

# Heavy-Metal Contamination and Distribution within the Urban Soil Cover in Mutah and Al-Mazar Municipal Area

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## Abstract

Thirteen sites allocated on grid bases covering the urban soil of Mutah – Al-Mazar municipal area (south of Al-Karak province) were collected. The collection was designed to cover inhibited or open areas and all occupational activities. The sites were investigated for their heavy-metal content to delineate the polluted areas and determine the potential pollution sources. The results show no or limited downward mobility of the heavy metals as there is no big difference in average heavy-metal contents between lower and upper soils. This might be due to high soil alkalinity and low rainfall quantities. Besides, it shows that traffic is the main source for pollution which was approved using the correlation coefficient and index of pollution (IP) techniques. Furthermore, the ratio of index of pollution for most of the sites are <1; few are >1 but not reaching 2, which indicates that a low extent of pollution prevails in the study area, because of the absence of heavy industrial firms and high density highways. The correlation coefficient results show that the upper soil differs from lower soil; in upper soils Cu correlated positively with Fe, Cr, Co, Mn, Zn, Ni, and Pb, whereas in the lower soil, it correlated with Fe, Cr, Co and Ni, which indicates a different source of contamination or an anthropogenic source that contains Zn, Mn, and Pb.

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**Keywords:** Urban soil, Heavy metals, Soil pH, Contamination, Anthropogenic

## 1. Introduction

The detection of soil pollution that could result from heavy metals (HM) has become increasingly important. Heavy metals occur naturally, but rarely at toxic levels. Anthropogenic activities and the use of synthetic products (e.g. pesticides, paints, batteries, and industrial waste) can result in heavy-metal contamination of urban and agricultural soils (Jiries et al., 2017). Moreover, traffic activities on roads can contribute to increasing the levels of heavy metals in these environments through fossil fuel combustion, wear and tear of many parts of the automobile (Alloway and Ayres, 1997).

Soil environmental pollution due to heavy metals in urban areas is extremely urgent, therefore, the following heavy metals (i.e. Cd, Zn, Cu, Ni, Fe, Cr, Mn and Pb) were chosen for analysis due to their effects on human and environmental components. Generally, heavy metal distribution is influenced by the nature of parent materials, climate and their relative mobility, as well depending on soil parameters such as pH, mineralogy, and texture (Jiries et al., 2017). The concentration of these metals in soil is related to the presence of humus and clay minerals which serve as adsorbents of heavy metals (Huisman et al., 1997, Vermeulen et al., 1997, Garnaud et al., 1999; Birke and

Rauch, 2000). Many workers have investigated the pollution of soil by heavy metals. El-Hasan (2002) found that heavy metals are concentrated on the surface of soils in the city of Sahab in central Jordan, but they decrease in the lower parts, without representing serious pollution problems. However higher Cu, Pb, Zn, and Cd concentrations in the soils might be attributed to anthropogenic inputs. The influence of urbanization and industrialization as a major cause for heavy-metal contamination either in the dust, sediments, soils, or plants was observed by many authors (e.g. Claridge et al., 1994; Vermeulen et al., 1997; Kim et al., 1998; Wilcke et al., 1998; Garnaud et al., 1999; Brike and Rauch, 2000). Urban geochemistry is a newly developed field that combines the basic knowledge of geochemistry with the urbanization development and its environmental consequences. It serves as environmental implication of known geochemical methods of survey. It was used in many areas around the world, e.g. for Hong Kong city, Ho and Tai (1988), for the city of Prague (Czech Republic), Duris and Zimova (1994), for the urban soil of Bangkok city, Wilcke et al., 1998; and Li et al., 2001, and for Berlin metropolitan area, Birke and Rauch (2000). Detecting and characterizing heavy-metal pollution in different areas in Al-Karak province have been done previously by many workers using several proxies

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such as soil (El-Hasan and Lataifeh, 2003; El-Hasan and Lataifeh, 2013), Wadi sediment (El-Hasan and Jiries, 2001), dry deposition (El-Hasan et al., 2008), lichens by (Jiries et al., 2008) and plants by (El-Hasan et al., 2002).

### 1.2 Aims of the Study

Henceforth, this work aims at obtaining a comprehensive picture of the soil geochemistry in urban areas with respect to their natural composition and the secondary contamination (anthropogenic). Also, it aims at delineating the distribution and mobilization of heavy metals within soil profile. Moreover, this study aims at investigating the factors which affect heavy-metal concentrations and mobility in soil profile such as pH, conductivity, soil composition, and wind direction as well as determining the various anthropogenic sources. Consequently, this work will assess the environment in terms of heavy-metal contamination. Therefore, it would provide a base-line data for future environmental assessment and monitoring of the soil contamination in the urban area of Mutah and Al-Mazar. To this purpose, the following objectives must be achieved:

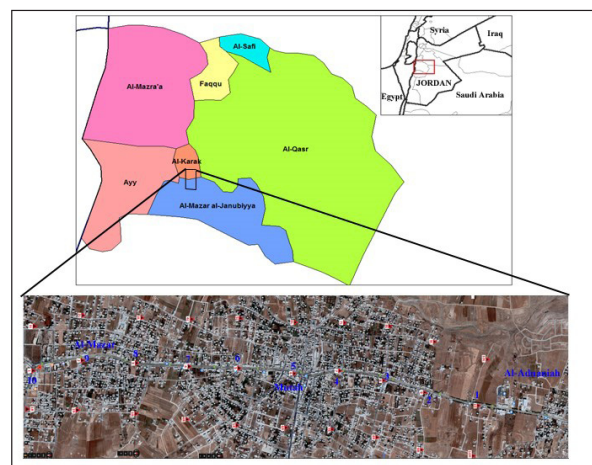
1. Determining the concentration of some heavy metals (Cd, Zn, Cu, Ni, Fe, Cr, Mn, and Pb) in the surface soil cover in the Mutah and Al-Mazar area using Atomic Absorption Spectrometry (AAS).
2. Establishing a reliable database for heavy-metal concentrations in order to monitor any increase in their concentrations in future, which pose alarming threats to the health and environment sector in the area when these elements exceed the permissible limits,

### 1.3 Study Area Settings

The study area includes Mutah and Al-Mazar towns which belong to one municipality. The study area is located in the southern part of Al-Karak governorate, in central Jordan to the east of the Dead Sea. The study area and the sampling sites are shown in (Figure 1). This area has a predominantly Mediterranean climate that is characterized by hot-dry summers and cold-wet winters ((Department of Metrology of Jordan, 2016)). The temperature exhibits large seasonal and diurnal variation. More frequently, seasonal mean temperatures vary from 6°C in January to 22°C in July, reaching a maximum of 38.5°C in summer and a minimum of -4°C in winter with an average temperature of 22°C in summer and 8°C in winter (Department of Metrology of Jordan, 2016)). The investigated area is about 1000-1200 m high above the sea level. The site is located in the rolling and rounded limestone plateau with phosphorite, which is referred to in the geology of Jordan as Al-Hisa Phosphorite Unit (AHP) (Powell, 1988).

Therefore, the activities vary depending on the area of Mu'tah and Mazar. These are two of the rapidly developing

and attractive areas for the population in the Al-Karak governorate, as a result of the population mobilization stations, the increase in transport, the movement of automobiles, and because of the activities of construction and factories. Activities such as industrial zones and fuel stations are also increasing. All this affects the environment of the region by means of increasing the load of heavy elements such as iron, lead, zinc, chromium, manganese and nickel in the soils. Since these factors have an impact on human health, this study is conducted to determine heavy metals' concentration as a basis for future monitoring.



**Figure 1.** Distribution of sampling sites along the 5 km Al-Mazar city to Al-Adnanieh Street.

## 2. Materials and Methodology

### 2.1. Soil Sampling

All soil samples were collected from thirty sites along the highway from Al-Mazar city to Al-Adnanieh village through Mutah, which is 5 km long. Two samples were collected from each site; at the depth of 10 and 20 cm. The soil samples were representatively collected by homogenizing soils from each depth. The distribution of the sampling sites was as follows: ten sites from the margins of the main street, ten sites from a distance of 500 meters to the right of the street, and ten sites from a distance of 500 meters to the left of the street. Therefore, the distance between any two samples in all directions was approximately 500 m (Figure 1).

The total area of investigation is around 10 km<sup>2</sup>; it was divided into 500 m × 1000 m grid. A total of forty-eight sample sites were assigned on the google map of Mutah and Al-Mazar towns. The sample density is five samples per km<sup>2</sup>. The sampling sites were allocated using the GPS system (Garmin GPS II Plus), with ± 10-meter accuracy. The sampling campaigning duration was three months (Feb-April 2016).

The soil samples were collected from two depths; the upper soil (0–10 cm) hereafter referred to as (A), and the lower soil (10–20 cm) hereafter referred to as (B). The soil samples were dried at room temperature for seventy-two

hours, and were then stored using plastic tools into sealed plastic bags.

The collected samples from the upper and lower soils (A, B) were left to dry up at room temperature. The samples were then sieved to less than 2 mm; then they were sieved again using ordinary stainless steel sieves 150 and 63  $\mu\text{m}$  and were divided into two sizes as follows: coarse (150–63  $\mu\text{m}$ ) referred to as (C) and fine (<63  $\mu\text{m}$ ) referred to as (F). As a result, each collected soil sample was divided into four samples (AC, AF, BC and BF); the sieved samples were kept in plastic sealed pages and stored for further analysis.

## 2.2. Soil Sampling

All of the sixty soil samples were collected in sealed plastic bags, sieved to < 2 mm grain size and air-dried for seventy-two hours. They were then kept in plastic bags until analysis. The soil acidity (pH) and electrical conductivity (EC) were analysed by mixing 1:5 ratios of soil and deionized water following the procedure of (Blakemore et al., 1987).

### 2.2.1 Soil Sample Digestion and Analysis

In order to find the best experimental setting that would produce a higher yield of elements from the leached soil samples, the following orientation test was executed: four parameters were tested to find their effect on the digestion process, those are (Temperature (25 and 70°C); Solvent used (2 M  $\text{HNO}_3$  and 2M aqua regia  $1\text{HNO}_3$ ; 3HCL v/v); Incubation time and type were as follows (i.e. 2 and 24 hours for the mechanical shaking) and the sonication time was (i.e. 30 and 120 minutes). Two elements (Pb and Fe) were chosen for this test. To statistically find the best settings, the matrix of the obtained data was treated using Minitab Program software. All samples were digested according to the best results obtained from the previous orientation test, which showed that the mechanical shaking for twenty-four hours with 2M aqua regia at 70°C and 150 rpm gave the higher elemental yield. Thus, the samples were digested using these settings.

The soil leaching procedure was achieved using the method of (Fialova et al., 2006) by which 2 g of the soil sample were mixed with the assigned solution mentioned above. Later, all samples were centrifuged at 3000 rpm for five minutes. The supernatant was collected, and the precipitate was then washed with 10 ml Deionized water. Then the supernatant was collected again and mixed with the first collected supernatant in a 50ml volume flask. Finally, the collected supernatant was diluted up to 50 ml. All samples were filtered using a syringe filter of a 0.45  $\mu\text{m}$  pore size and were kept in polyethylene vials for analysis. Then, the samples were analyzed by means of Flame Atomic Absorption Spectrophotometer (AA-7000, Shimadzu Scientific

Instruments, Japan) according to the Standard Method 3111 B. Finally, the result was evaluated and recalculated to be expressed in mg/kg soil. The solution was then transferred into 25-ml polyethylene bottles, filled up with distilled water exactly to 25-ml, then stored in the refrigerator until analysis time. The concentrations of heavy metals (Zn, Ni, Pb, Cu, Co, Cr, Fe, and Mn) in the soil samples were determined using the Flame Atomic Absorption Spectrophotometer (AA-7000, Shimadzu Scientific Instruments, Japan).

### 2.2.1.1. Soil pH

The pH values of all soil samples were measured according to the standard method SM 4500 H+B (Eaton et al., 2005) by preparing 1:5 (Soil: Deionized Water) suspensions. The suspensions were prepared by shaking 10 g of air-dried soil < 2 mm in 50 mL of deionized water in a rotating shaker for one hour at 15 rpm. The obtained pH values (pH meter 315i, WTW GmbH, Weilheim, Germany) were recorded when the equilibrium (stability in the reading) was reached while stirring with a mechanical stirrer (Rayment and Higginson, 1992).

### 2.2.1.2. Electrical Conductivity (EC)

The EC values of all soil samples were measured according to the standard method SM 2510 (Eaton et al., 2005). The soil EC was determined by shaking a 1:2.5 (w/w) ratio of soil and deionized water. The mixture was homogenized for thirty minutes at 15 rpm using a horizontal shaker, and was then left at room temperature until the soil settled down before EC measurement. The conductivity of the supernatant liquid was determined using the conductivity meter without disturbing the settled soil (Conductivity meter 4310, JENWAY, UK) (Chapman and Pratt, 1974).

## 2.3. Mineralogical Analysis of the Soil Samples.

Eight urban soil samples were selected. Each soil sample collected was powdered in an agate mortar for the XRD analyses. Organic tissues were previously removed to avoid the noise that organic matter produces in the XRD signal. XRD patterns were acquired by an automated PANalytical X'pert Pro diffractometer equipped with the X'Celerator detector, with the following measurement conditions: 5.01-69.98° 2 $\theta$  angular range, 0.0170° step-size, Ni-filtered Cu K $\alpha$ 1 radiation ( $\lambda = 1.54060 \text{ \AA}$ ), operating at 40 kV and 40 mA.

## 3. Results and Discussion

### 3.1. Soil Mineralogy

The XRD patterns of all samples are quite similar and mainly formed by quartz and calcite with subordinate contents of dolomite, clay minerals and feldspars. Quartz and calcite are identified by several peaks (Figure 2) whereas dolomite, plagioclase and K-feldspar can be recognized just by their strongest peaks at about 30.8°, 27.9° and 27.5° 2 $\theta$ , respectively. Quartz and calcite relative proportions vary

from one sample to another, as highlighted by the intensities of their strongest peaks (XRD patterns were collected under the same measurement conditions).

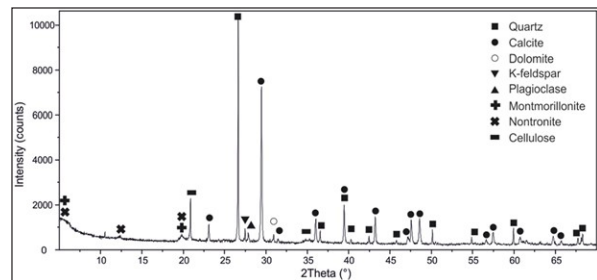


Figure 2. XRD pattern of a representative urban sample from upper soil.

In all XRD patterns of both lower and upper soils, the presence of two or three small peaks at low angles, between 8.9° and 12.4° 2θ have been detected. The peak at 12.4° 2θ (~ 7.15 Å) is always found and is attributed to kaolinite; a small peak, rarely found at 8.9° 2θ (~ 9.94 Å) is attributed to illite; other peaks, commonly occurring within this range cannot be precisely attributed due to the chemical and structural variability of clay minerals but can be assigned to montmorillonite or saponite and/or nontronite. In addition to the mineral phases, the signature of cellulose is clearly observed in all samples as testified by the (002) peak at about 20.8° 2θ and by the large, poorly-defined (040) peak in the 34.5-35.5° 2θ range.

3.2. Soil Chemistry

As for the soil chemistry, Tables (1 and 2) represent the analytical results of heavy metals, pH and EC for both the upper soil (i.e. 0-10cm and the lower soil (i.e. 10-20 cm)

in the study area. Additionally, the texture analysis for the selected soil samples from the area shows that it belongs to the Vertisol type of silty sand texture, this is similar to (Hararah et al., 2011), (Table 3).

In order to determine the chemical enrichment and depletion of the heavy metal, the correlation coefficient relationships were used. The correlation coefficient for both soils is presented in Tables (4-5). From these matrices, it can realize that a similar correlation coefficient relationship existed between Fe and other HM in both soils, the only obvious difference was that in upper soils there was a positive correlation between Cu and Pb and Zn, whereas in the lower soils, co correlation existed. In the upper soils Cu has a very positive correlation with all HM, whereas it is only correlated to Cr, Co and Ni in the lower soils. Moreover, there was a quite clear positive correlation between Cu and Mn, Pb and Zn in the upper soils, but no correlation between Cu and Zn and Pb was observed in the lower soils. Mn, Pb and Zn are positively correlated to each other; only Cu was in the upper soils. This suggests a different source of contamination or an anthropogenic source that produces the Zn, Mn and Pb, which is most likely to be traffic-related. Another difference between upper and lower soils in the behavior of pH and EC is that they have a clear negative correlation with all HM in the lower soils, but they have a neutral correlation with HM in the upper soils. This means that EC and pH are relatively higher in the upper soils, due to the effect of the higher evaporation and lower rainfall in the area.

Table 1. The analytical results of the upper soil; heavy metals (mg/kg), pH and EC (µs/cm).

Sample ID upper	pH	EC [µs/cm]	Fe [mg/kg]	Cu [mg/kg]	Cr [mg/kg]	Co [mg/kg]	Mn [mg/kg]	Zn [mg/kg]	Ni [mg/kg]	Pb [mg/kg]
1R	8.24	78.9	20255	13.7	26.8	6.7	530.2	183.8	21.0	20.3
1	8.21	95.1	19744	12.3	14.5	3.0	213.6	223.1	12.5	31.2
1L	8.12	68.1	26483	17.2	36.5	14.2	1255.6	111.8	37.6	16.8
2R	8.31	82	23992	15.6	36.0	9.6	660.1	78.2	27.1	20.3
2	8.17	140	24615	15.6	36.7	9.6	643.9	57.0	26.9	19.0
2L	8.13	69.9	27768	15.7	38.6	11.9	952.5	135.8	30.5	20.1
3R	8.22	121.6	21228	11.8	31.4	9.1	757.6	82.0	24.9	23.9
3	8.16	169.2	29014	30.1	39.1	13.7	1309.7	316.3	35.7	35.0
3L	8.24	117.2	27223	14.8	40.8	10.4	844.2	101.2	28.4	23.1
4R	7.97	97.9	26795	14.6	37.4	11.8	841.5	120.4	32.1	12.1
4	8.12	113.4	23408	13.8	30.8	11.2	920.0	195.3	28.8	15.3
4L	7.99	104	24537	15.8	30.8	13.0	1139.2	69.5	31.3	13.2
5R	7.94	120.4	22863	13.8	27.1	8.9	833.4	91.6	25.5	15.3
5	8.24	149.2	17763	13.1	17.4	6.7	665.6	66.6	17.4	18.1
5L	8.17	126	21481	11.1	17.9	8.0	852.3	74.3	23.1	15.6
6R	8.1	97.8	19243	12.9	11.3	7.8	947.0	199.1	23.2	15.6
6	8.25	149.9	14260	9.3	6.6	6.1	768.4	28.2	16.7	7.6
6L	8.1	92.5	16868	13.0	10.8	8.5	486.9	78.2	25.0	12.4

7R	8.26	75.3	16226	8.2	17.0	5.8	486.9	130.0	17.7	13.1
7	8.26	91.3	11515	9.2	11.2	3.9	346.2	182.8	13.7	17.1
7L	8.13	132.7	19301	17.9	44.6	5.9	508.6	162.6	28.0	12.8
8R	8.18	120.2	24770	12.0	32.1	9.7	898.3	87.8	28.3	11.8
8	8.22	81.9	23972	11.3	27.6	10.4	868.5	43.6	28.1	10.9
8L	8.16	73.4	24517	10.7	31.0	7.8	800.9	125.2	24.8	13.1
9R	8.22	95.8	24031	10.0	28.0	8.5	941.6	117.5	24.8	12.0
9	8.2	107.4	17977	8.8	21.4	6.3	752.2	101.2	20.3	15.6
9L	7.9	76	26950	12.4	49.6	10.1	703.4	135.8	29.3	7.9
10R	8.07	73.1	18231	9.2	18.2	6.2	589.8	59.0	20.1	10.3
10	8.11	89.7	13948	7.6	16.3	4.4	351.6	124.2	16.7	16.8
10L	8.11	48.1	25627	11.3	28.0	10.1	776.5	74.3	28.5	6.5
Maximum	8.31	169.2	29014	30.0	49.6	14.2	1309.7	316.3	37.6	35.0
Minimum	7.9	48.1	11515	7.6	6.6	3.0	231.6	28.3	12.5	6.5
Mean	8.15	101.9	21820	13.1	27.2	8.6	754.9	118.5	24.9	16.1
$\sigma$	0.1	27.9	4541	4.1	11.1	2.8	252.5	61.8	6.1	6.3

**Table 2.** The analytical results of the lower soil; heavy metals (mg/kg), pH and EC ( $\mu\text{s}/\text{cm}$ ).

Sample ID lower	pH	EC [ $\mu\text{s}/\text{cm}$ ]	Fe [mg/kg]	Cu [mg/kg]	Cr [mg/kg]	Co [mg/kg]	Mn [mg/kg]	Zn [mg/kg]	Ni [mg/kg]	Pb [mg/kg]
1R	8.27	82	20527	13.5	27.7	7.0	541.1	94.5	21.9	20.7
1	8.17	88.3	19160	15.1	22.5	2.9	156.7	150.2	17.0	26.5
1L	8.17	73.9	28274	16.9	36.8	14.0	1269.1	120.4	37.5	16.7
2R	8.4	78.4	25335	17.7	35.1	9.5	687.2	128.1	26.2	20.3
2	8.1	96.3	23525	15.7	34.5	9.8	673.7	97.4	25.9	22.2
2L	8.12	84	29052	15.9	40.0	12.5	1017.4	162.6	30.7	20.4
3R	8.27	116.4	23544	12.4	33.1	9.5	790.1	72.4	25.6	23.2
3	8.46	166.4	23213	12.8	35.8	10.8	838.8	68.6	25.7	24.2
3L	8.36	102.6	26055	16.4	33.4	10.8	681.8	105.0	31.1	13.7
4R	7.98	79.2	30142	30.3	51.2	12.8	925.4	168.4	35.5	12.1
4	8.14	103.3	25666	15.1	32.4	11.7	987.6	101.2	30.3	14.3
4L	8.12	113	25627	15.7	30.1	12.3	1120.3	206.8	31.3	14.3
5R	8.05	98.5	23544	13.9	25.7	9.7	982.2	101.2	27.7	14.5
5	8.19	116.2	18192	13.5	17.5	7.0	781.9	85.8	19.1	22.2
5L	8.22	109.7	23174	13.1	16.8	10.2	1101.3	97.4	26.1	15.6
6R	8.17	105.8	17841	12.4	9.0	6.9	936.2	97.4	21.7	15.9
6	8.32	120.2	15856	9.8	7.2	5.9	828.0	179.0	16.9	15.6
6L	8.2	80.3	24809	14.3	11.9	10.4	768.4	52.2	29.3	12.1
7R	8.27	76.1	14649	7.9	14.9	5.3	468.0	180.9	16.4	12.4
7	8.12	83.3	9686	6.5	9.5	3.2	332.7	203.0	11.2	15.4
7L	8.26	106	19184	17.9	46.5	6.0	535.6	237.5	28.3	12.4
8R	8.21	110.2	26386	12.5	33.8	10.0	971.4	87.8	29.3	11.2
8	8.11	107.5	25004	11.3	28.0	9.7	849.6	72.4	27.0	11.8
8L	8.26	71.3	22941	11.0	31.9	7.7	879.4	107.0	25.3	12.4
9R	8.31	91	24868	11.1	32.2	9.7	657.4	59.0	27.3	9.9
9	8.21	143.2	15895	8.3	20.4	5.7	725.1	94.5	18.6	16.0
9L	7.97	53.9	26678	12.9	44.4	10.6	687.2	93.5	28.8	8.4
10R	8.13	65.3	18308	9.2	19.7	6.3	578.9	85.8	19.2	10.1
10	8.09	76.2	12313	7.7	14.3	4.5	370.5	107.0	17.1	14.0
10L	8.18	55.3	27456	11.2	29.7	9.8	806.3	105.0	28.7	8.1
Maximum	8.46	166.4	30142	30.3	51.2	14.0	1269.1	237.5	37.5	26.5
Minimum	7.97	53.9	9160	6.5	7.7	2.9	156.7	52.2	11.2	8.1
Mean	8.19	95.1	22230	13.4	27.5	8.7	765.0	117.4	16.1	15.6
$\sigma$	0.11	24.5	5095	4.4	11.5	2.9	246.5	49.1	6.1	4.8

**Table 3.** Soil texture analysis for selected soil samples from the study area.

Sample	Sand %	Clay %	Silt %
4L	61	20	19
7R	68	8	24
9L	53	18	29
10L	70	14	16

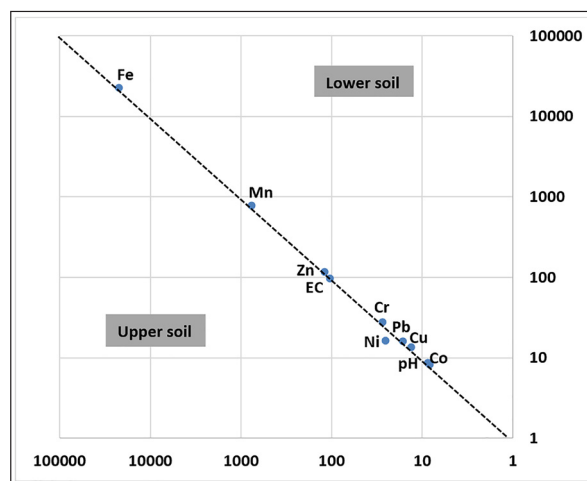
**Table 4.** Correlation coefficient matrix for the heavy metals, pH and EC in upper soil. n=30; at 95% confidence level (P<0.05).

upper	Fe	Cu	Cr	Co	Mn	Zn	Ni	Pb	EC	pH
Fe	1.0	0.54	0.81	0.89	0.77	-0.03	0.91	-0.02	0.03	0.03
Cu		1.00	0.56	0.62	0.54	0.51	0.67	0.57	0.43	0.32
Cr			1.00	0.65	0.43	0.12	0.78	0.11	-0.04	-0.02
Co				1.00	0.86	-0.02	0.94	0.04	0.13	-0.02
Mn					1.00	0.04	0.79	0.03	0.40	0.16
Zn						1.00	0.05	0.60	0.21	0.19
Ni							1.00	-0.05	0.08	0.00
Pb								1.00	0.44	0.42
EC									1.00	0.44
pH										1.00

**Table 5.** Correlation coefficient matrix for the heavy metals, pH and EC in lower soil. n=30; at 95% confidence level (P<0.05).

lower	Fe	Cu	Cr	Co	Mn	Zn	Ni	Pb	EC	pH
Fe	1.0	0.57	0.69	0.95	0.73	-0.27	0.93	-0.25	-0.12	-0.38
Cu		1.00	0.67	0.58	0.33	0.20	0.69	0.12	0.09	-0.34
Cr			1.00	0.61	0.26	0.08	0.74	-0.04	-0.05	-0.33
Co				1.00	0.80	-0.23	0.92	-0.13	-0.03	-0.41
Mn					1.00	-0.16	0.69	-0.13	0.09	-0.35
Zn						1.00	-0.12	-0.01	-0.03	-0.02
Ni							1.00	-0.22	-0.10	-0.46
Pb								1.00	0.42	0.40
EC									1.00	0.15
pH										1.00

The comparison in heavy metal distribution between the upper and lower soils was investigated using the 1:1 ratio charts and is shown in Figure (3). This type of charts is previously used to distinguish the enrichment and depletion of elements between two layers, (Jiries et al., 2004). This figure shows that Fe has a slightly higher content in the lower soil. This was mainly in the samples located in unused or unoccupied areas (i.e. background). These are characterized as red soils without any human activities. This slight enrichment could be explained by the aggressiveness of the acid mixture used in the soil sample digestion process which resulted in attacking the internal mineral composition of the soil mineral lattice in addition to the adsorbed metals on the soil surface, thus increasing the element content.



**Figure 3.** 1:1 ratio plot showing no difference between the upper and lower soils.

3.3 Source of Pollution

The heavy metal distribution within the surface soil samples was investigated to delineate the areas with pollution and to allocate the major source/s of pollution. To this purpose, the samples were classified according to the occupied activities into four categories: Background (open areas without activities); Housing (areas mainly occupied by normal houses); Traffic (sites dominated by high traffic density); and Industry (sites that are in areas which has certain industrial or semi-mechanical warehouses). These categories with average HM contents are illustrated in Table (6) and Figure (4).

Table 5. Surface soil samples categories, and there average heavy metal contents

Sample ID	Background	Houses	Traffic	Industry
No. Samples	5	14	7	4
pH	8.21	8.2	8.1	8.2
EC (µs/cm)	106.7	95.8	106.5	109.5
Fe (mg/kg)	15489	21749	24537	25228
Cu (mg/kg)	9.4	12.5	14.9	16.5
Cr (mg/kg)	14.0	28.3	31.5	32.2
Co (mg/kg)	4.7	8.3	10.8	10.8
Mn (mg/kg)	486.4	700.7	929.3	974.8
Zn (mg/kg)	131.9	104.7	107.2	170.1
Ni (mg/kg)	16.0	24.7	29.3	29.4
Pb (mg/kg)	17.7	14.6	16.4	18.6

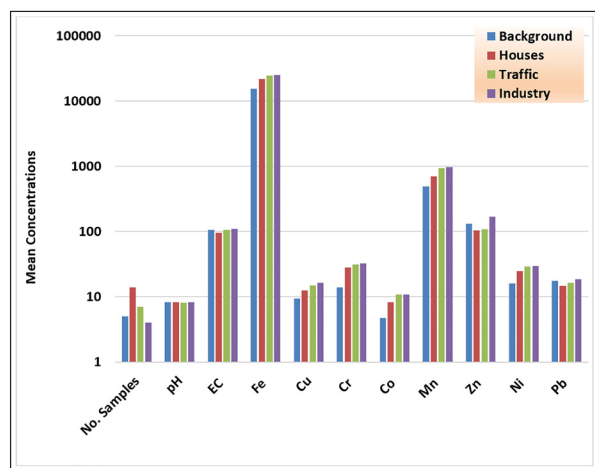


Figure 4. The average HM, pH and EC for the four categories in the study area.

3.4 Index of Pollution

For the purpose of the environmental evaluation of the HM and to elucidate the extent of their pollution in the surface soils of the study area, Index of Pollution (IP) was used. This statistical technique, that was first introduced by (Chester et al., 1985), and was used then by many in Al-Karak area, was used to delineate the pollution in the Wadi sediments (El-Hasan and Jiries, 2002; Jiries et al., 2004). It depends on soil sample categorization based on the occupied activities

in the specific soil sampling site (i.e. Background, Domestic, Traffic or Industrial). The prime step of this method is the assigning of the Artificial Background Samples (ABS), which were chosen from the background sampling sites that have the lowest HM concentrations to establish the base line that reflects a non-polluted area. The first step was to calculate the threshold using equation (1) (Saffarini and Lahawani, 1992).

$$\text{Threshold} = X + 2 \sigma \dots\dots\dots (1)$$

where X is the mean, σ is the standard deviation.

Secondly, individual samples should show lower heavy-metal concentrations relative to other samples, (Chester et al., 1985). The chosen ABS samples are shown in (Table 1). The new threshold was then calculated using the following equation (2):

$$\text{Threshold} = X_{\text{ABS}} + 2 \sigma_{\text{ABS}} \dots\dots\dots (2)$$

where X<sub>ABS</sub> is the mean of ABS samples, σ<sub>(ABS)</sub> is the standard deviation of ABS.

Finally, the IP was then calculated using the following equation (3).

$$\text{IP} = \text{Conc. E} / (X_{\text{ABS}} + 2 \sigma_{\text{ABS}}) \dots\dots\dots (3)$$

where (Conc. E) is the concentration of any element in the sample, and the (X<sub>ABS</sub> + 2σ<sub>ABS</sub>) is the ABS threshold of that element. Whenever IP >1.0, it indicates that additional pollutant input has been introduced to the sample.

The results are shown in Table (7). It is obvious that the degree of soil contamination by heavy metals is very low in the study area as it has no massive industries and high density traffic. Most of the upper soils at the sampling sites have IP < 1, which means no additions of HM were incremented to the soil. Meanwhile; only few sites which belong to the Traffic and Industrial categories have an IP >1, which means additional anthropogenic HM sources are presented affecting these site. The values and the distribution of sites, with an IP>1, reflect a low pollution extent and a very scarce dispersion. The Mutah and Al-Mazar areas have become the most attracting areas in Al-Karak province for the population because of the relatively higher work opportunities and the fast growth in urban development and the relatively good commercial situation. Thus an increase in traffic and more middle-size industrial firms are expected to be established in the coming few years, which will, therefore, be reflected on the size and type of pollution generation. Therefore, monitoring HM contamination is essential as a precautionary tool for enhancing the sustainable environmental conditions.

**Table 7.** Index of Pollution (IP) values for the heavy metals within the surface soil samples.

	pH	EC	Fe	Cu	Cr	Co	Mn	Zn	Ni	Pb
1R	0.99	0.50	0.92	1.06	1.07	0.88	0.53	0.65	0.95	0.58
1	0.99	0.61	0.89	0.95	0.58	0.39	0.21	0.79	0.56	0.90
1L	0.98	0.43	1.20	1.33	1.46	1.87	1.26	0.40	1.70	0.48
2R	1.00	0.52	1.08	1.21	1.43	1.26	0.66	0.28	1.23	0.58
2	0.98	0.89	1.11	1.21	1.46	1.27	0.64	0.20	1.22	0.55
2L	0.98	0.45	1.26	1.22	1.54	1.56	0.95	0.48	1.38	0.58
3R	0.99	0.77	0.96	0.92	1.25	1.20	0.76	0.29	1.13	0.69
3	0.98	1.08	1.31	2.34	1.56	1.80	1.31	1.12	1.62	1.01
3L	0.99	0.75	1.23	1.15	1.63	1.36	0.85	0.36	1.29	0.66
4R	0.96	0.62	1.21	1.13	1.49	1.55	0.84	0.43	1.45	0.35
4	0.98	0.72	1.06	1.07	1.23	1.47	0.92	0.69	1.30	0.44
4L	0.96	0.66	1.11	1.23	1.23	1.71	1.14	0.25	1.42	0.38
5R	0.96	0.77	1.03	1.07	1.08	1.17	0.83	0.32	1.15	0.44
5	0.99	0.95	0.80	1.01	0.69	0.89	0.67	0.24	0.79	0.52
5L	0.98	0.80	0.97	0.86	0.71	1.05	0.85	0.26	1.05	0.45
6R	0.98	0.62	0.87	1.00	0.45	1.03	0.95	0.71	1.05	0.45
6	0.99	0.95	0.64	0.72	0.26	0.81	0.77	0.10	0.76	0.22
6L	0.98	0.59	0.76	1.01	0.43	1.12	0.49	0.28	1.13	0.36
7R	1.00	0.48	0.73	0.64	0.68	0.76	0.49	0.46	0.80	0.38
7	1.00	0.58	0.52	0.71	0.44	0.51	0.35	0.65	0.62	0.49
7L	0.98	0.85	0.87	1.39	1.78	0.77	0.51	0.58	1.27	0.37
8R	0.99	0.77	1.12	0.93	1.28	1.28	0.90	0.31	1.28	0.34
8	0.99	0.52	1.08	0.88	1.10	1.36	0.87	0.15	1.27	0.31
8L	0.98	0.47	1.11	0.83	1.24	1.03	0.80	0.44	1.12	0.38
9R	0.99	0.61	1.09	0.77	1.11	1.12	0.94	0.42	1.12	0.34
9	0.99	0.68	0.81	0.68	0.85	0.83	0.75	0.36	0.92	0.45
9L	0.95	0.48	1.22	0.96	1.97	1.33	0.70	0.48	1.33	0.23
10R	0.97	0.47	0.82	0.72	0.72	0.82	0.59	0.21	0.91	0.29
10	0.98	0.57	0.63	0.59	0.65	0.58	0.35	0.44	0.76	0.48
10L	0.98	0.31	1.16	0.87	1.11	1.33	0.78	0.26	1.29	0.19

#### 4. Conclusions

This study has used the urban soil cover as a tool in determining heavy-metal contamination in relation to various anthropogenic occupational activities. The studied area bears low additional inputs of heavy metals as it has no massive industrial firms or high-density transportation infrastructures. Few sites have an index of pollution of  $IP > 1$  in areas with traffic activities and, therefore, traffic seems to be the only source of pollution by heavy metals in the study area. The prevailing climatic conditions in terms of high evaporation, low rainfall, and the lower pedogenesis process are reflected in higher EC and pH values at the upper soils. Moreover, this study shows different patterns of distribution of heavy metals between the upper and the lower soils, which might be attributed to the soil mineralogy, high alkalinity, and low rainfall. In conclusion, the heavy-metal pollution in the study area is not as severe as it is in many other cities in Jordan or elsewhere in the world. However, precautionary environmental requirements, as quick as possible, are

needed due to the rapid growth rate in the area especially that the results of this study do confirm the rapid effects of the human-related activities in changing the chemistry of the environment of the study area.

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