

## Metals distribution in soils around the cement factory in southern Jordan

Omar A. Al-Khashman<sup>a,\*</sup>, Reyad A. Shawabkeh<sup>b</sup>

<sup>a</sup> Water and Environment Study Center, Mutah University, Al-Karak 61710, Jordan

<sup>b</sup> Department of Chemical Engineering, Mutah University, Al-Karak 61710, Jordan

Received 10 August 2005; accepted 11 August 2005

*Metals concentrations in the surface and sub-surface soils around the cement factory have been studied and compared with metals in urban soils.*

### Abstract

Thirty one soil samples were collected from south Jordan around the cement factory in Qadissiya area. The samples were obtained at two depths, 0–10 cm and 10–20 cm and were analyzed by atomic absorption spectrophotometry for Pb, Zn, Cd, Fe, Cu and Cr. Physicochemical factors believed to affect their mobility of metals in soil of the study area were examined such as; pH, TOM, CaCO<sub>3</sub>, CEC and conductivity. The relatively high concentrations of lead, zinc and cadmium in the soil samples of the investigated area were related to anthropogenic sources such as cement industry, agriculture activities and traffic emissions. It was found that the lead, zinc and cadmium have the highest level in area close to the cement factory, while the concentration of chromium was low. This study indicate that all of the metals are concentrated on the surface soil, and decreased in the lower part of the soil, this due to reflects their mobility and physical properties of soil and its alkaline pH values. The use of factor analysis showed that anthropogenic activities seem to be the responsible source of pollution for metals in urban soils.

© 2005 Elsevier Ltd. All rights reserved.

*Keywords:* Metals; Cement; Soil; Statistical analysis; Jordan

### 1. Introduction

Metals are considered to be one of the main sources of the environmental pollution, since they have a significant affect on its ecological quality. The anthropogenic source leads to increasing levels of metals owing to atmospheric and industrial pollution accumulate in the soil and influence the ecosystem nearby (Tüzen, 2003). The determination of the metals in soil, dust, plant and sediments are very important in monitoring environmental pollution. The contribution of metals to environmental pollution from industrial, agricultural and mining processes beside automobile emissions have been the main subject of many studies and researches in recent years (Ndiokwere, 1984). The mobilization of metals into the atmosphere by

anthropogenic activity has become an important process in the geochemical cycling of the heavy metals. This is acutely evident in urban areas where various stationary and mobile sources release large quantities of heavy metals into the atmosphere, soil and plant exceeding the natural emission levels (Nriagu, 1989; Bilos et al., 2001). The influence of human activity as a major causes for metal contamination either in the ecosystem was observed by several researchers (Hewitt and Candy, 1990; Olajire and Ayodele, 1997; Jaradat and Momani, 1999; DeKimple and Morel, 2000; Matos et al., 2001; Manta et al., 2002; Tüzen, 2003; Charlesworth et al., 2003; Al-Khashman, 2004; Bin Chen et al., 2005; Banat et al., 2005). Metals in urban soil have been shown to be very useful tracers of environmental pollution they may come from various anthropogenic activities, such as mining, industrial and energy production, agricultural, construction, vehicle exhaust, waste disposal, as well as coal fossil fuel combustion (Chon et al., in press; Wong and Mak,

\* Corresponding author. Tel.: +962 3 237 2380; fax: +962 3 237 5540.

E-mail address: [omarkhashman@yahoo.com](mailto:omarkhashman@yahoo.com) (O.A. Al-Khashman).

1997; Martin et al., 1998; Li et al., 2001; Bin Chen et al., 2005). The anthropogenic activities send metals into the atmosphere and the metal subsequently are deposited into urban soil as the metal containing dust falls. Meanwhile, the metals in the soil can also generate airborne particles and dust, which may affect the air quality (Chen et al., 1997; Gray et al., 2003; Bin Chen et al., 2005; Biasioli et al., in press). The main goal of the present study was to evaluate the environmental impact caused by air emissions from a cement plant near a residential area with no other industrial air pollution source in the area. Specifically, this study was focused on the distribution and movement of the metals in soil around the cement plant.

## 2. Materials and methods

### 2.1. The study area

The study area was located in the southern part of Jordan in Qadissiya area. The Rashadiya cement plant is located 5 km north of Qadissiya area. The cement plant plays a significant role in the local economy. It was established by the government of Jordan in 1984 as a state owned enterprise and was a major employer in the area. The investigated area has a Mediterranean climate characterized by hot and dry in summer and cool, rainy winters. Mean minimum temperature in the study area are 1.2 °C in January and 25.2 °C in July. The plant was located on the edges of the mountainous desert of the Wadi Araba, which is about 1446 m above the sea level (Fig. 1). The surrounding area is essentially rural, consisting of open areas with scattered houses at distance varying from 200 to 350 m. Rainfall occurs only in the winter season, which is extended from November to April. Its precipitation is around (250 mm/year). Snowfall occurs occasionally, mainly in the highlands, in January to March. The mean number of days with snow is 7 per year and the maximum recorded annual snowfall is 50 cm to 75 cm. The prevailing wind direction is from westerly to northwesterly.

The investigated area is located in the northwest part of the Arabian plate, where most of the Jordan is located within the stable part of the plate. Upper cretaceous carbonaceous facies dominated the central part of country, whereas ancient basement (pre-Cambrian) and Cambrian Nubian sandstone dominated in the southern part of the country. Basalt desert in the northeast and the rift valley forming Jordan's western borders. Furthermore, the sandy facies within the carbonate rock increases south ward the country (Bender, 1974).

### 2.2. Sample collection

Thirty one composite samples were collected in a grid system around the cement plant in Qadissiya area at two depths, 0–10 cm and 10–20 cm (Fig. 2). The samples were most densely collected near the cement plant and became less densely collected with increasing distance from the cement plant. Stones and foreign objects were removed by hand. All the samples were collected with a stainless steel spatula and kept in plastic bags, at room temperature for not more than 24 h from starting analytical procedures. Particle size distribution was determined by hydrometer method (Gee and Bauder, 1986; Madrid et al., 2002). Soil chemistry properties were determined following standard procedures (Page et al., 1982; Madrid et al., 2002). The pH was determined in water with a 1:2.5 soil to solution ratio, electrical conductivity in 1:5 extract, calcium carbonate equivalent by a manometric method. The percentage of the organic matter in the soil samples was measured by the titration method which is based on the oxidation of organic matter by  $K_2Cr_2O_7$ . The values of CEC was obtained by calculation from exchangeable cations contents determined by measuring the solution content after treatment of 5 g taken from the less than 63- $\mu$ m soil fraction with sodium acetate and ammonium acetate solution (Hesse, 1972; Banat et al., 2005).

### 2.3. Preparation for the analysis

The soil samples were transferred from the collectors to a quartz crucible dried in the oven at a temperature of 105 °C for about four hours to constant weight. The dried samples were then sieved through a 2-mm plastic sieve to removal gravel-sized materials (Li et al., 2001; Manta et al., 2002; Madrid

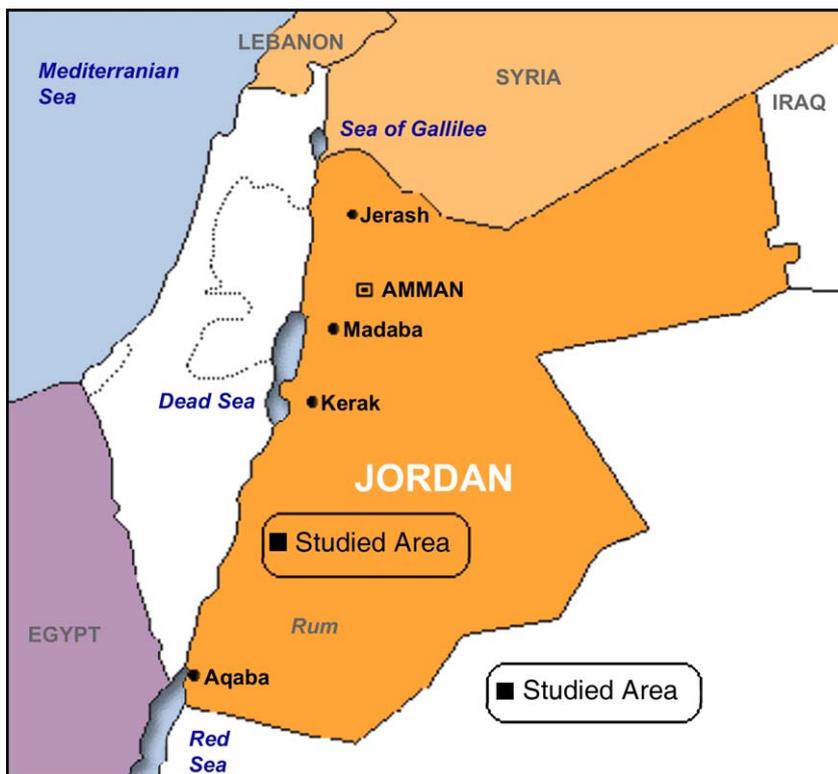


Fig. 1. Location map of the investigated area.

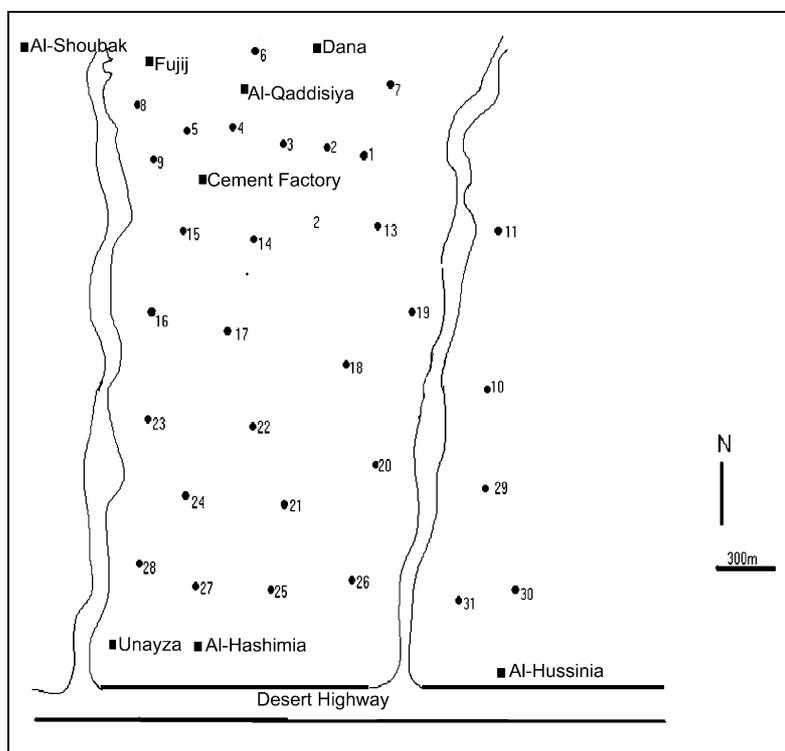


Fig. 2. The location of the sampling sites.

et al., 2002). Two grams of the sieved sample were accurately weighed, ashed for 30 min at 350 °C and then refluxed for 15 min with 25 ml of 25% HNO<sub>3</sub>. The solution was cooled, filtered and diluted to mark with 1% HNO<sub>3</sub> solution. Metals were determined using Shimadzu atomic absorption spectrophotometer (model AA-6200). All the standard solution were prepared from analytical grade compounds of Merck Company. For the elements (Fe, Cu, Cd, Pb, Zn and Cr) six standard solutions of different concentrations were prepared in 2 M HNO<sub>3</sub>, within the linear concentration range for measured. The calibration curve were prepared for each of the metals investigated by least square fitting. The accuracies of these methods have been evaluated by analysis of NBS standard reference materials and are better than  $\pm 10\%$  (Jaradat and Momani, 1999). All glassware was Pyrex washed several times with soap, distilled water and diluted nitric acid to remove any adhered impurities. Reference soil was collected at 1000 m west of the cement factory, since the prevailing wind direction in the studied area was westerly.

### 3. Results and discussion

#### 3.1. Physico-chemical parameters

The characteristics of soil samples: pH, electrical conductivity (EC), total organic matter (TOM), calcium carbonate (CaCO<sub>3</sub>) and cation exchange capacity (CEC) are given in Table 1. The soil in the investigated area is of the vertisol type order (Simonson, 1962). The sieve and hydrometer analysis of soil samples showed that the grain size particle composed of 34.2% sand, 38.9% clay and 26.9% silt which represent a clay loam texture. The study area is dominated by Wadi As Sir Limestone Formation (WSL) of Turonian age. This unit consist of massive light grey carbonates, with siliclastic present in the upper part of investigated area. The formation consist of white cream and grey, massive micritic limestone intercalated at the top with oolitic dolomitic limestone. Fuhays, Hummar, Shu'ayb

Formation (F/H/S) of Cenomanian age, and Cenozoic basalt volcanism (B) are outcropping at the east and northeast part of the area. Soil in the investigated area, soil *Sensu Lato*, covers the basalt plateau and the Pleistocene deposits. The soil mainly consist of yellow to brown loess-like silt, residual calcareous bedrock and clay. Soil rich in iron oxides, with thickness ranges from 0.5–1.5 m (Bender, 1974).

The Dana fault is one of the most distinctive E-W faults in the country. It crosses the study area from east to west, N-S, E-W and NW-SE with striking normal faults that affect the study area (Bender, 1974).

The pH values ranging in narrow interval (7.23 to 8.15), which suggests neutral to sub-alkaline conditions for all the soil samples. Also, high electrical conductivity values are found close to the cement factory with increasing values in Qaddisiya area. Cation exchange capacity (CEC) showed a very broad interval of variation, from 44 to 120 meq/100 g with a mean value of 92 meq/100 g. CaCO<sub>3</sub> contents of the analyzed soil vary from 3.09% to 27.88%, with an average

Table 1  
Mean, standard deviation and ranges for the descriptive parameters of the 31 soil samples and two depths

Parameters	0–10 cm			10–20 cm		
	Mean	St.dev.	Range	Mean	St.dev.	Range
PH	7.81	0.22	7.23–8.10	7.82	0.21	7.33–8.15
EC ( $\mu\text{s}/\text{cm}$ )	470	227.53	150–1201	443	245.25	123–1187
TOM%	3.18	1.04	1.29–4.94	2.87	0.81	0.78–3.98
CaCO <sub>3</sub> %	10.22	3.87	4.57–27.88	6.38	2.91	3.09–12.15
CEC meq/100 g	92	14.30	66–120	71	11.73	44–106

Table 2  
Mean, standard deviation and ranges for the metal contents (mg kg<sup>-1</sup>) for the 31 soil samples and two depths

Parameters	0–10 cm			10–20 cm		
	Mean	St.dev.	Range	Mean	St.dev.	Range
Pb	55	14.47	16.5–77	24.21	7.8	7–40
Zn	44.51	12.27	6.5–63	22.5	5.81	3.6–34
Cd	5	2.19	2.5–13	2.18	1.15	0.67–5.89
Fe	24.18	6.03	14.1–40.15	12.72	5.14	4.32–25.3
Cu	2.89	1.47	1.1–8.4	1.09	0.6	0.52–3.5
Cr	22.18	8.04	0.7–34	6	3.47	0.3–12

value of 10.22%. The total organic matter in the soil ranges from 0.78% to 4.94%, with a mean value of 3.18%. The highest values of organic matter found in the northwest of the investigated area, however, the distribution pattern of organic matter reflects the variable distribution of plant, grass and vegetation cover the soil in the investigated area.

3.2. Distribution of metals

The descriptive statistics for both depths are presented in Table 2. The metal concentrations in the soils of the study area are generally low. These metals originating from industrial activities are distributed in soil by the atmosphere within a distance that depends on the size of particles. The concentration of these metals in soil can vary greatly according to the strength and direction of wind, type of soil, composition and

cation exchange capacity and pH. Usually pH influences the CEC of soil composition, which in turn affects the heavy metal mobility and distribution in the soil samples.

Lead concentrations in upper soil (0–10 cm) were in the range of (16.5–77 mg kg<sup>-1</sup> dry soil) according to the results of the concentration at the 31 points (Fig. 3). The mean concentration of lead was found to be (55 mg kg<sup>-1</sup> dry soil) while, the highest value was 77 mg kg<sup>-1</sup> dry soil in the upper soil samples. This lead concentration was found in gate of plant located 10m away from the plant while the lowest lead concentration (16.5 mg kg<sup>-1</sup> dry soil) was found at the upper reference soil samples. The concentration in the lower soil (10–20 cm) were in the range of (7–40 mg kg<sup>-1</sup> dry soil), but the mean concentration of lead was found to be (24.21 mg kg<sup>-1</sup> dry soil) (Fig. 4). The highest lead concentration in the soil samples were recorded close to the cement plant. This could be attributed to the cement industry in which the process and production of cement industry require a substantial amount of energy supplied by burning fossil fuel and traffic activity in the plant (Banat et al., 2005; Carreras and Pignata, 2002).

Compared to mean concentrations in urban soils in the world (Table 3), the mean values of lead in the analyzed soils are much lower than those reported for the ones from different landuse areas in the world (i.e. London, Aberdeen, urban playground in Hong Kong, Hong Kong and central Jordan). In this study, it has been noted that the concentrations of metals are highest around the cement factory. Lead ions shows the

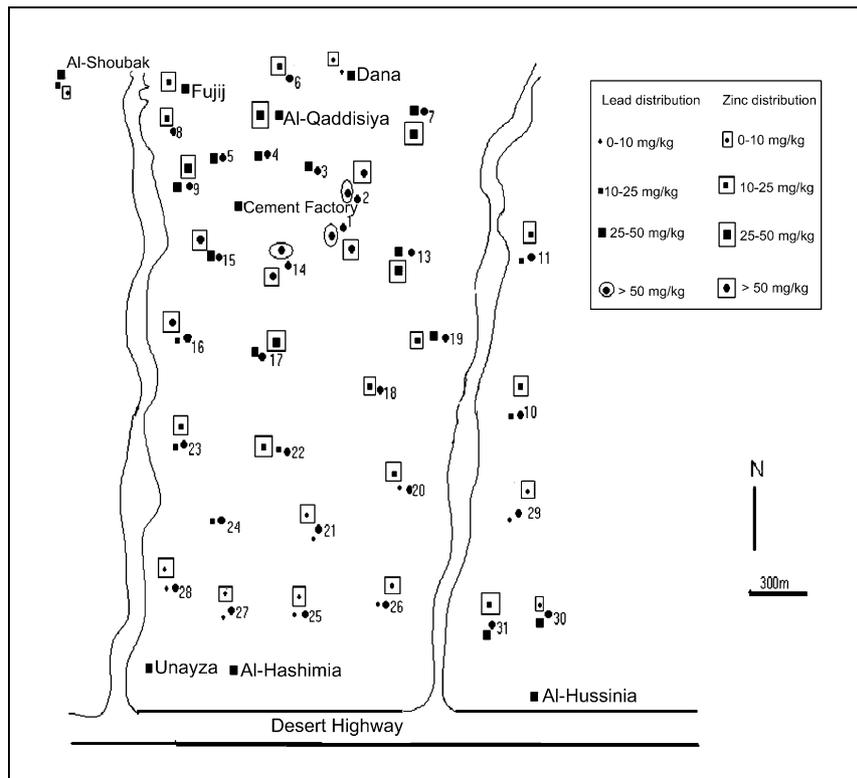


Fig. 3. Distribution of Pb and Zn contents in 0–10 cm samples for the various sampling site. The behavior at 10–20 cm and those of Cd, Fe, Cu and Cr data are entirely similar.

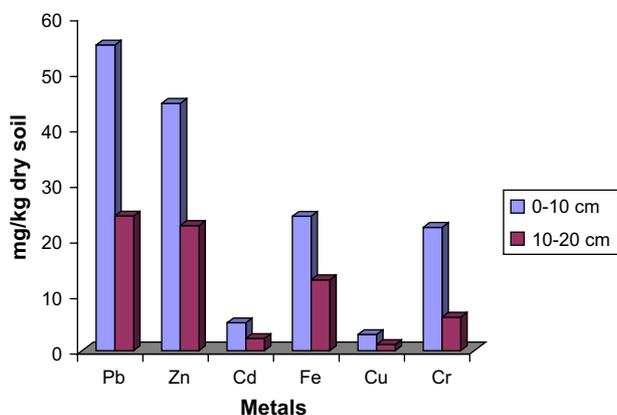


Fig. 4. Mean value of metal concentrations in lower and upper soils.

highest concentrations in the surroundings of the cement plant (Figs. 3 and 4). High level were also observed to the east and northeast of the cement plant. There are many high significant correlation coefficient between metals in all sampling points, such as Pb vs. Zn, Cd, Cu and Cr ( $R^2=0.84, 0.76, 0.72$  and  $0.70$  respectively) (Tables 4 and 5). Iron is one of the principle element in the earth crust and is mainly associated with the coarse atmospheric particles, if associated with other sources, it is generally deposited in the neighborhood of the emission sources (Berg et al., 1995; Carreras and Pignata, 2002). In the study area the higher levels were observed in the northeast of cement factory ( $40.15 \text{ mg kg}^{-1}$  dry soil), but the lowest value of iron was observed in the upper part of soil. The sample was collected 150 m away from the enter of the factory beside the traffic barking. However, higher levels were also observed by the influence of the already mentioned cement plant and mechanical traffic places in the factory.

The highest copper concentration ( $8.4 \text{ mg kg}^{-1}$  dry soil) were observed to the east and northwest of the cement plant (Fig. 3). Agricultural soils receive metals mainly from fertilizers, manure, pesticides, wastewater and other scattered diffuse pollution sources such as; industries, traffic emissions, incineration (Wong et al., 1996; Carreras and Pignata, 2002; Biasioli et al., 2005). The geographical distribution of copper in the investigated area is mainly dominated by the cement plant emissions. The lowest value was measured in the lower

part of soil (10–20 cm) with a value of  $0.52 \text{ mg kg}^{-1}$  dry soil (Fig. 4). A good correlation between Cu and Cd ( $R^2=0.78$ ) (Table 5) was obtained, while the copper and cadmium may be come from bedrocks contribution. This proves that anthropogenic activities are the main source of metals in soil. Cadmium is emitted into the atmosphere from natural sources, mainly basaltic rocks and from anthropogenic sources. Metal production (drying of zinc concentrates and roasting, smelting, and refining of ores) is the largest source of anthropogenic atmospheric cadmium emissions, followed by waste incineration and by other sources, including the production of batteries, fossil fuel combustion and generation of dust by industrial processes such as cement manufacturing (Yamagata, 1970). Generally, cadmium is found to be lower in concentration compared to the other metals in soil. The mean concentration of cadmium in the upper part of soil is  $2.89 \text{ mg kg}^{-1}$  dry soil while the mean concentration of cadmium in the lower part of soil  $2.18 \text{ mg kg}^{-1}$  dry soil. High correlation exists between Cd and Cu ( $R^2=0.78$ ). According to the results of metals concentration at 31 sample points, zinc concentrations is the second highest value after the lead concentration. The mean concentration of zinc were determined to be  $44.51 \text{ mg kg}^{-1}$  dry soil and  $22.5 \text{ mg kg}^{-1}$  dry soil in the upper part samples and lower part of soil samples, respectively. It is reported that the existing value of zinc is  $10\text{--}50 \text{ mg kg}^{-1}$  dry soil. The mean concentrations of zinc are below than its value  $50 \text{ mg kg}^{-1}$  dry soil. An acceptable correlation between Zn and Cd ( $R^2=0.68$ ) and between Zn and Cr ( $R^2=0.76$ ) were obtained. Zinc particles may be derive from industrial sources, whereas the abrasion of tires of motor vehicles may be a second source of emission (Beckwith et al., 1985; Garty et al., 1996; Carreras and Pignata, 2002; Al-Khashman, 2004). The high levels of zinc in the soil are associated mainly with the emission sources of the cement industry and traffic emissions in the investigated area. According to Ellis and Revitt (1982) zinc and cadmium may be derived from the mechanical abrasion of vehicles and also associated with tire wear.

The concentration of chromium in the upper part of soil varies from 0.7 to  $34 \text{ mg kg}^{-1}$  dry soil with a mean value of  $22.18 \text{ mg kg}^{-1}$  dry soil. The concentration of chromium in the lower parts of soil ranges from 0.3 to  $12 \text{ mg kg}^{-1}$  dry soil, with a mean value of  $6 \text{ mg kg}^{-1}$  dry soil. The highest

Table 3  
Comparison of mean concentrations ( $\text{mg kg}^{-1}$ ) of metals in urban soils

Parameters	London <sup>a</sup>	Aberdeen <sup>b</sup>	Hong Kong <sup>c</sup>	Hong Kong <sup>d</sup>	Central Jordan <sup>e</sup>	This study (0–10 cm)
Pb	294	94.4	100	93.4	62.17	$55 \pm 14.47$
Zn	183	58.5	93.9	168	146.94	$44.51 \pm 12.27$
Cd	1	—	1.89	2.18	4.98	$5.00 \pm 2.19$
Fe	—	—	—	—	—	$24.18 \pm 6.03$
Cu	73	27	27.5	24.8	—	$2.89 \pm 1.47$
Cr	—	23.9	—	—	83.93	$22.18 \pm 8.04$

<sup>a</sup> Thornton (1991).

<sup>b</sup> Paterson et al. (1996).

<sup>c</sup> Wong et al. (1996).

<sup>d</sup> Li et al. (2001).

<sup>e</sup> Banat et al. (2005).

Table 4  
Statistical variation (ANOVA) between metals and soil samples

Parameters	Sum of squares between groups	Degree of freedom	Mean square between groups	Sum of square within groups	Degree of freedom	Mean square within groups	F	Observed $\alpha$
pH	1.052	2	0.434	2.984	58	0.536	1.017	0.368
EC	50449.266	2	25224.633	3019406.5	58	52058.732	0.485	0.532
Pb	1175.935	2	587.967	18356.719	58	316.495	4.323	0.026*
Zn	238.974	2	119.487	12346.869	58	212.877	0.561	0.574
Cd	25.056	2	12.528	1003.386	58	17.300	5.440	0.010*
Fe	33.429	2	16.715	3587.487	58	61.853	0.270	0.464
Cr	268.336	2	134.168	14432.363	58	248.834	0.539	0.568
Cu	1.300	2	0.650	130.388	58	2.248	0.289	0.0450*

$\alpha$  significant level, F, found variation of the group averages/expected variation of the group averages.

\* Significant difference between the samples. Significant at  $P < 0.05$ .

concentrations of chromium are recorded in the eastern area of the cement industry. In the cement industry the linings for the rotaries contain chromium, which could be liberated by wear and friction to be the source of chromium in the soil samples (Banat et al., 2005). On the other hand, the lowest value of chromium was recorded in the reference soil (Fig. 5). Metal concentrations do not correlate with pH, EC, CEC, TOM contents. Owing to the narrow range of pH (7.23–8.15) measured in the soil samples. This parameters has limited importance on the metal mobility and distribution, substantially limiting their mobility, because of the neutral sub alkaline environment.

### 3.3. Statistical analyses and data treatment

Statistical analyses were performed with SPSS for windows 10.0.5. data were log-transformed prior Principle Component Analysis (PCA) to reduce the influence of high data (Moller et al., 2005). Principle Component Analysis was conducted using factor extraction with an Eigenvalue larger than 1 after varimax rotation. Concentrations of metal were compared using One-Way analysis of variance (ANOVA) to compute the statistical significance of the mean. If the difference for each metals concentration were significant at  $P < 0.05$  (Chen et al., 1997). The results of the ANOVA showed significant differences in metals between sites for Pb, Cd and Cu, whereas no significant differences was found for the rest of metals.

Table 5  
Correlation matrix between metals in urban samples; cells show the Pearson correlation coefficient and the corresponding P-value

	Pb	Zn	Cd	Fe	Cu
Pb					
Zn	0.841				
	0.000				
Cd	0.761	0.682			
	0.000	0.000			
Fe	0.513	0.573	0.574		
	0.000	0.000	0.000		
Cu	0.721	0.563	0.781	0.578	
	0.000	0.001	0.000	0.002	
Cr	0.701	0.761	0.649	0.437	0.721
	0.000	0.000	0.000	0.002	0.000

Pearson's correlation coefficient can be used to measure the degree of correlation between the logarithms of the metal data (Garcia and Millan, 1998). The correlation coefficient are shown in the Table 5. Lead and zinc result well correlated ( $R^2 = 0.84$ ), confirming their probable common origin, good correlation between Cu and Cd ( $R^2 = 0.78$ ) (Table 5) was obtained, while the copper and cadmium may be come from bedrocks contribution. On the other hand, there are many high significant correlation coefficient between metals in all sampling points, such as Pb vs. Zn, Cd, Cu and Cr ( $R^2 = 0.84, 0.76, 0.72$  and  $0.70$  respectively) (Table 5).

By using factor analysis to get associations of metals in factors that would give some information about the distribution and source of metal pollution. Factor analysis was performed by evaluation of principle component analysis (PCA) and computing the eigenvalues. The rotation of principle component was carried out by the varimax method. The factor loadings obtained by principle component analysis with varimax for various metals are presented in (Table 6). The loadings having a greater than 0.70 are marked bold in the table.

Factor 1 accounting for 39.90% of the total variance, while having high loadings on the elements Fe, Zn and Cd indicates the influence of local anthropogenic activities on soil samples. The anthropogenic influences were further corroborated by soil samples were collected around the cement factory depending on the prevailing wind direction (Garcia and Millan, 1998). On the other hand, factor 2 explains that about 11.71% of the variance, was composed by Fe, Cu, Cr and soil characteristics  $\text{CaCO}_3$ . This factor had high loadings of

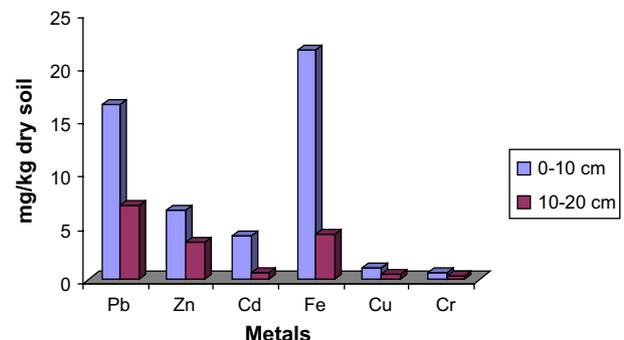


Fig. 5. Mean value of metal concentrations in reference soil.

Table 6  
Factor loadings for varimax rotated PCA of metal data in soil samples (bold loadings are statistically significant)

Parameters	Factor 1	Factor 2	Factor 3
pH	−0.215	−0.537	<b>0.931</b>
EC	−0.288	0.460	<b>0.764</b>
TOM	0.127	−0.242	<b>0.728</b>
CaCO <sub>3</sub>	0.364	0.599	0.135
CEC	−0.163	0.205	<b>0.750</b>
Pb	<b>0.713</b>	0.412	−0.279
Zn	<b>0.755</b>	0.298	−0.146
Cd	<b>0.745</b>	0.175	0.257
Fe	0.171	<b>0.721</b>	
Cu	0.549	0.580	−0.145
Cr	0.220	0.576	−0.237
Eigenvalue	4.389	1.288	1.127
% Variance	39.897	11.709	10.248
% Cumulative	39.897	51.606	61.853

natural and anthropogenic sources. (Moller et al., 2005; Biasioli et al., 2005). Factor 3 accounts for 10.25% of the total variance, was composed by the soil characteristics pH, conductivity, CEC and organic matter. This factor represents the physicochemical source of the variability and this factor has no significance. Factor 1 represents the contribution of metals from local anthropogenic activities, while factor 2 represents the contribution of metals from lithogenic and anthropogenic sources. Results of the statistical analysis and distribution of the pollutant metals suggested that cement emissions represents the most important pollutant source for the investigated area.

#### 4. Conclusions

The data obtained in this study demonstrate that the metal concentrations of urban soils can be used as a powerful geochemical tracers of monitoring the impact of anthropogenic activity, provided that background levels have been correctly interpreted and established. The soil samples of the investigated area can be classified as clay loam texture, from the geological study, the area is dominated by Wadi As Sir formation (WSL) of Turonian age. The distribution of the metal concentration of the soil in the study area indicated that this area has been affected by anthropogenic activity, in particular the cement industry, leading to a high accumulation of heavy metals compared with the natural background levels. The distribution of the metal concentration of the soil in study area indicated that the cement industry together with the agricultural activities and traffic emissions were mainly responsible for metal pollution, as the highest metal concentrations were found close to the cement factory. No significant variations were found in pH values between the soil samples. This can be attributed to buffering effect of carbonate content in the cement industry in which carbonate materials are used as a raw materials and from the major constituents of the emitted dust and aerosols released to environment. With regards to health risks, bioavailability and mobility of metals can be stated to be of minor significant in the soil. In future, further study is need not only to

assess the distribution of metals in soil but also to examine variation on small scale. More intensive sampling and examine will be required to know any change or increase of metals in the investigated area.

#### References

- Al-Khashman, O.A., 2004. Heavy metal distribution in dust, street dust and soil from the work place in Karak Industrial Estate, Jordan. *Atmospheric Environment* 38, 6803–6812.
- Banat, K.M., Howari, F.M., Al-Hamad, A.A., 2005. Heavy metals in urban soils of central Jordan: should we worry about their environmental risks. *Environmental Research* 97, 258–273.
- Beckwith, P.R., Ellis, J.B., Revitt, D.M., 1985. Particle size distribution of Cu, Pb and Zn across a road surface. Abstract of the international conference heavy metals in the environment. Sept. 1985. Athens 1, 174–176.
- Bender, F., 1974. *Geology of Jordan*, Gerbruder Borntraeger, Berlin, Germany.
- Berg, T., Royset, O., Steinnes, E., Vadset, M., 1995. Atmospheric trace element deposition: Principle Component Analysis of ICP-MS data from moss samples. *Environmental Pollution* 88, 67–77.
- Biasioli, R., Barberis, R., Marson, F.A. The influence of a large city on some soil properties and metal content. *Science of the Total Environment*, in press.
- Bilos, C., Colombo, J.C., Skorupka, C.N., Presa, M.J.P., 2001. Source, distribution and variability of airborne trace metals in La Plata city area, Argentina. *Environmental Pollution* 111, 149–159.
- Bin Chen, T., Ming Zheng, Y., Lei, M., Chun Huang, Z., Tao Wu, H., Chen, H., Ke Fan, K., Yu, K., Wu, X., Zheng Tian, Q., 2005. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. *Chemosphere* 60, 542–551.
- Carreras, H.A., Pignata, M.L., 2002. Biomonitoring of heavy metals and air quality in Cordoba city, Argentina, using transplanted lichens. *Environmental Pollution* 17, 77–87.
- Charlesworth, S., Everett, M., McCarthy, R., Ordones, A., de Miguel, E., 2003. A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry, West Midlands, UK. *Environment International* 29, 563–573.
- Chen, T.B., Wong, W.J.C., Zhou, H.Y., Wong, M.H., 1997. Assessment of trace metal distribution and contamination in surface soil of Hong Kong. *Environmental Pollution* 96, 61–68.
- Chon, H.T., Ahn, J.S.G., Jung, M.C., 1995. Metal contamination of soils and dusts in Seoul metropolitan city, Korea. *Environmental Geochemistry and Health* 17, 23–37.
- DeKimple, C.R., Morel, J.F., 2000. Urban soil management: a growing concern. *Soil Science* 165, 31–40.
- Ellis, J.B., Revitt, D.M., 1982. Incidence of heavy metals in street surface sediments: solubility and grain size studies. *Water, Air and Soil Pollution* 17, 87–100.
- Garcia, R., Millan, E., 1998. Assessment of Cd, Pb and Zn contamination in roadside soils and grasses from Gipuzkoa (Spain). *Chemosphere* 37 (8), 1615–1625.
- Garty, J., Kauppi, M., Kauppi, A., 1996. Accumulation of airborne elements from vehicles in transplanted lichens in urban sites. *Journal of Environmental Quality* 25, 265–272.
- Gee, G.W., Bauder, J.W., 1986. Particle size analysis. In: Klute, A. (Ed.), *Methods of Soil Analysis Part 1. Physical and Mineralogical Methods*. Agronomy Series No. 9. American Society of Agronomy, Madison, WI.
- Gray, C.W., McLaren, R.G., Roberts, A.H.C., 2003. Atmospheric accessions of heavy metals to some New Zealand Pastoral Soils. *The Science of the Total Environment* 305, 105–115.
- Hesse, P.R., 1972. *Textbook of soil chemical analysis*. Pub, New York, 520 pp.
- Hewitt, C.N., Candy, G.B.B., 1990. Soil and street dust heavy metal concentrations in and around Cuenca, Ecuador. *Environmental Pollution* 36, 129–136.
- Jaradat, Q., Momani, K., 1999. Contamination of roadside soil, plants and air with heavy metals in Jordan, a comparative study. *Turkish Journal of Chemistry* 23, 209–220.

- Li, X.D., Poon, C.S., Pui, S.L., 2001. Heavy metal contamination of urban soils and street dusts in Hong Kong. *Applied Geochemistry* 16, 1361–1368.
- Madrid, L., Barrientos, E.D., Madrid, F., 2002. Distribution of heavy metal contents of urban soils in parks of Seville. *Chemosphere* 49, 1301–1308.
- Manta, D.S., Angelone, M., Bellanca, A., Neri, R., Sprovieri, M., 2002. Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. *The Science of the Total Environment* 300, 229–243.
- Martin, A.C., Rivero, V.C., Marin, M.T.L., 1998. Contamination by heavy metals in soils in the neighborhood of a scrapyards of discarded vehicles. *The Science of the Total Environment* 212, 142–152.
- Matos, A.T., Fontes, M.P.F., Costa, L.M., Martinez, M.A., 2001. Mobility of heavy metals as related to soil chemical and mineralogical characteristics of Brazilian soils. *Environmental Pollution* 111, 429–435.
- Moller, A., Muller, H.W., Abdullah, A., Abdelgawad, G., Utermann, J., 2005. Urban soil pollution in Damascus, Syria: concentrations and patterns of heavy metals in the soils of the Damascus Ghouta. *Geoderma* 124, 63–71.
- Ndiokwere, C.L., 1984. A study of heavy metal pollution from motor vehicle emissions and its effect on roadside soil, vegetation and crops in Nigeria. *Environmental Pollution B* 7, 35–42.
- Nriagu, J.O., 1989. A global assessment of natural sources of atmospheric trace metals. *Nature* 338, 47–49.
- Olajire, A.A., Ayodele, E.T., 1997. Contamination of roadside soil and grass with heavy metals. *Environment International* 23 (1), 91–101.
- Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), 1982. *Methods of soil analysis. Part 2. Chemical and mineralogical properties. Agronomy Series No. 9.* American Society of Agronomy, Madison, WI.
- Paterson, E., Sanka, M., Clark, L., 1996. Urban soils as pollutant sinks – a case study from Aberdeen, Scotland. *Applied Geochemistry* 11, 129–131.
- Simonson, R.W., 1962. Soil classification in the united state. *Science* 137, 1027–1034.
- Thornton, I., 1991. Metal contamination of soils in urban area. In: Bullock, P., Gregory, P.J. (Eds.), *Soil in the Urban Environment*. Blackwell, pp. 47–75.
- Tüzen, M., 2003. Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. *Micro Chemical Journal* 74, 289–297.
- Wong, J.W.C., Mak, N.K., 1997. Heavy metal pollution in children playgrounds in Hong Kong and its health implications. *Environmental Technology* 18, 109–115.
- Wong, M.H., Chen, T.B., Wong, J.W.C., 1996. Trace Metal Contamination of the Hong Kong Soil Environment: A Review. *Contaminants and the Soil Environments in the Australia-Pacific Region*. Klummer Academic Publisher, Dordrecht, pp. 501–511.
- Yamagata, N., 1970. Cadmium pollution in perspective. In: *Koshu Eisein Kenkyi Hokoku*, vol. 19. Institute of Public Health, Tokyo 19, pp. 1–27.