition is one of the major sources of heavy metal pollution in soils and plants in urban environments (62). The Cd and the Pb are the most common elements from atmospheric deposition. Lead and cadmium are common pollutants in urban soils. The use of leaded fuels is one of the major sources of lead in urban soils (63) and the leaded building-paints (64) and the main source of Cd is tyre abrasion (65). The Cd and the Pb have not a biological function in plants, animals and humans and they are highly toxic. Lead toxicity caused to impair hematopoietic and nervous systems (66). The major hazard to human health from cadmium is its chronic accumulation in the kidneys, where it can cause dysfunction (67). The major hazard to human health from the Cd is its chronic accumulation in the kidneys. The main organ for long-term cadmium accumulation is the kidney. The kidney damage has a long-period case, since it has been described to be the main problem for patients exposed to cadmium chronically. Cadmium is known for it's accumulation in the human kidney.

Conclusion

For the first time analysis of the soil samples from eleven urban parks for the Cd and the Pb content showed the presence of these metals in all samples collected from the urban areas of Asadabad, Iran. The results of this study suggest that there is no significant threat from these metals to soils. Overall, results showed that the concentration of the Pb and the Cd have increasing trend from northern to southern and southwest that represent the role of the traffic and human activities. Also findings indicated that the park location was an important factor which is related to the accumulation of heavy metals in the soils. The soil pollution in this study was assessed, using geo-accumulation index value. The application of the geo-accumulation index based on Muller's classification showed that the soil which was uncontaminated with the Cd and uncontaminated to moderately contaminated with the Pb. Data available in this research can be applied as the exploitation base line data at Asadabad, Iran. These findings indicate that more attention should be paid to heavy metal pollution of the park soils in Asadabad, Iran. Further research has to be carried out to determine the concentration of heavy metals in various locations by urban soil of the study area.

Footnotes

Conflict of Interest:

The authors declared no conflict of interest.

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