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Soil Contamination of Metals in the Three Industrial Estates, Arak, Iran

Eisa Solgi · Abbas Esmaili-Sari · Alireza Riyahi-Bakhtiari · Mehrdad Hadipour

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Abstract The aim of this study was to determine the concentrations and degree of metals contamination (Chromium, Cadmium, Nickel and Lead) and Arsenic in the soils of the three Industrial Estates in Arak city, Iran. The average concentrations of Arsenic, Chromium, Cadmium, Nickel and Lead were 5.06, 1.26, 37.13, 67.84 and 60.22 mg kg^{-1}, respectively. Pearson correlation indicated that Arsenic, Cadmium and Lead were mainly derived from anthropogenic inputs, and Chromium and Nickel were controlled by natural source, whereas Nickel appeared to be affected by both anthropogenic and natural sources. The geo-accumulation Index (Igeo) calculated in three industrial estates gave values indicating unpolluted to strongly polluted.

Keywords Soil Contamination · Metals · Industrial estates · Arak city

Soil contamination by metals has become a widespread serious problem in many parts of the world. Metal contamination of soil results from anthropogenic such as mining, smelting procedures, agriculture and various industrial activities as well as natural activities (Chen et al. 2005). With the development of urbanization and industrialization, soils have become increasingly polluted by metals, which threaten ecosystems, surface and ground waters, food safety and human health (Chen et al. 2005; Krishna and Govil 2005).

Recently, there has been growing public concern over pollution by elements being used increasingly in modern industry for the production of a wide variety of materials (Takeda et al. 2004).Various industrial activities contribute metals to soil environment directly or indirectly through the release of solid wastes, waste air, and wastewater. In fact, various metals such as Cu, Pb, Cr, Cd, Ni, and Zn have been used in the production of alloys and steels (Li et al. 2009). Industrial estates are specific areas zoned for industrial activity to facilitate the growth of industries and to minimize impacts on the environment. Most of the solid wastes and wastewaters are discharged into the soil and water bodies and thus ultimately pose a serious threat to human and routine functioning of ecosystem. A wide range of chemicals are used at facilities within the estate, including many organic compounds as well as many metals and their compounds. Soils not only serve as sources for certain metals but can also function as sinks for metal contaminates (Krishna and Govil 2005). Therefore, analysis of metals in soil offer an ideal means to monitor not only the pollution of soil itself, but also to quantity the overall environment, as reflected in soil (Govil et al. 2008).

The three Industrial Estates (Arak1, Arak2 and Arak3) in Arak city were chosen for this study. There are seven major industry groups in Arak industrial estates including: Metal, Chemical, Textile, Cellulose, Non-metallic minerals, Electrical and Electronics, Pharmaceutical/Cosmetics. These industries produce products such as paper, glass, food processing, furniture, insecticide, herbicide, paint, disinfectant, types of shampoo, PVC pipes, plastic containers,

E. Solgi (✉) · A. Esmaili-Sari (✉) · A. Riyahi-Bakhtiari
Department of Environment, Faculty of Natural Resources and Marine Science, Tarbiat Modares University, P.O. Box 46414-356, Noor, Mazandaran, Iran
e-mail: e.solgi@yahoo.com

A. Esmaili-Sari
e-mail: abbasesmailisari@yahoo.com

M. Hadipour
Department of Environment, Faculty of Natural Resources, Arak University, Arak, Iran

aluminum profiles, detergent Industry, phosphate materials, metal skeleton, Car spare parts, types of household refrigerators and freezers, electrical equipment, oven, ethanol, metal plating and so on. Therefore, the objectives of the study were to determine the concentrations and degree of metals contamination (Cr, Cd, Ni and Pb) and Arsenic in the soils of the three Industrial Estates in Arak city, Iran.

Arak is the capital of the Markazi province and is 295 km from Tehran. This city is one of the industrial centers of the country. Markazi Industrial Estates Corporation registered in 1989. From the beginning according to entrusted responsibilities it focused on planning, locating, taking possession of grounds, designing and performing constructive projects to prepare ground and infrastructural facilities and provide an appropriate way for industry establishment in different cities of the province in the form of Industrial Estates.

Three industrial estates in Arak city in Markazi province were selected as case studies for this research (Fig. 1). Three industrial estates near to the Arak City known as important Industrial estates (Arak 1 (Serahikhomein), Arak 2 (Eybakabad) and Arak3 (Kheirabad)) were choose to be included into the study. Arak1 (Serahikhomein: 34°4′4″N 49°46′32″E) is located in 5 km to Arak city, an important chemical industry centre and area is 48.6 hectares. Arak 2 Industrial Estate (34°17′5″N 49°41′7″E) which is also called Eybakabad has located in the 17 km of Arak-Farmahin road. The area is 331 hectares. Industrial Estate of Arak 3 (34°9′21″N 49°58′49″E) due to proximity to the Kheirabadi village is well known Kheirabad, located in the city of Arak and the distance about 30 km from the city. The area is 1,344 hectares.

Materials and Methods

Twenty representative surface soil samples (0–20 cm depth) were taken from industrial estates in Arak city during May 2011. All samples were obtained from green areas and open spaces within the industrial estates. A total of 6 samples were collected in Arak1, 6 samples were collected in Arak2 and 8 samples were collected in Arak3. About 1 kg of each soil sample was collected using a stainless steel spade. Each of the composite soil samples was made of nine sub-samples. The collected soil samples were stored in zip locked polythene bags for transport and storage. The coordinates of sampling locations were recorded with a GPS.

All samples were air-dried at room temperature (25°C), removed stones or other debris, and then sieved to 2 mm sieve. Portions of soil samples (about 50 g) were finely ground manually using mortar and pestle and passed through a 0.149 mm sieve. The prepared soil samples were then stored in polyethylene bags for analysis.

These samples were analyzed for pH and soil metals including cadmium (Cd), chromium (Cr), nickel (Ni) lead, (Pb) and metalloid such as arsenic (As). Soil pH was measured by pH meter with a soil/water ratio of 1:5. Soil samples (1 g) were digested with a mixture of HNO3 (7.5 mL), HCLO4 (5 mL) and HF (2.5 mL) at about 160°C for about 6 h in a PTEF vessel. The mineral residues were diluted with deionized water to 50 mL in a volumetric flask and stored in fridge at 4°C before analysis. The total contents of Cr, Ni and Pb in the digested solution were measured by Flame atomic absorption spectrometry (FAAS). The concentrations of As and Cd were determined by means of a graphite furnace atomic absorption spectrometry (GFAAS).

Standard reference material (SRM) of National Institute and Technology (NIST, 1633b Coal Fly Ash 2709 San Joaquin Soil) were used for the quality assurance and control (QA/QC). The precision was calculated as a percentage relative standard deviation (%RSD) of three replicate samples of the prepared standard, and was found to be less than 5%. Recovery was between 96.2% and 107%. All samples were analyzed in triplicate. The instrument's

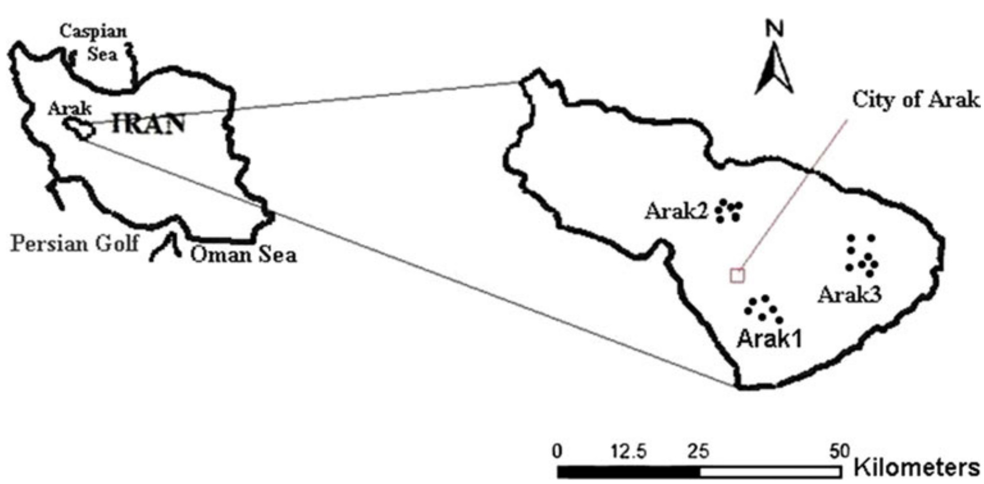

Fig. 1 Location of study area and sampling sites in industrial estates, Arak, Iran

Table 1 Summary statistics for metal concentration (mg kg^{-1}) in topsoils

Industrial estates	Metals and pH					
	As	Cd	Cr	Ni	Pb	pH
1						
Min	4.76	0.37	25.17	50.69	48.82	6.5
Max	8.39	1.15	43.25	88.60	61.79	9.02
Mean	6.13	0.74	37.70	72.99	54.29	7.89
SD	1.34	0.25	6.7	13.61	4.98	0.75
2						
Min	1.99	0.79	13.19	40.41	45.2	7.79
Max	9.12	1.58	80.15	80.11	57.78	8.31
Mean	4.63	1.23	45.55	62.47	52.82	7.95
SD	2.72	0.32	26.39	15.74	4.87	0.21
3						
Min	2.79	1.39	11.24	42.42	52.83	7.62
Max	6.52	2.01	58.65	85.99	110.04	8.38
Mean	4.6	1.63	34.13	67.40	68.29	8.07
SD	1.31	0.21	16.38	14.53	16.79	0.22
All samples						
Min	1.99	0.37	11.24	40.41	45.2	6.65
Max	9.12	2.01	80.15	88.6	110.04	9.02
Mean	5.06	1.26	37.13	67.84	60.22	7.99
SD	1.81	0.45	17.21	14.35	13.66	0.43

limit of detection for As, Cd, Cr, Ni and Pb were 0.005, 0.0005, 0.25, 0.0005 and 0.0005 mg kg^{-1}, respectively.

The descriptive statistics and other statistical analyses were performed by using SPSS version 17.0 for Windows statistical software. The distribution of the data was tested for normality by Kolmogorov–Smirnov (K–S) test. Basic descriptive statistics such as minimum, maximum, mean, median and standard deviation (SD) was calculated to reflect the distribution of different metals. Correlations between metals were assessed by using Pearson correlation analysis.

The geo-accumulation Index (Igeo) has been used widely to evaluate the intensity of metal pollution in the soil profile at the different depths (Matini et al. 2011). Mathematically, Igeo is expressed as: $Igeo = \log_2 (Cn/1.5Bn)$.

Where, Cn is the concentration of element 'n', Bn is the geochemical background value and 1.5 is the background matrix correction factor due to lithogenic effects. In the present work, geoaccumulation index was computed from the equation modified by Loska et al. (2004), where Cn is the measured concentration of the element in the soil sampled and Bn is the geochemical background value in the Earth's crust (Taylor and McLennan 1995). The geo – accumulation index (Igeo) scale consists of seven grades or classes, they are: ($Igeo \leq 0$) unpolluted; ($0 < Igeo < 1$) unpolluted to moderately polluted; ($1 < Igeo < 2$) moderately polluted; ($2 < Igeo < 3$) moderately to strongly polluted; ($3 < Igeo < 4$) strongly polluted; ($4 < Igeo < 5$) strongly to very strongly polluted, and ($5 \leq Igeo$) very strongly polluted.

Results and Discussion

Descriptive statistics (mean, standard deviation, minimum and maximum) for total concentrations of As, Cd, Cr, Ni and Pb as well as pH contents are reported in Table 1. Among the metals, Ni had the highest mean concentration (67.84 mg kg^{-1}), while the lowest value was for Cd (1.26 mg kg^{-1}). The mean concentrations of other metals were 5.06 mg kg^{-1} for As, 37.13 mg kg^{-1} for Cr and 60.22 mg kg^{-1} for Pb. The sample set exhibited a wide range of values. Total concentrations varied from 1.99 to 9.12 mg kg^{-1} for As, 0.37 to 2.1 mg kg^{-1} for Cd, 11.24 to 80.15 mg kg^{-1} for Cr, 40.41 to 88.6 mg kg^{-1} for Ni and 45.2 to 110.4 mg kg^{-1} for Pb. Soil pH was also variable ranging from 6.65 to 9.02, with the mean value of 7.99. There were differences in concentrations of metals among different soil industrial estates.

Pearson's correlation coefficient can be used to measure the degree of correlation between the metal data and can provide suggestive information regarding metal sources and pathways (Manta et al. 2002; Al-Khashman and Shawabkeh 2006). Many factors control their relative abundance, e.g., the concentrations of metals in parent materials, the processes of soil formation, and human activities. At the most polluted site concentrations of all metals were positively correlated with each other. To study the relationships among metal concentrations, a Pearson's correlation analysis was applied. The correlation coefficient of the five metals is shown in Table 2. Correlation matrix (Table 2) of the trace metal data indicates strong positive correlations ($r^2 > 0.5$) among As, Cd, Cr, Ni and Pb. Ni–Cr had a significant correlation at 0.05 level This result was in agreement with previous studies (Facchinelli et al. 2001; De Temmerman et al. 2003; Chen et al. 2008), while Pb–Cd showed a significant correlation at 0.01 level, These results are similar to those obtained by (Malik et al. 2010; Sun et al. 2010; Yaylalı-Abanuz, 2011). Also As–Ni showed a significant correlation (at 0.01 level) similar to results of Ahsan et al. (2009). The high correlation between soil metals might express that these metals had similar pollution level and sources (Li et al. 2009).

In general Pb and Cd correlated significantly and positively in the studied areas showing anthropogenic factors such as industrial production that previously studies have showed that Pb and Cd are typically anthropogenically influenced. There is also a positive and significance correlation between Ni and Cr probably indicating a natural source. Meanwhile, Ni also showed a strong correlation with As ($r^2 = 0.749$) suggesting that Ni could be controlled by mixed sources similar to those Gong et al. (2010). Comparatively, the correlations between As and other metals were less significant, probably indicating distinct origin, whose mean concentration exceeded the background value in the Earth's crust (Taylor and McLennan 1995) by about 2.8 times and which could be regarded as a anthropogenic source.

Also in order to better understanding of the metal sources and degree of metals contamination, the Index of geoaccumulation (Igeo) was computed for the metals under investigation, and the minimum, maximum, and mean of the Igeo values are given in Table 3. However, all Igeo ranges for the metals in question were variable from unpolluted to strongly polluted, with the Igeo for Cd being the largest value. The environmental pollution distribution of Cd in soil samples (0.31–2.74) had one sample with values that were $0 < \text{Igeo} < 1$, which is unpolluted to moderately polluted. In addition, seven samples had values that were in the range $1 < \text{Igeo} < 2$, which is moderately polluted. Furthermore, twelve samples had values that were in the range $2 < \text{Igeo} < 3$, which is moderately to strongly polluted. The contribution of Pb (1.26–2.55) is as follows: eighteen samples show $1 < \text{Igeo} < 2$, moderately polluted; two samples show $2 < \text{Igeo} < 3$, Moderately to strongly polluted. For the content of As (−0.43–1.75); one sample shows $\text{Igeo} < 0$, unpolluted; thirteen samples show $0 < \text{Igeo} < 1$, unpolluted to moderately polluted; and six samples show $1 < \text{Igeo} < 2$, moderately polluted. All samples studied had $\text{Igeo} < 0$ for Cr, indicating that the environment was unpolluted by Cr. These samples also had $\text{Igeo} < 0$ for Ni, which is unpolluted. With respect to the overall behavior of the metals under study, on the basis of Igeo the environment of industrial estates of Arak was unpolluted to strongly polluted.

Igeo for Cr and Ni in the studied soils was negative. The Igeo being negative showed that the soils studied are practically uncontaminated with Cr and Ni. This implies that, the Cr and Ni content of the soils is not from anthropogenic sources rather it is from natural source but with regard to significant correlation between Ni and As, that is showing anthropogenic source, it seem that considered background value in this formula for Ni is more than background value in soil of study area.

Probably anthropogenic sources of Pb in soil samples are associated with paints, metal works and textile industries in industrial estates. Also it may be a consequence of the industrial estates proximity to highways and main roads. However, in addition to the Pb derived from the industrial inputs and processes, another possibly significant source of Pb in the industrial estate is from the emissions of small electricity power generators which are used on a large scale by each industry (Fakayode and Onianwa 2002).

High As concentrations in industrial estates soils are due to industrial activities. Significant anthropogenic sources of

Table 2 Pearson correlation coefficients between metal concentrations and pH in soil samples

	As	Cd	Cr	Ni	Pb	pH
Metals						
As	1					
Cd	−0.290	1				
Cr	0.332	−0.051	1			
Ni	0.749[b]	−0.031	0.521[a]	1		
Pb	0.164	0.593[b]	−0.190	0.383	1	
pH	0.094	0.132	−0.116	−0.221	0.094	1

[a] Correlation is significant at the 0.05 level (2-tailed)

[b] Correlation is significant at the 0.01 level (2-tailed)

Table 3 Geoaccumulation index (Igeo) of metals in the soil of Industrials Estates, Arak, Iran

Statistical values	Metals				
	As	Cd	Cr	Pb	Ni
Minimum	−0.43	0.31	−3.73	1.26	−0.76
Maximum	1.75	2.74	−0.9	2.55	−0.34
Mean	0.81	1.96	−2.17	1.65	−0.76

As are related to industrial activities such as metallurgical, chemical industries, domestic and industrial detergents, insecticide, paint and glass. Cadmium concentration in topsoils is attributed to metal smelting, sewage waters, metal plating and the use of phosphate fertilizers (Yaylalı-Abanuz 2011). The source of Ni contamination in the study area seems to be associated with metal works**,** food processing**,** tire wear, traffic and corrosion of cars (Al-Khashman 2004).

This study revealed that the soil of the whole industrial estates was polluted by metals as a result of industrial activities, and more attention should be paid to this pollution. The results provided interesting information on correlation among metals and their sources of origin either natural or anthropogenic. The geo-accumulation index exhibited that the environment of the industrial estates of Arak was unpolluted to strongly polluted. In future, further work is needed to assess the spatial distribution of metals and examine variations on a smaller scale.

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References

Ahsan DA, DelValls TA, Blasco J (2009) Distribution of arsenic and trace metals in the flood plain agricultural soil of Bangladesh. Bull Environ Contam Toxicol 82:11–15

Al-Khashman OA (2004) Heavy metal distribution in dust, street dust and soils from the work place in Karak Industrial Estate, Jordan. Atmos Environ 38:6803–6812

Al-Khashman OA, Shawabkeh RA (2006) Metals distribution in soils around the cement factory in southern Jordan. Environ Pollut 140(3):387–394

Chen TB, Zheng YM, Lei M, Huang ZCh, Wu HT, Chen H, Fan KK, Yu K, Wu X, Tian QZ (2005) Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. Chemosphere 60:542–551

Chen T, Liu X, Zhu MZ (2008) Identification of trace element sources and associated risk assessment in vegetable soils of the urban–rural transitional area of Hangzhou, China. Environ Pollut 151:67–78

De Temmerman L, Vanongeval L, Boon W, Hoenig M (2003) Heavy metal content of arable soil in northern Belgium. Water Air Soil Pollut 148:61–76

Facchinelli A, Sacchi E, Mallen L (2001) Multivariate statistical and GIS based approach to identify heavy metal sources in soils. Environ Pollut 114:313–324

Fakayode SO, Onianwa PC (2002) Heavy metal contamination of soil, and bioaccumulation in Guinea grass (*Panicum maximum*) around Ikeja Industrial Estate, Lagos, Nigeria. Environ Geol 43:145–150

Gong M, Wu L, Bi XY, Ren LM, Wang L, Ma Z, Bao Z, Li Z (2010) Assessing heavy-metal contamination and sources by GIS-based approach and multivariate analysis of urban–rural topsoils in Wuhan, central China. Environ Geochem Health 32:59–72

Govil PK, Sorlie JE, Murthy NN, Sujatha D, Reddy GLN, Rudolph-Lund K, Krishna AK, Rama Mohan K (2008) Soil contamination of heavy metals in the Katedan Industrial Development Area, Hyderabad, India. Environ Monit Assess 140:313–323

Krishna AK, Govil PK (2005) Heavy metal distribution and contamination in soils of Thane-Belapur industrial development area, western Indian. Environ Geol 47:1054–1061

Li FY, Fan ZP, Xiao PF, Oh K, Ma XP, Hou W (2009) Contamination, chemical speciation and vertical distribution of heavy metals in soils of an old and large industrial zone in Northeast China. Environ Geol 54:1815–1823

Loska K, Wiechula D, Korus I (2004) Metal contamination of farming soils affected by industry. Environ Int 30:159–165

Malik RN, Jadoon WA, Husain SZ (2010) Metal contamination of surface soils of industrial city Sialkot, Pakistan: a multivariate and GIS approach. Environ Geochem Health 32:179–191

Manta DS, Angelone M, Bellanca A, Neri R, Sprovieri M (2002) Heavy metals in urban soils: a case study from the city of Palermo (Sicily) Italy. Sci Total Environ 300(1–3):229–243

Matini L, Ongoka PR, Tathy JP (2011) Heavy metals in soil on spoil heap of an abandoned lead ore treatment plant, SE Congo Brazzaville. Afr J Environ Sci Technol 5(2):89–97

Sun Y, Zhou Q, Xie X, Liu R (2010) Spatial, sources and risk assessment of heavy metal contamination of urban soils in typical regions of Shenyang, China. J Hazard Mater 174:455–462

Takeda A, Kimura K, Yamasaki S (2004) Analysis of 57 elements in Japanese soils, with special reference to soil group and agricultural use. Geoderma 119:291–307

Taylor SR, McLennan SM (1995) The geochemical evolution of the continental crust. Rev Geophys 33:165–241

Yaylalı-Abanuz G (2011) Heavy metal contamination of surface soil around Gebze industrial area, Turkey. Microchem J 99:82–92