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Heavy Metal Contamination of Soil, Plant and Air of Scrapyard of Discarded Vehicles at Zarqa City, Jordan

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Ninety soil samples, forty plant samples (Anabasis articulata), and twenty air samples were collected from the scrap yard of discarded vehicles near Zarqa city, Jordan. These samples were analyzed for heavy metals: Cd, Pb, Zn, Cu, Mn, Al, and Fe. Longitudinal and vertical profiles of soil samples were studied. Generally, the levels of all heavy metals studied in the scrap yard area were found to be higher than those of the control samples. The levels of heavy metals decreased with depth until reaching a constant value at 9 cm depth. The levels of heavy metals also decreased at distances farther away from the scrap yard area. A significant difference in heavy metal concentrations was found between washed and unwashed plant samples. On the other hand, no significant differences have been found between plant samples from inside and outside the scrap yard area. Air samples showed wide variations in heavy metal levels among the sampling sites. The enrichment factors for non-crustal elements such as Pb, Cd, Cu, and Zn, in both soil and particulate matter, were found to be more than 10, indicating anthropogenic sources such as dust, rust, and exhaust emissions from the scrap yard area, whereas the crustal elements such as Fe and Mn showed enrichment factors of less than 10.

Keywords Heavy metals, discarded vehicles, scrap yard, soil.

1. Introduction

Mineral rock weathering and anthropogenic sources provide two of the main types of metal input to soil-plant system. Higher quantities of certain metals are being released into the environment by anthropogenic activities, primarily associated with industrial process, manufacturing, and the disposal of industrial and domestic waste materials (Ross, 1996). On the other hand, burning coal and oil, incineration, exhausts, mining and smelting of metals are considered as main sources of air contamination.

Many studies had been conducted to investigate the heavy metal contamination of soil. In general, it was observed that there was a significant increase in the total content of the heavy metals in soil closer to the source, which clearly decreases with increasing distance (Abul Kashem *et al.*, 1999; Shallari *et al.*, 1998; Feng *et al.*, 2000; Collett *et al.*, 1998; Meneses *et al.*, 1999). Many trace metals are present in leaded and unleaded petrol, diesel oil, anti-wear substances added to lubricants, brake pads, and tires, and emitted by vehicle

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exhaust pipes. Lead is added to gasoline to prevent engine knock, so that the cars become a major source of lead to the environment (Monacci and Bargagli, 1997). Metals such as Fe, Cu, and Zn are essential components of many alloys, pipes, wires and tires in motor vehicles and are released into the roadside environment as a result of mechanical abrasion. Many studies investigated the heavy metal concentration profiles in the soil. The results showed that very high concentrations in the top few centimeters of the soil and then the heavy metal concentration decrease with depth and reach the background levels between 30 and 100 cm.

Environmental impact assessment studies carried out on the end-of-life vehicle stores reveal that Pb, Cd, Zn, and Cu are the major inorganic contaminants, and engine oil and break fluids are the major organic contaminants. IHOBE, 1994, and Martín *et al.*, 1998, observed that there is a significant increase in the total contents of Pb, Cd, Cr, Cu, Ni, and Zn as well as Fe and Mn oxides in the soils closer to the scrapyard of discarded vehicles.

The aim of this work is to assess the heavy metal contamination in Zarqa Scrapyard of discarded vehicles. The heavy metal content in soil, plant and air, inside the scrapyard area, and the heavy metal levels, as a function of a distance from scrapyard, were evaluated.

2. Experimental

2.1. Sampling Sites

The field sampling points in the studied area are shown in Figure 1. This area is called Zarqa Scrapyard of discarded vehicles. It is located near the highway between Amman, the capital of Jordan, and Zarqa city. For more than 30 years, the end-life-vehicles had been discarded in this site without any regulations. Over the years, this area has been expanded and distributed to cover about 15 km square.

Samples were collected from inside and outside of the scrapyard. The outside samples include a control area (presumably free of anthropogenic contamination), and an area outside the scrap yard up to different distances, depending upon the sample type (air, plant, soil). Samples were collected during the summer of 2002 to avoid rain from washing the heavy metals out of the sampled materials. Figure 1 illustrates the sampling sites of each type of sample where S: represents scrap yard soil samples, P: represents plant samples (*Anabasis articulata*), A: represents air samples.

2.2. Sample Collection

2.2.1. Soil Samples. A total of 90 soil samples were collected from inside and outside the scrapyard soils from 18 sites, each sample representing a composite of three sub-samples from each sampling site. Samples were taken at various depths of 0–3, 3–6, 6–9, 9–12, and 12–15 cm from the soil surface using a stainless steel auger. To study the effect of the distance from the end-life vehicles on contamination of the soil, some samples were collected by longitudinal transect at irregular intervals (5, 10, 20, 50) m from the scrap yard. In addition to these samples, control soils at about 1000 m from the scrapyard were sampled. The collected soil samples were sieved through 1 mm stainless steel sieve and stored refrigerated in prewashed plastic bags for subsequent sample preparation and analysis.

2.2.2. Plant Samples. Forty plant samples (roots and shoots) were collected from twenty sites including sites of soil samples with some differences in the longitudinal transect

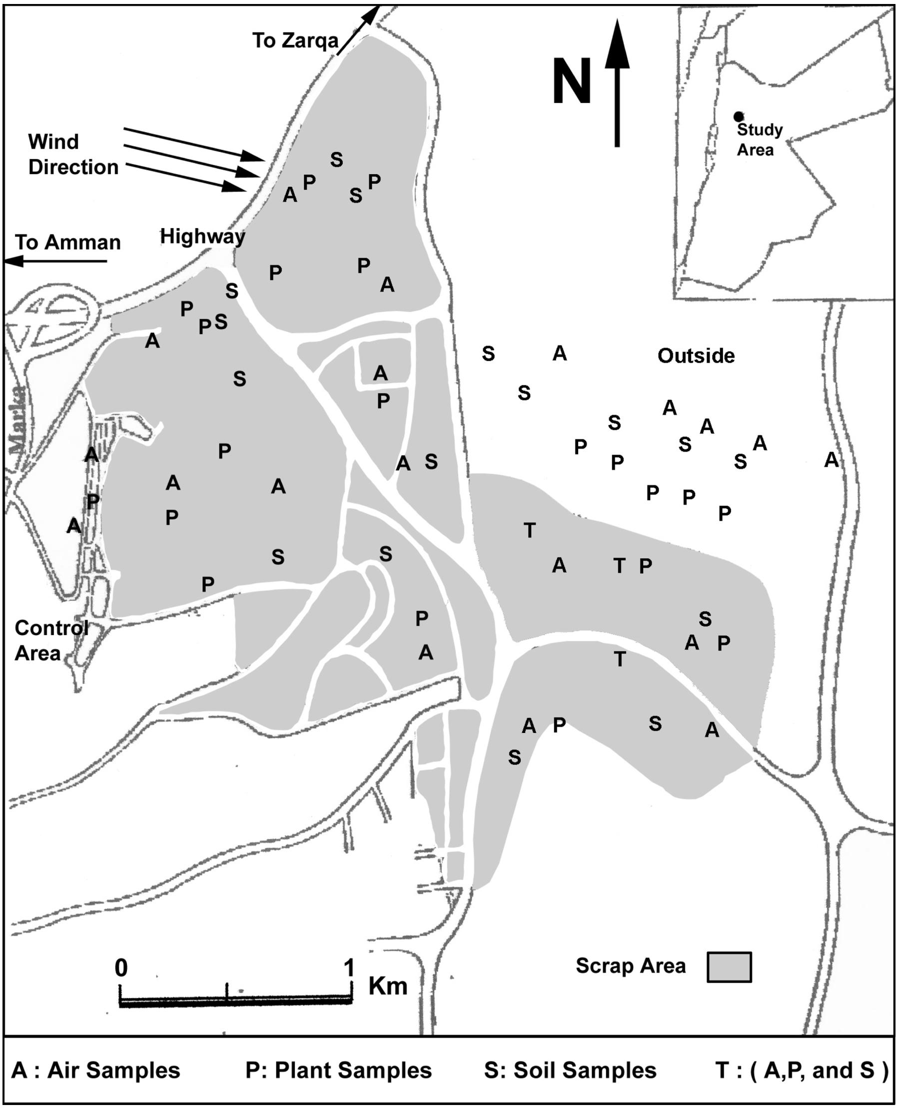

Figure 1. Location map of sampling sites of the discarded vehicles scrap yard at Zarqa City.

intervals. To study the effect of the distance from the end-life vehicles on the contamination of the plant, some samples were collected by longitudinal transect at irregular intervals (50, 100, 200, 500, 1000) m from the scrap yard. The collected plant samples were stored in pre-washed plastic bags and stored in refrigerator for subsequent analysis.

2.2.3. Air Samples. A total of 20 air samples were collected inside and outside of the scrapyard. A high volume air sampler (GL 2000 H From Graseby, Ohio, USA) was operated for one to two hours for each sample, and an average of 42 $m^3$of air were passed through each glass-fiber filter (20.3–30.5 cm, and 0.45 μm). These filters were used because of their high collection efficiency for all particle sizes (Lodge, 1991), and their low hygroscopicity, which allows the determination of total suspended particulate (TSP) (Appel, 1993). Before and after sampling, the filters were carefully handled in a humidity- and temperature-controlled atmosphere, being weighed and packed into pre-washed plastic bags. Total suspended particulate matter was calculated gravimetrically, and then the collected samples were stored in a refrigerator.

Thirteen air samples were collected from the scrapyard area. Five samples were collected by longitudinal transect at irregular intervals (100, 500, 1000 and 2000) m from the scrap yard. Two control samples were collected 2 km before scrapyard, according to the annual wind direction.

2.3. Sample Pretreatment and Extraction Procedure

2.3.1. Soil. One gram of soil sample was accurately weighed, then it was heated in an oven at 105°C for 12 hours to reach constant weight in order to determine the moisture content. The weight loss was calculated based on the difference between the final and the initial weights. The same samples were burned in a furnace at 550°C for 4 hrs to determine the organic matter content, which then was calculated gravimetrically based on the weight difference (Preer *et al.*, 1980).

The soil pH values were determined in deionized water (soil-to-water volume ratio of (1:2.5) that was equilibrated overnight (Abul Kashem and Singh, 1999; Esser, 1996). Metrohom Ltd. Ch-9101 Hrisau, Switzerland, was used for pH measurement. Electrical conductivity was measured in saturation extract of soils using an EC meter (JENWAY 4010 Conductivity Meter).

Extraction of heavy metals from soil samples was carried out by accurately weighing about 1.0 g of the dry sample, which was digested in 10 ml concentrated HNO_3 (high purity) and $HClO_4$ (in a 4:1 ratio), and taken to dryness on heating block at 96°C. The residue was then leached with 5 ml HCl and diluted with deionized water in 50 ml polyethylene volumetric flask up to the mark (Li and Thornton, 2001).

2.3.2. Plant Samples. For all samples, each shoot sample was divided into two parts. One part of these samples, along with the root sample, was washed 3 times with tap water, followed by distilled water and then deionized water to remove any particulates dust. The other shoot samples were analyzed without any washing. The washed and unwashed samples were dried in an oven at 65°C for 24 hrs. After drying, the samples were crushed and homogenized using mortar and pestle.

Extraction of heavy metal was achieved by ashing an accurately weighed 1.0 g of the dry, crushed sample in a furnace at 550°C for 4 hrs. The ash was then digested with 5 ml HNO_3 and heated in a test tube for 2 hrs, then sonicated for 30 minutes in an ultrasonic bath at 50°C. The samples were then filtered, washed, and diluted with 1% HNO_3 to 25 ml in polyethylene volumetric flask (Sanka *et al.*, 1995). A blank solution was then prepared in the same way as employed for the plant samples.

2.3.3. Air Samples. The filters were subjected to acid extraction. The filter was cut into strips and was placed in a Teflon beaker. An acid digestion of the sample with 15 ml of concentrated nitric acid was carried out for about 8 hr employing low heat until the nitric acid was almost completely evaporated. Subsequently, the residue was dissolved in boiling DIW, filtered through Whatman -41 filter paper, and then made up to 25 ml with DIW (Morales *et al.*, 1996). Blank filters were analyzed as indicated and the concentration was subtracted from the values obtained for the atmospheric samples.

2.3.4. Quality Control. An analysis of reference material by a tested analytical method was carried out and results obtained were compared with the certified values. In this study, duplicate trials of standard reference material: soil 7 and tomato leaves 1573 (from IAEA, Vienna, Austria) were subjected to the extraction procedure applied for soil and plants, respectively. The percent recovery for the soil sample for Cd, Pb, Cu, Zn, Mn and Fe were 96, 95, 95.3, 94, 97 and 94, respectively. The percent recovery of tomato leaves for Cd, Cu, Zn, Mn and Fe were 96, 103, 93, 98, and 104, respectively. Analysis of duplicate samples was performed. Replication improves the quality of the results and provides a measure of their reliability. Blank and standard solutions were used to calibrate the instruments. The r^2 values were 0.9995, 0.9996, 0.9997, 0.9992, 0.9999, and 0.9991 for Mn, Cd, Cu, Fe, Pb, and Zn, respectively. Linear regression and relative standard deviations were employed when measuring the concentration of heavy metals in soil, plant, and air samples. Also periodically standard mixtures were analyzed to verify the reliability of the measuring instruments.

2.4. Chemical Instrumentation

All glassware used in the extraction procedures were initially cleaned with soap, rinsed thoroughly with tap water and distilled water, and then soaked in 1% HNO_3 (v/v) overnight. To remove any contamination by heavy metals, the glassware were washed thoroughly with distilled and DIW.

Heavy metals (Cd, Pb, Zn, Cu, Mn, Al, and Fe) were determined using an atomic absorption spectrophotometer (Perkin Elmer AAS Analyst 300) with a graphite furnace (HGA 800) and auto sampler.

One thousand ppm of Pb, Cd, Zn, Cu, Mn, Fe, and Al calibration standards were purchased from Merck.

3. Results and Discussion

Cd, Pb, Zn, Mn, Cu, and Fe and the reference element Al were analyzed in soil, plants, and air samples that were collected from the discarded-vehicles scrapyard at Zarqa city and the surrounding areas.

The Minitab package and Excel sheet were used to analyze the results statistically. The mean, standard deviation and 95% confidence interval were calculated for the data. The sample population was analyzed using a T-test. A significant difference between pairs of means was tested at a probability of 0.05. Analysis of variance (ANOVA) was also used to analyze the results. For all results, there were good agreements between T-tests and ANOVAs.

3.1. Soil Samples

Table 1 presents the soil characteristics including moisture content, organic matter, soil pH, and conductivity as a function of sample depths. The results show that the pH for samples inside and outside scrapyard is slightly basic, $pH > 7$. These results are comparable to those reported for a similar area by Martin *et al.*, 1998, where the pH ranged from 7.72 to 8.09.

The measured conductivities of the water-extracted soils indicate the relative water-soluble salt content of the soil (Sheppard *et al.*, 2000). The mean conductivity of the water extracts in the scrapyard samples ranged from 645 μs/cm at a depth of 12–15 cm to 814 μs/cm at a 6–9 cm depth in the scrapyard samples and no significant difference was found between samples inside and outside of the scrapyard. These values are higher than

Table 1
Properties of soil (inside & outside)

	Inside (n = 12)				Outside (n = 6)			
Depth	pH	EC*	Moisture (%)	Organic (%)	pH	EC	Moisture (%)	Organic (%)
(0–3) cm	7.73	795	2.48	6.19	8.03	603	2.11	5.45
(3–6) cm	7.71	782	2.74	5.91	7.82	636	3.13	5.98
(6–9) cm	7.72	814	4.07	6.12	7.69	826	2.87	7.8
(9–12) cm	7.63	659	5.24	5.9	7.67	616	5.08	6.28
(12–15) cm	7.73	645	6.05	5.73	7.92	580	4.86	5.44

*EC: Electrical conductivity.

those found by Martin *et al.*, 1998 (170–270 μs/cm), which may indicate higher content of soluble salts. For most of the samples studied, the topsoil had the highest conductivity.

The moisture content of the soils increased with depth, as expected, and ranged from 2.48% for 0–3 cm samples to 6.05% for the 12–15 cm samples.

The average organic matter content of samples inside the scrapyard ranged from 5.73% for the 12–15 cm samples to 6.19% for the 0–3 cm samples and from 5.44% for the 12–15 cm samples to 7.8% for the 6–9 cm samples in the outside area. These values are not significantly different from those of the control samples.

The mean and standard deviation of spatial distribution of heavy metal content in soil samples at different depths (0–3, 3–6, 6–9, 9–12 and 12–15 cm) are summarized in Table 2. Elevated levels of the studied elements were found in soil samples inside the scrapyard compared to the control soil samples. These results suggest that discarded vehicles may be considered as a major source for these elements to the soil. A progressive decrease in concentration of heavy metals through the longitudinal transect from the scrapyard area (outside area samples) is observed. The gradual decrease with distance can be attributed to the emission of heavy metals from the scrapyard, which were largely caused by the escape of fly ash from tire incinerators that is released to the atmosphere. The fly ash is dispersed and transported by wind and eventually is deposited either by settling through the atmosphere as dry deposition or by dissolving into or being washed down by rain drops as wet deposition.

Figure 2, which shows the heavy metal concentration profiles in the soil, and Table 2 show that the heavy metal content of soil decreases with increasing sample depth, reaching almost constant values at a depth of 9 cm. As a result, sampling deeper than 15 cm was considered unnecessary.

Figure 3 shows that the levels of heavy metals in soil decrease with increasing distance from the scrapyard area. Most of the heavy metal levels show sharp decrease in concentration within the first 20 meters from the scrapyard area and then a gradual decrease is observed.

Elevated levels of heavy metals in the scrapyard area could be attributed to stores of scrap iron and the activities related to them. Zinc is largely used in galvanizing iron and steel products, which provides corrosion resistance; such products are used in automobile door panels. Zinc diecast products (zinc-base alloys), the second largest consumer, are used in trim pieces, grills, door and window handles, carburetors, pumps, door locks and other mechanical components in automobiles; zinc oxide is also required for paints. Lead is mainly used in acid storage batteries to increase the average battery life and performance. Cadmium is mainly found in the end products, including parts and finishes in automobile

Table 2
Spatial distribution of heavy metals (μg/g)

	Fe	Mn	Pb	Cu	Zn	Cd
			Depth (0–3) cm			
Control soil	6129 ± 211	101 ± 7	79 ± 72	25 ± 14	83 ± 26	0.66 ± .19
Scrap yard	12277 ± 2624	188 ± 44	308 ± 135	131 ± 73	426 ± 157	2.15 ± .85
Outside	8735 ± 2262	146 ± 40	156 ± 90	37 ± 17	241 ± 112	1.07 ± .21
			Depth (3–6) cm			
Control soil	5318 ± 973	85 ± 28	44 ± 39	19 ± 6	66 ± 9	0.52 ± .09
Scrap yard	10311 ± 2540	139 ± 31	114 ± 48	84 ± 49	243 ± 87	1.18 ± .44
Outside	6593 ± 2040	85 ± 23	55 ± 41	25 ± 10	101 ± 49	0.57 ± .15
			Depth (6–9) cm			
Control soil	5783 ± 137	82 ± 29	19 ± 3	14 ± 1	89 ± 45	0.44 ± .01
Scrap yard	6886 ± 885	102 ± 26	51 ± 22	48 ± 24	120 ± 25	0.75 ± .23
Outside	6547 ± 758	62 ± 3	35 ± 22	19 ± 5	84 ± 23	0.50 ± .05
			Depth (9–12) cm			
Control soil	4795 ± 668	70 ± 8	14 ± 2	12 ± 1	59 ± 3	0.45 ± .03
Scrap yard	4672 ± 1505	71 ± 20	24 ± 6	16 ± 5	80 ± 14	0.48 ± .18
Outside	5127 ± 377	53 ± 10	24 ± 6	14 ± 2	64 ± 5	0.35 ± .03
			Depth (12–15) cm			
Control soil	4864 ± 161	50 ± 26	16 ± 6	17 ± 6	56 ± 6	0.37 ± .02
Scrap yard	4831 ± 1284	65 ± 13	23 ± 5	17 ± 6	61 ± 6	0.56 ± .13
Outside	5012 ± 333	48 ± 12	18 ± 2	14 ± 1	69 ± 11	0.45 ± .05

and automobile paints. Cadmium is employed extensively in batteries, automobile radiator fine stock, switch, and automobile distributor contacts. Copper is mainly found in buss bars, magnet wire and windings in motors, generators, and transformers (Brady, 1982). Finally, iron is the main material of construction of all vehicles.

In the top soil (0–3 cm) of samples inside the scrapyard, a significant correlation was found between Pb and Cu ($r = 0.69$), Pb and Zn ($r = 0.74$), and Cu and Zn ($r = 0.83$), which means there may have been a single source of each pair of these metals. There are no significant correlations between the other metals, which could indicate independent sources. On the other hand, the top soil of the samples outside the scrapyard shows a significant correlation between Fe and Mn ($r = 0.81$), Pb ($r = 0.87$), Cu (0.98), and Zn (0.97), Mn is correlated with Pb ($r = 0.93$), Cu ($r = 0.86$) and Zn ($r = 0.92$), Pb is correlated with Cu ($r = 0.96$) and Zn ($r = 0.95$), Cu is correlated with Zn ($r = 0.99$). This significant correlation means probably that the common sources for these metals was in the outside area topsoil samples.

Comparisons between the means of the heavy metal concentrations in the topsoil of the scrapyard samples, and the control soil samples, and the outside area samples are shown in Table 3. The scrapyard soil sample means are significantly higher ($P < 0.05$) than those for the control soil sample. The means of Cd, Zn, Cu, and Fe concentrations in the scrapyard soil samples were significantly higher ($P < 0.05$) than those for the outside area samples. For Mn and Pb, there was no significant difference ($P > 0.05$).

When comparing the means for the heavy metals in the scrapyard soil samples for the topsoil (0–3) with other depths it was shown that for all the studied elements, except Cu

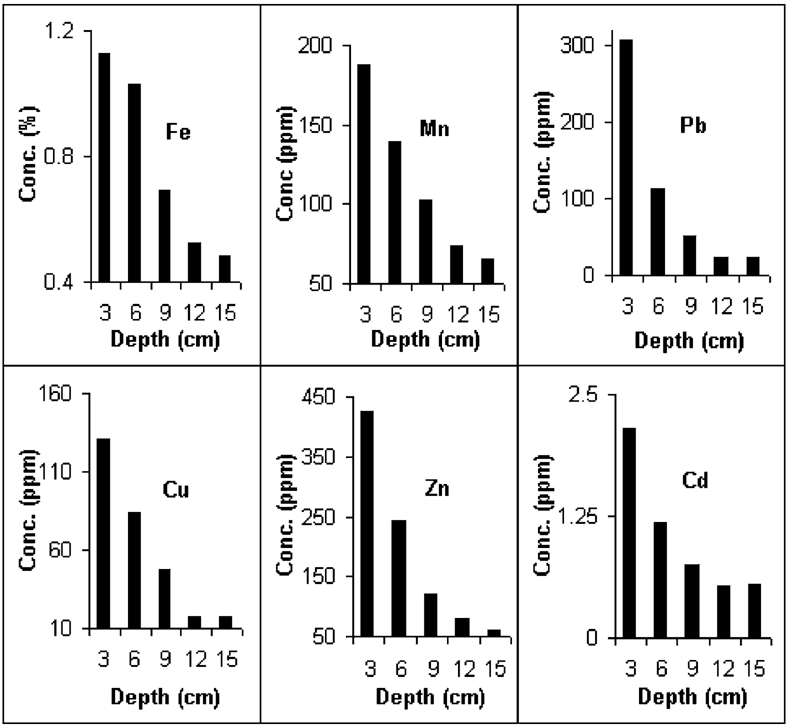

Figure 2. Heavy metal concentration profiles in soil.

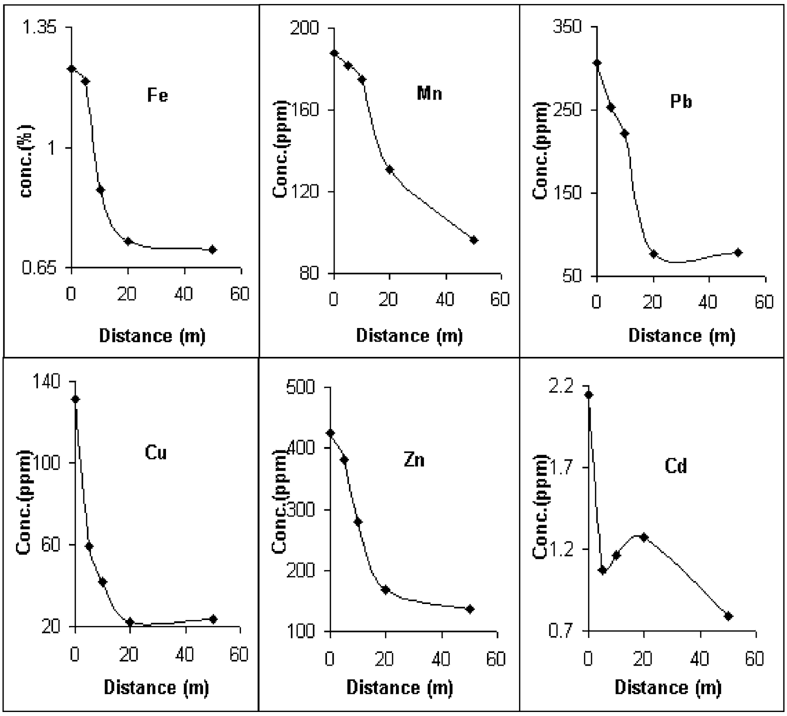

Figure 3. Concentrations of heavy metals in the topsoil outside area within longitudinal transect from scrapyard.

Table 3

Comparison between the heavy metal concentration in the topsoil (0–3) in scrapyard and surrounding areas

Metal	Inside ($n = 12$) Mean ± S.D (μg/g)	Control Soil ($n = 4$) Mean ± S.D (μg/g)	
	a. Inside and control soil samples		
Fe	12277 ± 2624	6129 ± 211	P
Mn	188 ± 44	101 ± 8	P
Pb	307 ± 134	79 ± 72	P
Cu	131 ± 73	25 ± 14	P
Zn	426 ± 157	83 ± 26	P
Cd	2.15 ± 0.85	0.66 ± 0.19	P
Metal	Inside ($n = 12$) Mean ± S.D (μg/g)	Outside Area ($n = 4$)	
	b. Inside and outside area samples		
Fe	12278 ± 2625	8736 ± 2262	P
Mn	188 ± 44	146 ± 40	N.S
Pb	307 ± 134	156 ± 90	N.S
Cu	131 ± 73	37 ± 17	P
Zn	425.7 ± 157	241 ± 112	P
Cd	2.15 ± 0.85	1.07 ± 0.21	P

N.S: No significant difference ($P > 0.05$).
P: Significant difference ($P < 0.05$).

and Fe, there is a significant difference ($P < 0.05$) between the topsoil (0–3 cm) and the next depth (3–6 cm). By continuing the comparison between the mean of heavy metals concentrations in the followed layers, such as (3–6) with (6–9), (9–12) and (12–15), etc. the result shows significant differences ($P > 0.05$) between heavy metals in various depths except between 9–12 and 12–15 cm depths, where no significant difference is observed between all heavy metals studied in these two last layers. These results mean that the background values were reached at about 9 cm depth. In other studies (Hindy *et al.*, 1983) 30–100 cm is considered as the depth at which the background values were reached. This depends on the average rainfall, soil pH, organic matter and moisture content, and other characteristics related to the soil. The studied area is considered an arid area, with a rainfall average not exceeding 150 mm/year.

Enrichment factors (EF) for heavy metals in soil were calculated according to the formula developed by Ogunsola *et al.*. (1994).

$$EF = [C_X/C_N]_{soil}/[C_X/C_N]_{crust} \tag{1}$$

$[C_X]_{soil}$ = concentration of the element in soil sample.
$[C_N]_{soil}$ = concentration of the normalizing element Al in soil sample.
$[C_X]_{crust}$ = concentration of the element in the earth crust (Abollino *et al.*, 2002).
$[C_N]_{crust}$ = concentration of the normalizing element Al in the earth crust (Abollino *et al.*, 2002).

Table 4

Average enrichment coefficient for heavy metals in topsoil samples

Sample	Fe	Mn	Pb	Cu	Zn	Cd
Control area	2.1	1.7	77.9	5.8	10.4	72.6
Inside	4.2	3.1	291.7	31.6	48.6	257.5
Outside	2.7	2.3	146.8	8.1	27.8	113.6

Enrichment factors for the heavy metals in all soil samples are higher than unity. The means of the enrichment factors in this study are shown in Table 4. These means are higher than those obtained in another study for the Jordanian Petroleum Refinery soil, which were reported as 101.6, 27.9, 24.8, 8.4, and 1.3 for Cd, Pb, Zn, Cu, and Fe, respectively (Momani *et al*., 2002). Table 4 shows that the highest enrichment factors were observed in scrapyard samples. This may be explained by the fact that this site is containing the main sources of these metals (scrap iron, motor vehicles, tires, etc). Elements with enrichment factors greater than 10 is assumed to be due to other sources rather than background contribution (Parekh *et al.*, 1989). The element of crustal origin such as Fe and Mn are not enriched to higher than 10 indicating that they are originated from soil. Other elements show high enrichment factors indicating the presence of additional sources such as anthropogenic sources and the discarded vehicles themselves.

3.2. *Plant Samples*

Washed, unwashed shoots and washed roots samples were analyzed for Cd, Pb, Zn, Cu, Mn, and Fe. The mean concentrations of these metals in plant samples are summarized in Table 5.

Significant differences in the levels of heavy metals between washed and unwashed shoots were observed. For the scrapyard samples, a comparison between the mean of the heavy metals in washed and unwashed shoots, and in washed shoots and roots, shows that the mean concentrations of Cd, Pb, Zn, Cu, and Fe in unwashed shoots were significantly higher ($P < 0.05$) than those in washed shoots; for Mn, the results indicate no significant difference. For unwashed samples, the total concentrations of heavy metals represent the heavy metals taken up by the plant from soil in addition to the amount deposited on the plant surface by atmospheric dust fall. It is also shown that the mean concentrations of Pb, Mn, Cu, and Fe in washed roots are significantly higher ($P < 0.05$) than those in the washed shoots. This means that shoots took up less Pb, Mn, Cu, and Fe than roots. The results further show that there are different accumulations in the roots between elements and between plant parts (shoots and roots). For example, Fe and Cu are accumulated in roots more than Pb, Zn and Mn. On the other hand, the results show that Cd has high uptake by shoots.

The concentrations of Pb in plants are low when compared with what had been obtained in other studies on the same plant (Jaradat and Momani, 1999). A comparison between the means of the heavy metal concentrations in the washed shoots in the scrapyard samples with the control area samples and with outside area samples show that there was no significant difference ($P > 0.05$) in the mean concentrations of Pb, Zn, Cu and Mn. However, for Fe the mean concentrations in the scrapyard samples are significantly higher ($P < 0.05$) than those in control area samples.

Table 5

Heavy metals concentrations (μg/g) in washed, unwashed shoots and washed roots

Element	Fe	Mn	Pb	Cu	Zn	Cd
			Control area samples			
Unwashed	109 ± 18	48 ± 4	1.23 ± .52	7.23 ± 1.87	61.55 ± 34.89	0.681 ± .057
Washed	34 ± 1	47 ± 7	0.78 ± .07	5.64 ± 1.91	48.89 ± 25.69	0.698 ± .061
Roots	331 ± 93	151 ± 14	1.99 ± .19	21.81 ± 6.31	48.79 ± 22.72	0.421 ± .175
			Inside area samples			
Unwashed	236 ± 102.43	81 ± 54	2.37 ± 1.72	17.22 ± 13.37	58.35 ± 26.56	0.612 ± .113
Washed	58 ± 17	54 ± 36	0.82 ± .29	7.06 ± 1.36	36.68 ± 16.89	0.43 ± .117
Roots	864 ± 251	115 ± 55	2.01 ± 1.42	187.69 ± 86.75	51.77 ± 16.48	0.4 ± .157
			Outside area samples			
Unwashed	214 ± 115	85 ± 30	1.86 ± .49	18.54 ± 12.23	28.8 ± 7.73	0.484 ± .158
Washed	54 ± 23	63 ± 24	0.6 ± .07	4.88 ± 1.1	22.32 ± 8.39	0.412 ± .16
Roots	609 ± 147	99 ± 25	1.12 ± .49	96.15 ± 56.45	52.11 ± 15.21	0.33 ± .167

Table 6
Comparison of the heavy metal concentrations in air samples (ng/m^3)

Metal	Scrapyard samples n = 13	Outside area samples n = 5	
	Mean ± S.D (ng/m^3)	Mean ± S.D (ng/m3)	
Cd	3.83 ± 1.89	6.30 ± 4.70	N.S
Pb	81.9 ± 73.8	379.8 ± 292.0	P
Zn	171.5 ± 120.5	41 ± 11.5	P
Cu	152 ± 68.0	112 ± 53.0	N.S
Mn	38.1 ± 10.6	49.3 ± 62.6	N.S
Fe	2353.5 ± 791.4	3770 ± 2877.0	N.S

P: Significant difference ($P < 0.05$).
N.S: No significant difference ($P > 0.05$).

3.3. Air Samples

The concentration of total Suspended Particulate (TSP) along with the six heavy metals Cd, Pb, Zn, Cu, Mn, and Fe in the scrapyard and the surrounding area are given in Table 6. All these concentrations except Cd were determined in the air filter by flame AA. Cadmium was undetected by this technique so a Graphite Furnace AA was employed. Total Suspended Particulate measurements show high levels (394–1614 μg/m^3) in all sites when compared with those found in Amman (66 to 326 μg/m^3) (Jaradat *et al.*, 1997). The elevated levels of TSP concentrations could be attributed to turbulent eddies or vortices and the tire incineration in morning and afternoon hours. The scrapyard atmosphere is relatively contaminated when compared with the background values (control area) as Table 6 shows. These values are lower (or comparable in the case of Zn) than those found in Amman area, where the concentrations found were 0.31, 0.61, and 0.17 μg/m^3 for Cu, Pb, and Zn, respectively (Jaradat and Momani, 1999). The scrapyard air samples collected at different sites have considerable variation among the samples sites in both heavy metals and TSP.

Statistical analysis results show that there are no significant difference ($P > 0.05$) between the mean of the heavy metals (Cd, Cu, Mn, and Fe) concentration in the scrapyard samples and the outside area samples. Whereas, the mean concentrations of Pb in the outside area air samples (379.8 ng/m^3) is significantly higher than what was found in scrapyard air samples (81.9 ng/m^3).

Table 7 illustrates the enrichment factors for the heavy metals in all air samples. The results show that most elements in most samples have high enrichment factors (>10).

Table 7
Enrichment factors of heavy metals in air particulates

Site	Fe	Zn	Pb	Mn	Cu	Cd
Control area	5	79	497	7	243	1590
Inside area	6	176	462	5	310	2521
Outside area	25	149	481	20	466	1228

This is due to the fact that the heavy metals are usually associated with the anthropogenic factors as air particulates rather than soil. The crustal-origin metal such as Fe and Mn show enrichment factors below 10, where the other heavy metals show enrichment factors above 10 indicating anthropogenic activities such as scrapyard activities, automobile exhaust, and tire incinerations, etc.

4. Conclusions

From the results obtained, the following could be concluded:

1. The heavy metal concentrations observed in the scrapyard soil are considerably elevated above those found in control area samples and outside area samples.
2. The results of the present investigation suggest that the activities carried out in the vehicles scrapyard, tire incinerators, and vehicle exhausts are mainly responsible for heavy metal contamination of the soil in the vicinity of the scrapyard.
3. Heavy metals concentrations profiles in the scrapyard soil show very high concentrations in the topsoil (0–3) cm. However, the concentrations of Cd, Pb, Zn, Cu, Mn, and Fe fall rapidly with increasing soil depth. As a result, sampling beyond 15 cm depth was considered unnecessary, because background concentrations had been reached.

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