Calculating Pollution Indices of Heavy Metal along Irbid/Zarqa Highway-Jordan

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Abstract

The concentration of seven soil heavy metals(Zn , Cr ,Co,Pb ,Ni, Cu and Cd) was measured in twenty one sampling sites along Irbid –Zarqa highway during January 2011. These samples were determined using atomic absorbtion spectrometer . The assessment of heavy metal pollution was derived using the enrichment factors (EF) and geoaccumulation index (I(geo). This study revealed that the soil is predominantly by Cd >Ni > Co > pb > Zn> Cr> Cu. As recorded the highest EF value at 38.7 for Cd followed by Ni (12.35), Co (5.33), Pb (2.40), Zn (2.04), Cr (0.75) and Cu (0.40). This is similar to the I(geo), which indicates that the highest level goes to Cd (1.41), exhibits moderately polluted. Meanwhile, Pb recorded 0.20 and Zn(0.13), which illustrates that both of these elements vary from unpolluted to moderately polluted. The Co, Cr, Ni and Cu levels are below 0, which demonstrates background concentrations.

Keywords: Heavy metals(Zn , Cr ,Co,Pb ,Ni, Cu and Cd); Highways; Pollution; enrichment factor ; index of geoaccumulation.

1. Introduction

Road dust originates from the interaction of solid, liquid and gaseous materials which are produced from different sources and deposited on a road. The composition and quantity of chemical matrix of road dust are indicators of environmental pollution (Banerjee, 2003). Road dust receives varying inputs of heavy metals from diversity of mobile or stationary sources such as vehicular emission, industrial plants, power generation plants, oil burning, waste incineration, construction and demolition activities as well as resuspension of surrounding contaminated soils (Ahmed and Ishiga, 2006; Al-Khashman, 2007). Lead (Pb), for example is known to come from the use of leaded gasoline whereas Cu, Zn and Cd from tyre abrasion, lubricants, industrial and incinerator emissions (Thorpe and Harrison, 2008; Wilcke *et al*., 1998). The source of Ni and Cr in street dust is believed to be due to corrosion of vehicular parts (Lu *et al*., 2009; Akhter and Madany, 1993; Ferguson and Kim, 1991) and chrome plating of some motor vehicle parts (Al-Shayep and Seaward, 2001). The phenomenon contributes significantly to the pollution of urban environment. This makes the study of road dust important for determining the origin, distribution and level of heavy metal in urban surface environments.

2. Materials and methods

2.1. The study area

The study area, situated in the northern part of Jordan limited between 35º 75´ – 36 º10 ´ N, and between 32º 25´ – 32 º45 ´E (Fig. 1). The climate of the study area is Mediterranean with more than 370 mm mean annual rainfall that is decreasing gradually from the west (450 mm/year) to the east (200 mm/year). Mean winter air temperature ranges from 5 to 9 °C, and mean summer air temperature ranges from 22 to 29 °C (Khresat et al., 1998). The investigated area is dominated by Amman Silicified Limestone Formation from the Companian age. This unit consists of limestone, chert, massive chalky and marl (Powell, 1988).Large parts of the studied area are covered by soil. The soil in the investigated area is yellow-brown with calcareous concretions. It is composed of loess-like silt and residual calcareous bedrock.

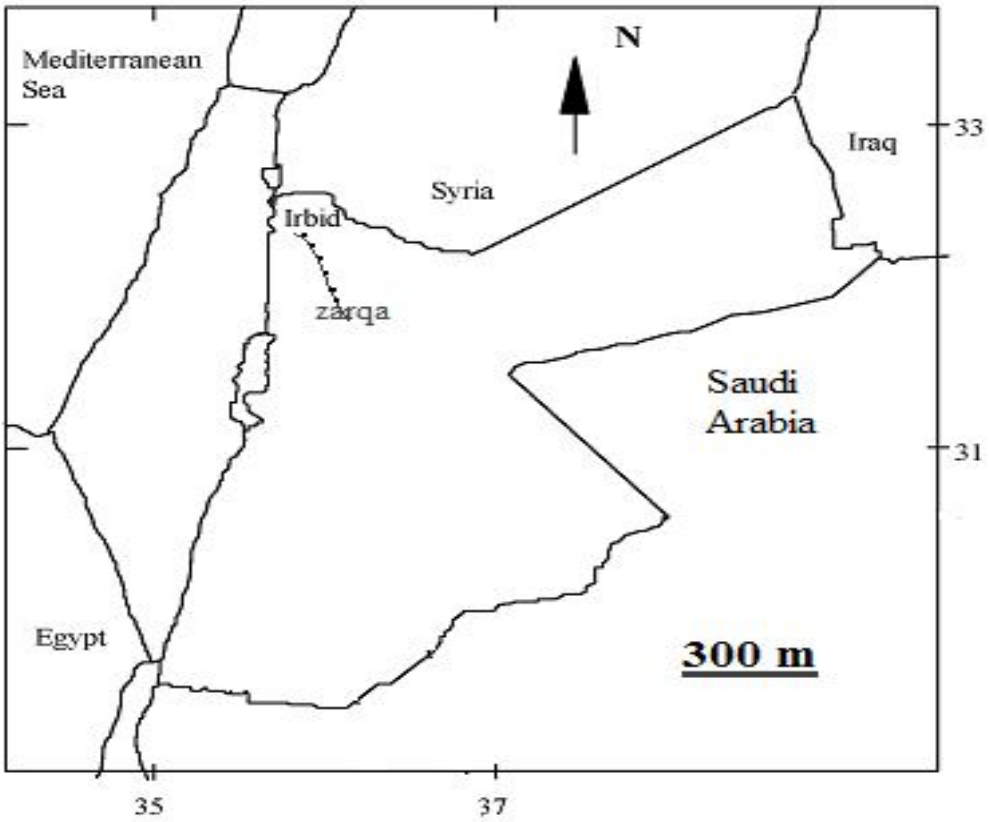

Fig. 1: Location map of the study area

2.2. Sediments Sampling

21 soil samples were collected during January 2011 from different depth with an interval of 10 -30 cm. 1 kg of each soil sample were collected using a stainless steel spade and a plastic scoop, All Samples collected were stored in sealed polythene bags and transported to the laboratory for pre-treatment and analyses.

2.3. Chemical Analysis

The soil samples were dried, mechanically in the laboratory, the soil samples after air drying at room tempeture, were sieved with nylon mesh (2mm). The < 2mm fraction was grinded in an agate and pestle and passed through a 63 micron sieve. Soil samples were analyzed for heavy metals. These samples were digested in aqua regia (1:3 HNO3: HCL). Metals in the final solutions were determined using Pyeunicam, SPQ PHilips, Atomic Absorption Spectrometer(AAS). Standard stock solutions for all the elements were procured from Merck as well as prepared in the laboratory following the procedures as described in APHA (1989). The glassware used was Pyrex, which was washed several times with soap, distilled water and diluted nitric acid to remove any impurities.

2.4 Contamination Assessment Methods

The assessment of soil or sediment enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation and enrichment factors, (Lu et al,2009). In this work, the index of geoaccumulation (Igeo) and Enrichment Factor (EF) have been applied to assess heavy metals (As, Cr, Cu, Mn, Ni, Pb and Zn) distribution and contamination in the road dust samples along Irbid –Zarqa highway. A quantitative measure of the extent of metal pollution in the studied soil was calculated using the geo-accumulation index proposed by Muller (1969). This index (I-geo) of heavy metal is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration using the following mathematical relation (Muller, 1969; Ntekim et al., 1993):

I-geo = log2 (C*n*/1.5B*n*),

where C*n* is the measured total concentration of the element *n* in the mud grain size fraction of sediment; B*n* is the average (crustal) concentration of element *n* in shale (background), and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects.(Lu et al ,2009) gave the following interpretation for the geoaccumulation index: Igeo < 0 = practically unpolluted; 0 < Igeo < 1 = unpolluted to moderated polluted; 1 < Igeo < 2 = moderately polluted, 2< Igeo < 3 = moderately to strongly polluted;3< Igeo<4=strongly polluted;4< Igeo<5= strongly to extremely polluted; and Igeo >5 = extremely polluted.

2.5 Enrichment Factor

Enrichment factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers (Loska et al, 2003). Its version adapted to assess the contamination of various environmental media is as follows:

$$\mathbf{EF}= \frac{[\ C_x / C_{ref}\ ]_{Sample}}{[B_x / B_{ref}\ ]_{Background}}$$

Where:
Cx = content of the examined element in the examined environment;
C*ref* = content of the examined element in the reference environment;
Bx = content of the reference element in the examined environment; and
Bref= content of the reference element in the reference environment;

An element is regarded as a reference element if it is of low occurrence variability and is present in the element in trace amounts. It is also possible to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects i.e. synergism or antagonism towards an examined element. Five contamination categories are recognized on the basis of the enrichment factor: EF < 2 states deficiency to minimal enrichment; EF = 2-5 moderate enrichment; EF = 5-20 severe enrichment; EF = 20-40 very high enrichment; and EF > 40 extremely high enrichment ,(Manno et al., 2006). "Metal distribution in road dust samples collected in an urban area close to a petrochemical plant at Gela, Sicily", Atmos Environ, 40, 5929-5941 (Al-Khashman, 2004). Despite certain short comings (Reimann and Carinat, 2000). The enrichment factor, due to its universal formula, is relatively simple and easy tool for assessing enrichment degree and comparing the contamination of different environment.

3. Results and Discussion

3.1. Heavy metal concentrations

Table 1 summarizes the minimum, maximum, mean, standard deviation and median concentrations of a number of metals (Zn , Cr ,Co,Pb ,Ni, Cu and Cd) in twenty one soil samples collected along Irbid / Zarqa highway of Jordan. A close look at Table 1 shows that the variability in the range of all the metal distributions as compared with their means respectively is an indication of pollution of the sample with that metal ion. The decreasing trend of averages of metal levels was as follows: Ni > Co > Zn > Cr > Pb > Cu >Cd.

Table 1: Basic statistical parameters for the distribution of heavy metals in the investigated soil samples.

Variables	Min	Max	Mean	SD	Median	Skewness	Kurtosis
Cu (ppm)	7.51	50.21	27.72	8.84	27.10	0.13	1.49
Cr (ppm)	23.85	124.23	67.40	23.23	64.66	0.42	0.70
Cd (ppm)	7.51	17.22	11.61	2.72	11.16	0.33	-1.07
Co (ppm)	11.16	1544.24	506.02	472.80	353.87	1.15	0.46
Pb (ppm)	18.51	79.99	47.95	16.96	51.22	0.12	-0.69
Zn (ppm)	113.30	325.22	193.33	46.80	193.67	1.08	2.21
Ni (ppm)	225.57	1711.84	926.18	349.13	944.76	0.20	0.31

3.2. Distribution and Enrichment of Metals

The enrichment factor (EF) of Co, Cr, Ni and Cu concentration in the soil are 5.33 ,0.75, 12.35, 0.40, respectively (Table 2) , and the calculated results of *I*geo for these heavy metals have *I*geo ≤ 0 indicating that the environment is unpolluted by these elements .

Meanwhile, enrichment factor (EF) of Pb and Zn recorded 2.40 and 2.04 , whereas the value of the geoaccumulation index are 0.21 and 0.13,respectively which indicates that pb and Zn exhibits from unpolluted to moderately polluted. The soils of the study area were mainly derived from the upper cretaceous carbonate rocks. But carbonates in general have low concentrations of lead. It is clear that the carbonate parent rocks are not the only source of lead and it must be other sources which are more likely anthropogenic ones. Since the soil samples have been taken along highways with considrable heavy traffic rates, so the motor vehicles burning leaded gasoline can be considered as the main source of the lead in the soils of the study area (Lu *et al*., 2009).

The behavior of Cd show that the enrichment factor (EF) is 38.7 , whereas the value of the geoaccumulation index is 1.41. Relatively higher values of cadimium concentrations in the analyzed soil samples reflect anthropogenic effects may be burning of fossil fuel, wear and tear of tyres. According to Kabata-Pendias and Pendia (1984) the soil lying at the vicinity of high ways may have a cadimium ranging from 1 to 10 ppm. This may explain the relatively high concentrations of Cd in the soils of the study area.

Table 2: Average, background, enrichment factor, calculated I-geo index, and grade of pollution intensity of heavy metals in metals in soil samples collected along Abed El-Aziz road.

Metal	Ave. shale value	Soil along Irbid -Zarqa	Enrichment factor	I-geo. value	I-geo. grade	Pollution intensity
Pb	20	47.95	2.40	0.21	1	Un polluted / moderately
Cd	0.3	11.61	38.7	1.41	2	Moderately polluted
Zn	95	193.33	2.04	0.13	1	Un polluted / moderately
Co	95	506.02	5.33	< 0	0	Un polluted
Cr	90	67.40	0.75	< 0	0	Un polluted
Ni	75	926.18	12.35	< 0	0	Un polluted
Cu	70	27.72	0.40	< 0	0	Un polluted

4. Conclusions

The concentration of heavy metals Zn , Cr ,Co, Pb ,Ni, Cu and Cd and their pollution level collected along Irbid – Zarqa highway have been studied in this work. The pollution level of the elements was estimated using enrichment factor (EF) and geo-accumulation index (Igeo) . This study revealed that the soil is predominantly by Cd >Ni > Co > pb > Zn> Cr> Cu. As recorded the highest EF value at 38.7 followed by Ni (12.35), Co (5.33), Pb (2.40), Zn (2.04), Cr (0.75) and Cu (0.40). And the mean Igeo provided the same trend of pollution levels as in the case of the EF. , which indicates that the highest level goes to Cd (1.41), exhibits moderately polluted. Meanwhile, Pb recorded 0.20 and Zn(0.13), which illustrates that both of these elements vary from unpolluted to moderately polluted. The Co, Cr, Ni and Cu levels are below 0, which demonstrates background concentrations. In conclusion, data obtained for the study demonstrated that the distribution of metal concentration in the study area has come about as a result of anthropogenic influences, in particular vehicular emissions.

References

Ahmed, F. and H. Ishiga, 2006. Trace metal concentrations in street dusts of Dhaka city, Bangladesh, Atmos. Environ., 40: 3835-3844.

Akhter, M.S. and I.M. Madany, 1993. Heavy metals in street dust and house dust in Bahrain, Water Air Soil Pollut., 66: 111-119.

Al-Khashman, O. A. (2004) "The investigation of metal concentrations in street dust samples in Aqaba City, Jordan" Environmental, Geochemical and Health, 29, 197-207

Al-Khashman, O.A., 2007. The investigation of metal concentrations in street dust samples in Aqaba city, Jordan, Environ. Geochem. Health, 29: 197-207.

Al-Shayep, S.M. and M.R.D. Seaward, 2001. Heavy metal content of roadside soils along ring road in Riyadh (Saudi Arabia). Asian J. Chem., 13: 407-423.

APHA., (1989). Standard Methods for Examination of Water and Wastewater. 17th ed. Washington DC: APHA

Banerjee, A.D.K., 2003. Heavy metal levels and solid phase speciation in street dusts of Delhi, India. Environ. Pollut., 123: 95-105.

Fergusson, J. E., (1991). The Heavy Elements: Chemistry Environment Impact and Health Effects. Oxford: Pergamon.

Fergusson, J. E., and Kim, N. D., (1991). Trace elements in street and house dusts: sources and speciation. Science of the Total Environment, 100, 125–150.

Kabata – Pendias.A. and Pendias, H.,(1984). Biogeochemistry of trace elements.(in Polish). PWN Warszawa, pp 397 .

Khresat, SA, Z. Rawajfih and M. Mohammad, 1998. Morphological, physical and chemical properties of selected soils in the arid and semi-arid region in Northwestern Jordan. 1.Arid Environ., 40: 15-25. 1. Gee, G.W. a

Lu, X., Wang, l., Lei, k., Huaing, J. and Zhai, Y. (2009) "Contamination assessment of copper, Lead, Zinc, Manganese and Nickel in street dust of Boaji, N. W china" J hazardous Materials, 161, 1058-1062

Loska, K.; Wiechula, D.; Barska, B.; Cebula, E. and Chojnecka,A., (2003) "Assessment of arsenic enrichment of cultivated soils in Southern Poland" Pol. J. Environ. Stud., 12 (2), 187– 192

Manno, E., Varrica, D. and Dongarrá, G. (2006). "Metal distribution in road dust samples collected in an urban area close to a petrochemical plant at Gela, Sicily", Atmos Environ, 40, 5929-5941

Muller, G., 1969. Index of geoaccumulation in sediments of the Rhine River, J. Geol., 2: 108-118.

Ntekim, E.E., Ekwere, S.J., and E.E. Ukpong. 1993. Heavy metal distribution in sediments from Calabar River, southeastern Nigeria. Environmental Geology. 21:237- 41.

Reimann, C. and de Carinat, P. (2000). Heavy metals contamination in fungicide treated cocoa plantation in Cross River State, Nigeria", In: Aikpokpodion et al (2010). American-Eurasian J. Agric/ & Environ. Sci., * (3): 268-274

Thorpe, A. and R.M. Harrison, 2008. Sources and properties of non-exhaust particulate matter from road traffic: A review. Sci. Total Environ., 400(1-3): 270-282. doi:10.1016/j.scitotenv.2008.06.007

Wilcke, W., S. Muller, N. Kanchanakool and W. Zech, 1998. Urban soil contamination in Bangkok: heavy metal and aluminium portioning in topsoils. Geoderma, 86: 211-228.