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The Distribution of Heavy Metals in Urban Street Dusts of Karak City, Jordan

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Street dust samples from urban and suburban areas were collected from the city of Karak, Jordan, during the summer season of 2004. Samples were analyzed for their heavy metal concentrations (Pb, Cu, Zn, Ni, Fe, Cr, Cd, and Mn). The results showed that all heavy metals are higher in city urban areas than the surrounding suburbs. The distribution and concentrations of heavy metals in all areas show automobile originated sources such as emissions and wear and tear of automobiles were the main source of pollution. Despite the fact that the city of Karak and the capital Amman are under the same climatic conditions and same type of fuel used in both cities, the heavy metal concentrations of street dust samples were lower in Karak than Amman due to the lower traffic density.

Keywords Heavy metals, street dust, traffic density

Introduction

Heavy metals are natural constituents in nature, usually occurring in low concentration under normal conditions. Anthropogenic activities can cause elevated levels of these metals in various parts of the ecosystem. Environmental pollution by heavy metals may occur via various diffuse and point sources. Heavy-metal scattering by traffic is an example of diffuse spread, while the emission of heavy metals by industrial establishments like metal smelters and iron works represents point sources. Traffic activities on roads can contribute to elevated levels of heavy metals in these environments through fossil fuel combustion, wear and tear of many parts of the automobile, in addition to natural sources, as they might exist in the rocks of the surrounding areas.

Heavy metals have been widely used in other research projects and therefore comparative data are readily available. Many studies have examined the contribution of individual components of the urban hydrological cycle to the transport and storage of heavy metals (Lees, 1994; Xanthopolous and Hahn, 1993; Morrison *et al.*, 1988; Gibson and Farmer, 1984; Hamilton *et al.*, 1984). Jiries *et al.* (2003a) investigated a class of organic pollutants (Polycyclic Aromatic Hydrocarbons, PAH) in addition to some heavy metals that were related to

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traffic in both rainwater and sediments from different areas in Amman. They found that precipitation is responsible for removal of these pollutants from air, especially at the beginning of the rainy season. Many investigations were done on heavy metal content in dust samples from different environments in Jordan. Jiries *et al.* (2003a) found elevated levels of Pb and Cd in the city center of Amman, 1041.7 and 2.85 ppm respectively, which was attributed to the fossil fuel emissions at these sites. El- Hasan *et al.* (2002) investigated air pollution in Amman using tree bark as a bio-indicator. They found higher levels of heavy metals in the tree bark of the areas surrounding industrial estates and in the city center of Amman than in residential areas. Similar results were reported by Jiries (2003b) in street dust samples collected from different parts of Amman. Impact of traffic on soil along the sides of a major highway in Amman was studied by Jaradat *et al.* (1999). They found that the concentration of all analyzed heavy metals decreased while sampling a further distance away from the road.

As an indicator of environmental pollution, the following metals were chosen for analysis: cadmium (Cd), zinc (Zn), copper (Cu), nickel (Ni), iron (Fe), chromium (Cr), manganese (Mn), and lead (Pb). Wood (1974) indicated that these metals have known pollutant properties, are toxic and readily available to the environment. Such heavy metal elements are commonly found in the urban environment as they are used in both production and consumption-related processes (Brown *et al.*, 1999). The purpose of this paper is to assess the environmental impact of traffic by investigating the distribution of heavy metal concentrations in urban street dust of major roads in the city of Karak, Jordan.

Sampling, Digestion and Analytical Methodology

Study Area

Karak is located in the central part of Jordan. It was selected for this investigation since previous work in Amman, the capital city of Jordan, showed elevated levels of some heavy metals, and no previous research has been conducted on the quality of the street dust in this area.

Due to the fact that Jordan belongs to the Mediterranean climate, where rainfall occurs only in the winter seasons starting in November and ending in April, no removal of heavy metals occurred during the investigation period through surface runoff. The street sampling campaign was conducted at the end of the summer season in 2004. Road sediment samples were collected with a plastic scoop from three areas within Karak province: Site A representing downtown of high traffic (10000–12000 vehicle/day (El-Hasan and Lataifah, 2003)) and industrial density, Site B, which is a suburban area representing lower traffic (6000-8000 vehicle/day (El-Hasan and Lataifah, 2003)) and industrial activities, and Site C reflecting background (control) conditions since it is a remote location within Karak province having very low traffic density (100–200 vehicle/day). A total of 29 samples (12 (Site A) + 11 (Site B) + 6 Site C)) were collected for sampling location (Figure 1). In the present study, Amman City urban dust Jiries (2003c) will be used as a benchmark comparative study. The traffic density in a bigger city like Amman is 5–6 times the density found at Site A.

Extraction Efficiencies

All samples were oven dried at 80°C for three days to remove any water content. The samples were sieved through a 2 mm nylon sieve to remove large particles and other materials that were collected with the samples. Samples were ground using a porcelain mortar in order to homogenize the sample and to increase the surface area for contact with acids during digestion. Approximately 2 g of each sample were accurately weighed and digested for total heavy metals analysis using wet digestion method.

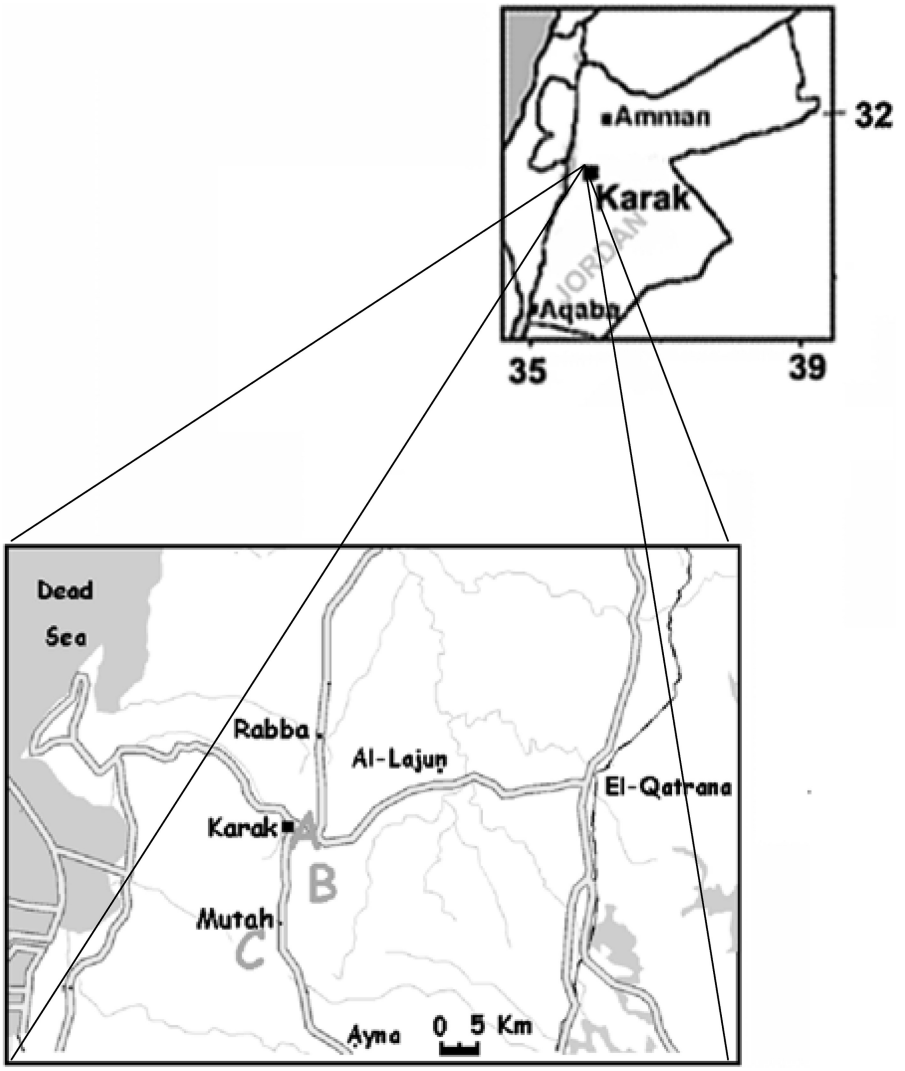

Figure 1. Location Map.

A pilot study was done prior to the analytical process to determine the best method for digesting the samples. Five replicates of four different samples of each of the above mentioned heavy metals were analyzed using three different digestion methods (A, B, and C), and the most consistent response was determined by statistical evaluation of the results.

In each of the digestion methods A and B, 2 g of the sediment were transferred into a test tube and 15 mL digestion fluid was added (Method A: concentrated HNO3, Method B: 1:1 HNO_3: $HClO_3$ Poikolainen (1997)). The test tubes were heated to 80°C for 2–3 hours using heating blocks. The tube content was dissolved with 10 mL of 10% HNO_3 and transferred through a simple filtration apparatus into 25 mL volumetric flasks. The filter paper was washed several times with 1% HNO_3 into the volumetric flask, and the flask was filled to the mark with 1% HNO_3, (Jiries, 2003b). In Method C, 2 g of sediment were transferred into an evaporating dish and ashed in a furnace at 700–800°C overnight. The ashed content was transferred into a 50 mL beaker and dissolved with 10 mL 1% HNO_3. The treated

sample was filtered through a simple filtration apparatus into a 25-mL volumetric flask and completed to volume with 1% HNO_3. The results of these analyses showed that Method B was the best digestion method, as it yields the highest metal concentrations. Thus all samples were digested using this method. The solutions were stored in sealed plastic bottles prior to analysis using the flame atomic absorption spectrophotometer (Smith-Heftie 11 model 757 AA) with deuterium lamp background correction. Error quantification for all heavy metals was completed using (Merck ICP4) standard solutions; the error range was less than $\pm 0.5\%$.

Results and Discussion

The concentrations of heavy metals in dust collected from different parts of Karak province are summarized in parts per million (ppm) as maximum, minimum and average concentration in Table 1. Significant differences were found between heavy metal concentrations of control samples and samples from other investigated areas (Figure 2). It is worth mentioning that the highest Pb concentration is found in the Karak City center samples, which is attributed to the use of leaded fossil fuel. There is no gasoline station that sells unleaded fuel in Karak province. Similar results were found in other parts of the world (Caselles *et al.*, 2002; Pouyat *et al.*, 1995).

The major source of Mn is considered natural, but the concentrations reported in this study are higher than might be expected (see Figure 2). However, Mn and Ni are fuel additives as is Pb, especially in burning fuels (diesel) that are used in residential heating systems (Ho and Tai, 1988; Sheppard *et al.*, 2000; Loranger and Zayed, 1994). Similar high concentrations of Mn in soil from other areas of the Karak province were reported by Jiries *et al.* (2003a).

The study area showed elevated concentrations of aluminum and iron, which are major natural constituent of the soil, and they do not reflect any specific anthropogenic source in the

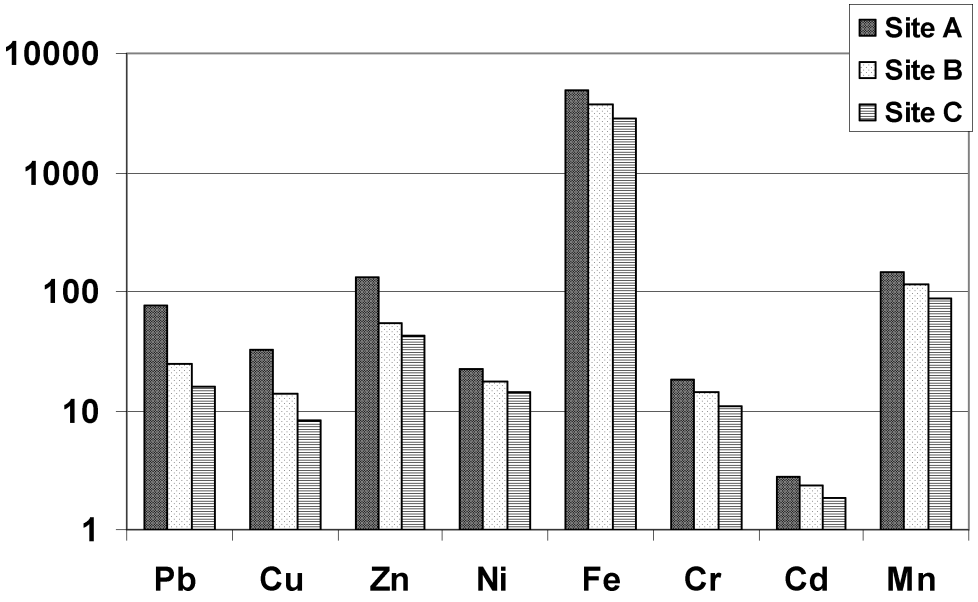

Figure 2. Histogram showing the average concentration of heavy metals in ppm for each sampling sites.

Table 1
Heavy and trace elements concentrations in ppm for street dust samples collected from different sites in Karak City

Elements	Site A Downtown	Site B Suburbs	Site C Blank
Pb			
Min	31	16	14
Max	175	57	18
Average	75.33	25.09	16
Cu			
Min	18	8	6
Max	75	25	11
Average	33	14	8.33
Zn			
Min	79	45	34
Max	165	78	53
Average	131	55	43
Ni			
Min	18	15	13
Max	26	20	17
Average	22	17.36	14.33
Fe			
Min	3665	2625	2169
Max	7491	5180	3909
Average	4966	3732	2859
Al			
Min	1814	2231	1761
Max	4381	5381	7211
Average	3328	3542	4635
Cr			
Min	11	10	4
Max	25	21	16
Average	18	14.1	11
Co			
Min	10	7	7
Max	13	11	10
Average	11	9.27	8.33
Cd			
Min	2	2	1
Max	4	3	2
Average	2.83	2.36	1.83
Mn			
Min	87	69	55
Max	275	162	127
Average	144.33	113.36	86.67

city (Moreno-Grau *et al.*, 2002). Therefore, a significant variation between concentrations of suburban and city center samples in Karak province does not occur. Similar elevated iron content was also found in dust in Amman (Jiries, 2003b). The aluminum concentrations in the control area were found to be higher than in the more polluted city center. This situation is due to rainfall intensities in the control area being higher in previous seasons than in the other study areas. Aluminum is considered an immobile element as reported by many authors (Wilcke *et al.*, 1998; Komuro and Kajiwara, 2003; Algeo and Maynard, 2004). Therefore, it has been accumulated at a higher concentration in the control areas than in the city center as shown in Table 1.

The cadmium levels of the dust samples were very low and similar to average concentration of control area samples. Although cobalt and chromium are major part of automobile bodies, their concentration in the street dust samples in the city center exceeded slightly the control level; they were only 1.5 times higher than the background. However, these concentrations are not considered dangerous.

The correlation coefficient statistical analysis was conducted on heavy metal concentrations. A significant positive correlation relationship was found between Pb and Cu ($r = 0.86$), between Pb and Zn ($r = 0.62$), and between Pb and Cd ($r = 0.60$). This might be explained by the presence of all of these metals in similar source (i.e. the bodies and tires of automobiles).

The concentrations of some of the heavy metals are comparable to that of Amman City, such as Cd, Cr, Ni, Mn, Fe as shown in Figure 3, whereas other elements show clear enrichment in Amman City Street dust samples (Zn, Pb, Cu) (Jiries, 2003c). These observations can be explained by the heavy automobile traffic in Amman as compared to Karak. The results of this study are comparable to that of worldwide data. The median values of the data presented in this study are comparable to "source state" concentrations of street dust samples from Coventry City (Charlesworth and Lees, 1999). These observations are logical as this study is based on three months of sampling during the summer with no rainfall.

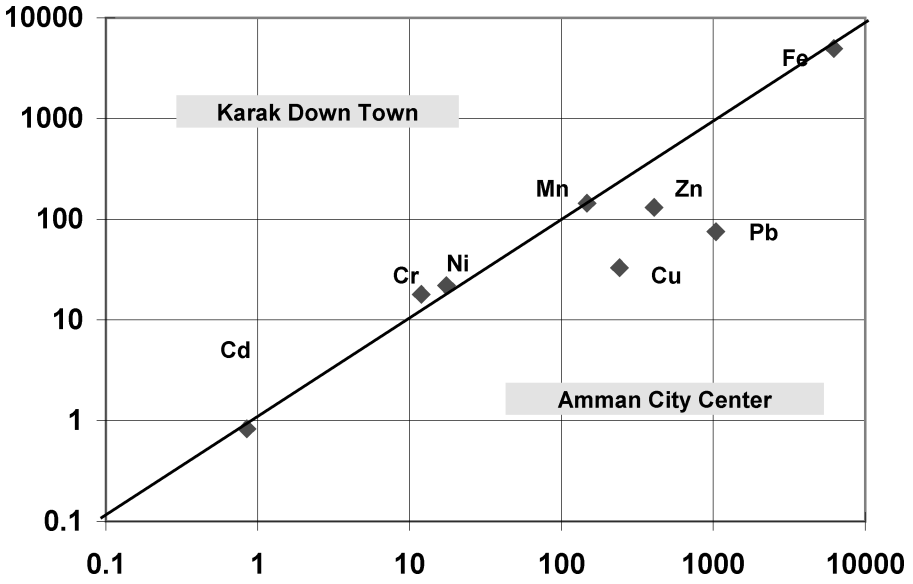

Figure 3. Scatter plotting showing the comparison between the heavy metal concentrations in the street dusts of both Karak down town and Amman City center.

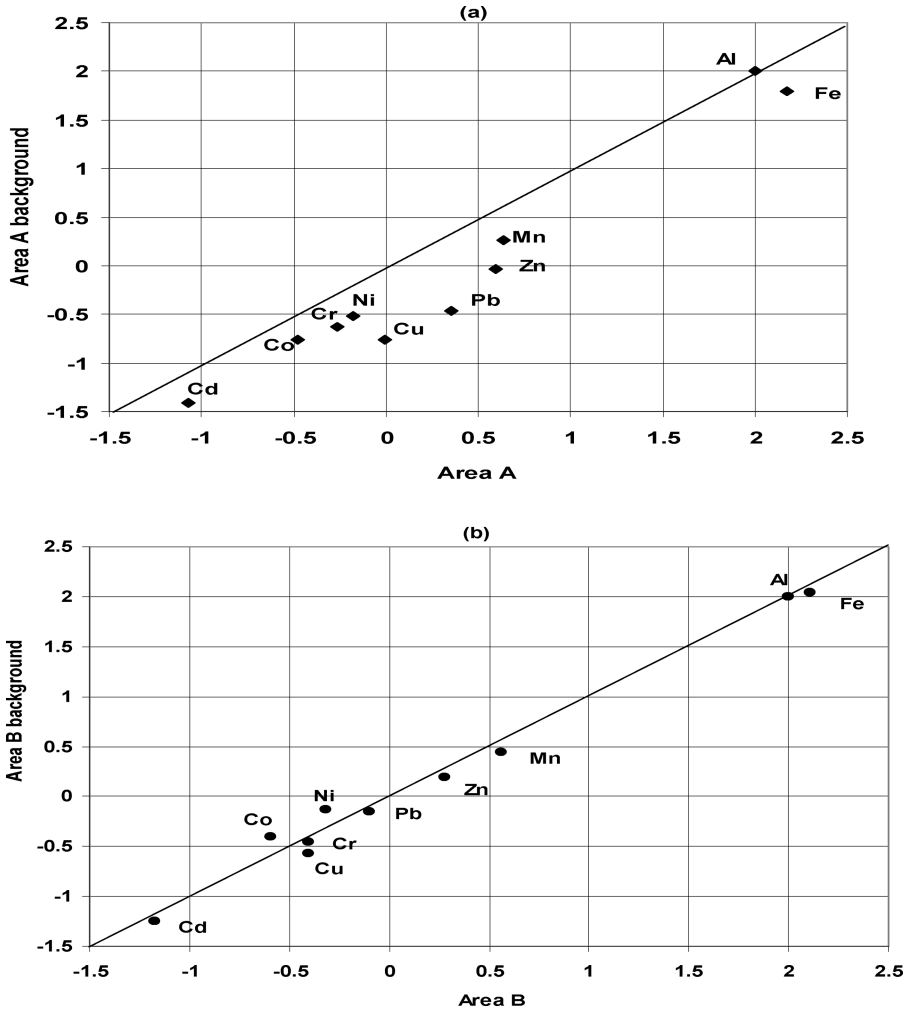

Figure 4. Scatter plotting showing the log of the Al-normalized values of city center (Site A) vs. its background (a); and suburbs (Site B) vs. its background (b).

Furthermore, in order to determine the heavy metals origin whether they are naturally occurring or from anthropogenic sources, the samples of downtown (Site A) and the suburb (Site B) were normalized to aluminum, assuming it is entirely naturally occurring and insoluble leading to the immobility of this element in nature. These data were plotted against their background values as shown in Figure 4a and b. This figure illustrates that all heavy metals are higher than their background values, which indicates that they are resulting from pollution, rather than natural contribution. Similar results were reported (Sutherland and Tolosa, 2001). This might be attributed to pollution sources, particularly automobile exhaust. Although the figure shows that data of area A and B are slightly different, this conclusion is more obvious in area A due to higher traffic density.

Conclusions

All heavy metal concentrations are 1-3 times higher at site A than site B, mainly Pb, Cu, and Zn, which illustrates higher anthropogenic sources at Site A. The distribution and

concentrations of heavy metals in all areas show that automobile–originated sources (emissions or by wear and tear of different parts of the car) are the main source of pollution. Furthermore, heavy metal concentrations of street dust samples are lower in Karak than Amman due to lower traffic density and are directly related to the type of fuel used. Aluminum and iron are not seen to vary in concentration between the impacted and control sample sites, which is attributed to natural deposition processes and immobility of aluminum.

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