Original Research Paper

Assessment of Heavy Metal Cu, Pb, Cd Contamination in Dust in Zahedan City using Pollution Indices and GIS and Geo Statistics Technologies, Zahedan, Iran

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Abstract: Assessment of heavy metal contamination is of great importance given its hazardous impacts on humans and the environment. Atmosphere is an important path for heavy metals transportation and plays a major role in the bioaccumulation of heavy metals in the environment. The present research aims to assess soil pollution to heavy metals of lead, copper and cadmium in Zahedan using pollution indices and Geo statistics technology. For the study, 90 dust samples from the studied area were systematically collected randomly and the concentrations of lead, copper and cadmium were measured using a flame atomic absorption device. Geocoding indices, pollution index, ecological risk index and potential environmental risk index were used to determine the contamination level in the study area. The comparison of the mean concentration of the elements showed that the frequency of metals in the study area was Pb> Cu> Cd. Also, the index of contamination, ecological risk and environmental potential of the cadmium element are 14.18, 44.34 and 1333.03, respectively, then the other metals. The plot of land accumulation chart showed that the heavy metal content during the sampling period varies from moderate to severe/maximum contamination, so the concentration of heavy metals in addition to their natural origin was also related to human activities. The Pollution Index map (PI) also showed that the elements of copper, lead and cadmium are low, medium and high levels of pollution respectively.

Keywords: Pollution Index, Ecological Risk, Accumulation Index, Heavy Metals

Introduction

Environment pollution by heavy metals is a global issue mostly due to the stability of the metals in the environment and the toxic effects of most of them on living organisms, (Chakraborty *et al*., 2009). Heavy metals are also known to be low in low concentrations due to their non-degradability and physiological effects on living organisms. Due to its endless profiteering, humans have relied on advanced technology to destroy and destroy the surrounding environment. Agricultural and industrial pollutants are among the environmental disruptors, including heavy metals due to non-degradation and physiological effects they are also important for living organisms and humans at low

concentrations. Among these elements are lead, copper and cadmium (Namazi and Salehi, 2016).

Heavy metals are introduced into the soil from various paths such as atmospheric fall, use of chemical and animal fertilizers, compost, sewage sludge and pesticides (Rahnama: Afuoni and Khademi). This leads to the gradual accumulation of heavy elements in the soil. The process of accumulation of heavy elements in the soil is very slow and its effects can be detected after decades (Keller and Schulin, 2003). On the other hand, heavy metals tend to accumulate in soil and sediments and have a long life span. For this reason, they remain in the food chain and ultimately cause neurological and motor disorders in living organisms. Heavy metals are also classified as the most dangerous group of human

pollutants due to their toxicity and shelf-life in the environment (Sharma *et al*., 2008) and are permanently suspended in nature, but with consumption of more than to the extent, their toxicity occurs (Kabadayi and Cesur, 2010). Several studies have shown that the atmosphere is an important route for the transport of heavy metals and plays a major role in the bioaccumulation of heavy metals in the environment. This property is a potential threat to the environment and humans (Bermudez *et al*., 2012). Establishing and approving environmental quality standards, an important part of environmental standards in order to maintain ecosystem equilibrium, Human health and the identification of adverse effects on the environment are always necessary and necessary. To this end, based on the ecological characteristics of living organisms, toxicology and geochemical of pollutants and health policies of countries, range and confidence limits are defined in different parts of the world (Azimzadeh and Khademi, 2013). Due to the destructive effects of heavy metals on humans and the environment, evaluation of heavy metal contamination is of particular importance. The evaluation of heavy metals contamination is based on various indicators such as Igeo 1, Enrichment Factor (EF) 2, Contamination factor (PI) 3 and Pollution Index (PLI) 4 (Loska *et al*., 2004). Many studies have been done on the effects of natural sources on the concentration of elements in soil and water resources. Duong and Lee (2011) conducted a study to investigate the levels and sources of heavy metal contamination in road dust in high-traffic areas in an industrial city in Korea. In this study, the concentration of total cadmium, copper, lead, zinc and nickel was measured. Became the results of the study showed that heavy metal contamination levels in road fumes were high due to high traffic axis depending on the traffic volume and atmospheric deposition. Baghaye *et al*. (2007) the spatial variations of absorbable lead and nickel in soils around the two factories Mobarakeh Steel Complex and Isfahan Steel Company. The results showed that lead concentration near iron and nickel smelting near the two plants was higher than other points. Considering the importance of knowing the amount of heavy metals in soil, several studies have been done. The accumulation of heavy elements in the long run contributes to soil contamination, ground water contamination, absorption by plants, entry into the food chain and serious health risks for humans. Therefore, due to the importance of contamination of heavy elements, this study was conducted to evaluate the contamination of some heavy elements using environmental indicators.

Materials and Methods

Study Area

The study was carried out in Zahedan City. The height of this city is 1385 m and is 605125 latitudes east longitude and 293045 latitudes. According to meteorological data, the average annual precipitation is 72 mm, the average annual temperature is 42.5°C and the average annual temperature is 12.6°C. The weather in Zahedan is hot and dry in most days of the year and during summer it is very hot days and relatively low relative temperatures.

Sampling and Preparation

A systematic random classification method was used to determine the sampling points. Thus, 30 stations were selected in the city. Moss sediment trap (MDCO) was used to collect dust samples. The sampler was placed at a height of 1.5 m from the roof surface. Sampling lasted for 3 months and a total of 90 samples were collected. Samples were weighed accurately using a scale of 0.001 g. Analysis of samples was performed using ISO11466. Extraction was performed to determine the concentration of heavy metals using nitric acid and hydrochloric acid (Black *et al*., 1965). The concentration of heavy metals, copper, lead and cadmium was measured by atomic absorption spectrometry of the Analytic jena-350 flame model.

Pollution Index Calculation

In environmental studies especially when the geochemical distribution of elements in the environment is the result of a combination of human and natural factors, changes in trends should be evaluated using pollution indices (Guidance: Sotoudeh and Azimzadeh).

Geo Accumulation Index

Geo accumulation index (Igeo) is a geochemical factor for determining the degree of soil contamination and describing the concentration of metals in each region (Muller, 1969), this index was first proposed by Müller and the molar index is calculated and calculated as follows (Müller, 1979):

$$Igeo = log \ 2 \ ((Cn)/1.5Bn) \tag{1}$$

In this regard, *Cn* is the concentration of the element studied in soil or sediment samples, *Bn* is the concentration of the same element in the amount of field and the coefficient of 1.5 to eliminate the impact of linguistics (Ghrefat and Yusuf, 2006; Chen *et al*., 2007).

Pollution Index

Soil contamination to heavy metals is used to determine the contamination factor. Based on this factor, the amount of heavy metals is measured relative to its natural value and the amount of soil pollution is determined:

$$PI = Cn/Bn \tag{2}$$

where, *Cn* is the concentration of metal in each sample and *Bn* is the amount of field of this metal in the dust (Guidance: Azimzadeh).

Potential Environmental Risk Index (RI)

In this study, the potential environmental Risk Index (RI) was also calculated for the ecological and environmental effects of heavy metals. This method was introduced by Hawkinson in 1980 and is widely used in soil and dust studies. The index is calculated according to the equation:

$$RI = \sum_{i=1}^{n} Er_i \qquad (3)$$

In the equation above, *RI* shows the ecological risk of the sum of the elements. This indicator is calculated for the total sum of several metals or different factors of contamination. *Er* also shows the ecological risk of each element that is calculated according to the formula:

$$Eri = Tr. PIi \qquad (4)$$

In this regard, *Tr* is the toxic reaction factor for heavy metals proposed by Hawkinson for lead, cadmium and copper, respectively, 5, 30, 5. For analysis of the obtained values, *RI* is defined as four groups and for *Er*, there are five different groups that are shown in Table 1.

Statistical Analysis of Land

Unlike the classic statistics methods, Geo statistics-based methods, while considering the location of the points and the relationship between them, are more effective in analyzing the distribution of heavy metals. These methods are capable of time and space modeling to describe the variables (Barati *et al.*, 2012). In order to identify areas infected with heavy elements, the spatial

distribution map of heavy metal concentrations was drawn. For this purpose, conventional Krejnig interpolation method was used in ARC GIS 9.3 software environment. Descriptive statistics including mean, maximum, minimum, elongation and skidding of total heavy metals were obtained by SPSS V. 16 software. The data were normalized by Kolmogorov-Smironov test.

Results

Statistical Description of the Total Concentration of Heavy Metals in the Study Area

A summary of the descriptive statistics of heavy metals studied, including Cu, Pb and Cd, is presented in Table 2. Comparison of the average concentration of the elements indicates that the frequency of metals in the study area is Pb> Cu> Cd.

The results of the Kolmogorov-Smirnov test show that the concentration of all three elements studied follows the normal distribution function.

In order to study the correlation between elements in dust samples, Pearson correlation coefficient was used (Table 3). According to this table, Pb-Cu ($r = 0.145$) and Cd-Cu ($r = 0.412$) have high correlation coefficients that show the same origin or similar geochemical characteristics. But other elements do not have a good positive correlation and sometimes negative correlations indicate that their origin is different or their reaction is different from the conditions for releasing the environment.

Considering that dust samples were collected during the sampling period from residential areas, Table 4 shows the mean of total Pollution Index (PI), IGEO index, Ecological risk (Er) and potential environmental risk index RI) shows heavy elements for residential use in the study area.

Table 1: Classification of pollution index, land accumulation index, ecological risk index and environmental potential risk index

Geo accumulation index degree of contamination	Ecological ris degree of contamination
Uninfected 0 Igeo ≤	
1 Uninfected to medium Igeo ≤0<	Low 40 Er <
2 Medium Igeo ≤1<	medium 80 Er < ≤ 40
3 Medium to Intense Igeo <<2 Intense	160 Much Er < ≤ 40 80
4 Igeo ≤ 3 < Extreme to Max 5 Igeo ≤ <4	Er < 320 Too much ≤ 160 Dangerous 320 Er ≥
5 Max Igeo >	
Potential ecological risk degree of contamination	Pollution index degree of contamination
150 Low RI <	Low 1 PI ≤
Medium RI <300≤150	Medium < PI ≤ 3 1
RI < 600 Much ≤ 300	Much 3 PI >
Too much ≥ 600 RI	

Reference: (Muller, 1969)

Table 2: Statistical summary of cumulative concentration of heavy metals in the study area

Element	Min	Max	Average (mg/kg)	St.d	Skidding	Elongation	K-S
Copper	44/25	60/37	49/45	7-Mar	0.89	1.07	0.84
Lead	78/03	100/65	90/17	5.93	-0.17	-0.14	0.97
Cadmium	25/15	36/61	29/62	2.42	0.93	1.51	0.89

Table 3: Pearson correlation coefficient of heavy metals in the study area

	Correlation matrix		
	Pb	Cd	Cu
Pb	1	-0.215	145*.
Cd		1	0.412
Cu			1

*Significantly at a level of 0.05%

Table 4: The mean of total Pollution Index (PI), IGEO index, ecological risk index (Er) and potential environmental hazard index (RI) of heavy metals for residential use in the study area

Element	User	Mean PI	Degree of contamination	Mean Igeo	Degree of contamination	Mean Er	Degree of contamination	Mean RI	Degree of contamination
Copper	Residential	0.12	Low	4.11	Extreme to max	0.61	Low	0.61	Low
Lead	Residential	1.12	Medium	3.67	Intense	5.63	Low	16.90	Low
Cadmium	Residential	14.81	Much	1.48	Medium	444.34	Dangerous	1333.03	too much

Table 5: Modifiers with their parameters for the studied variables

Parameter	Model	Piece effect	Threshold	Spatial dependency	Mean squared error	Spatial dependency class
Copper	Spherical	5.2500	17.9300	0.29	3.38	Medium
Lead	Gaussian	0.0007	0.0047	0.14	4.91	Strong
Cadmium	Spherical	0.0000	6.5200	0.00	2.46	Strong

Using the averages indicated in Table 4, the contamination index, land accumulation, ecological risk and potential environmental risk indicator for residential use were plotted (Fig. 1). The diagrams (a, c, d) show that the index of pollution, ecological risk and environmental potential of the cadmium element are 14.18, 44.34 and 1333.03, respectively, then the other metals. The Earth's accumulation chart shows the degree of heavy metal contamination during the medium to severe/maximum sampling period of contamination.

Statistical Analysis of the Geo Statistics

The study of variograms (Fig. 2) shows that all variables are compatible with the Gaussian and Spherical model. Although the size of the study area is high, sampled samples are suitable representatives for the entire study area and the low piece effect is attributable to the threshold. The type of fitted models with their parameters are presented in Table 5 and based on the above models, the changes are depicted. As shown in Fig. 3, lead is fitted with a Gaussian, cadmium and copper model with a spherical model. In order to control the validity of the design changes and to provide a spatial distribution map, the Mean Squared Error (RMSE) was also calculated. The degree of spatial dependence of variables was obtained by dividing the effect of the component into the threshold (total variance). If this ratio is less than 25%, strong correlation, 25-75% moderate correlation and more than 75% correlation will be weak (Cambardella *et al*., 1994). The results of the determination of spatial dependence indicate the spatial dependence of the class of concentration of lead and cadmium elements and the average spatial dependence of the copper element. Wu

et al. (2008) reported a moderate to strong spatial dependency class for calculated heavy metal concentration variograms in the Fuyang Valley of China. The zoning and preparation of spatial distribution maps the concentration of heavy elements is one of the important steps in deciding whether to isolate contaminated areas or to determine the appropriate areas for conservation measures. After optimizing the Kriging Estimator Parameters, the concentration of metal elements was zoned (Fig. 3).

According to the distribution map of total lead concentration (Fig. 3a) in the region, the minimum concentration of lead is 78.03 and maximum 100.65 mg/kg. The highest concentration of lead in the region is in the range of 94.21-1.95 mg/kg, extending from the southwest to the northwest. Based on the distribution of total copper concentration in the region, the minimum concentration of copper is 25/44 and maximum 36/60 mg/kg, with the highest concentration in the form of a spot in the northeast of the region. The highest concentration of cadmium in the range of 31.36-36.16 mg/kg is observed in the northeastern and northwest spots. Martín *et al*. (2006) investigated various geological units as important factors in determining the concentration of chromium and nickel in the surface soil of the region in studying the concentration of heavy metals in the surface soil of the brow area in Spain. Barati *et al*. (2012) showed the highest concentrations of these elements in the western regions of the province with igneous and metamorphic beds in the study of spatial distribution of chromium, cobalt and nickel in surface soils of Hamedan province. As shown in (Fig. 3), the spatial distribution of the elements is related to the geographical location of the sampling points.

The maximum concentration of these elements is in parts of the northeast and northwest. Such a trend in the concentration of elements can be attributed to factors affecting and controlling, such as the direction and velocity of wind, the history and intensity of development activities and the difference in urban density and topographic complications. Figure 4 shows the contamination index (PI) map of the elements studied.

Accordingly, copper, lead and cadmium are respectively low, medium and high levels of pollution. The obtained values for the pollution index were zoned by Kriging method. According to the obtained maps, it is observed that the degree of pollution of cadmium metal with a range of 12/16 to 18/7/18 mg/kg is more than other elements, therefore, considering the ecological risk of cadmium compared to other metals, studies and studies more needs.
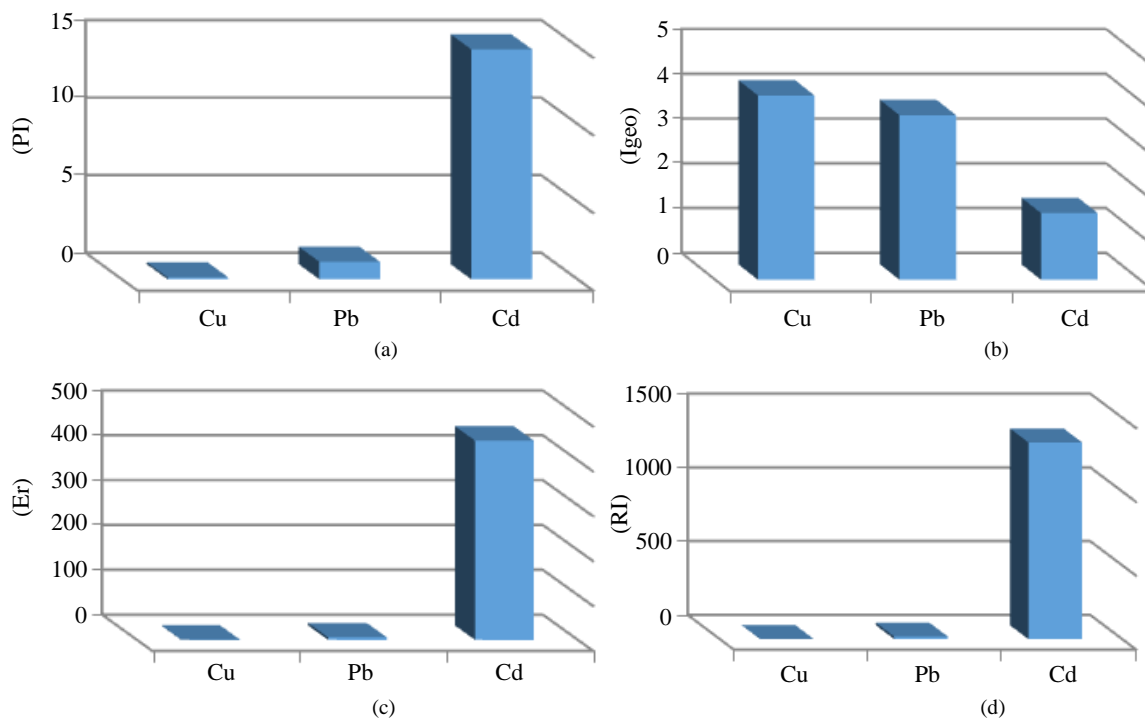
Fig. 1: Average total pollution index, land accumulation, ecological risk and potential environmental risk indicator of residential use
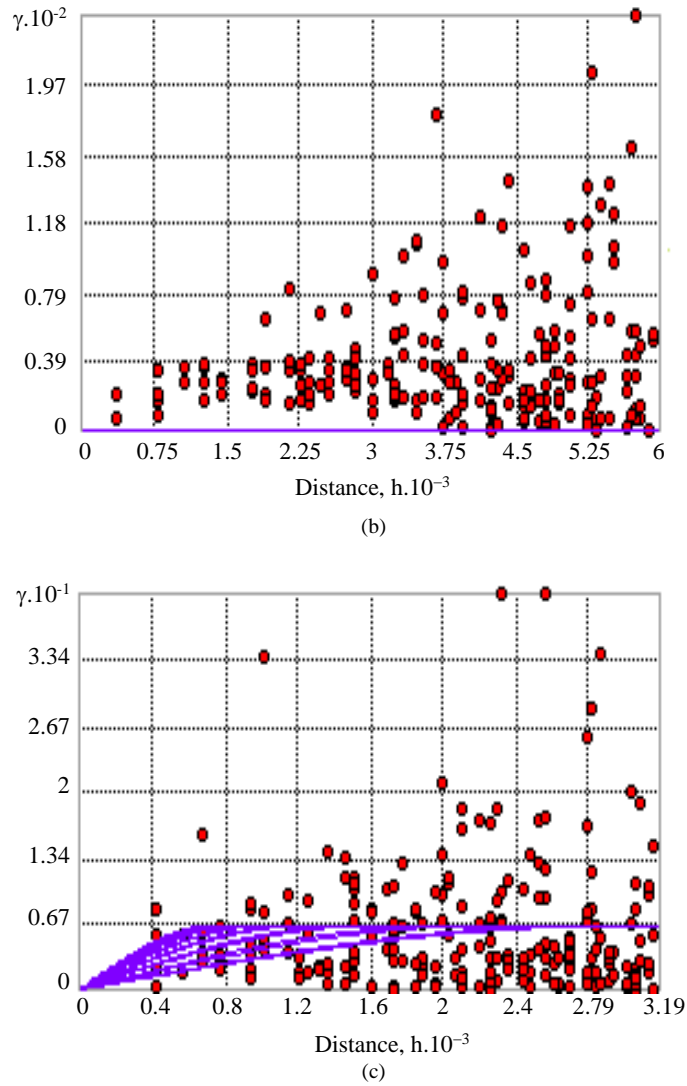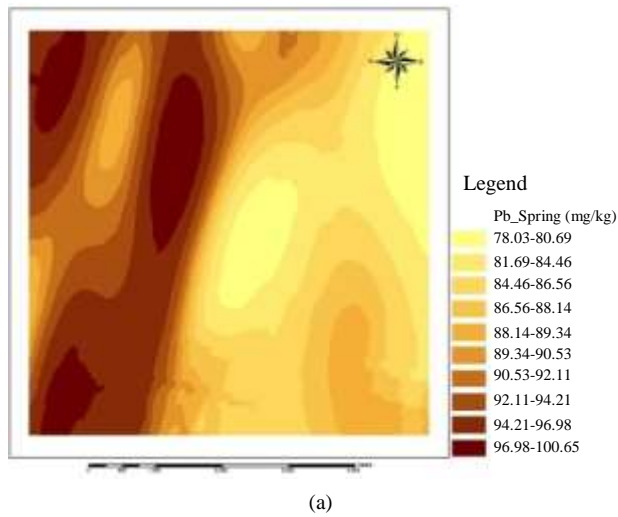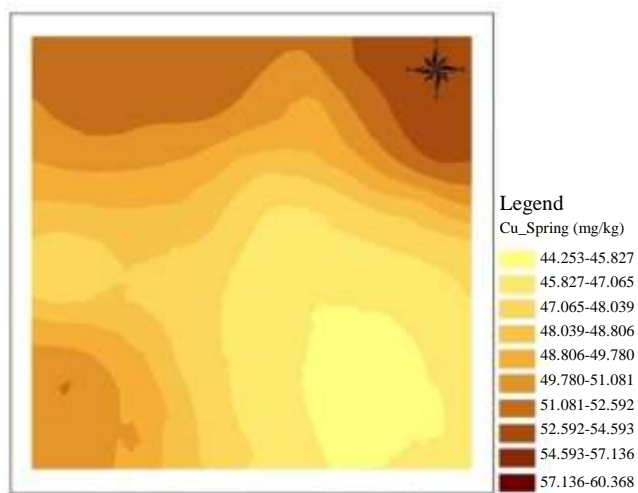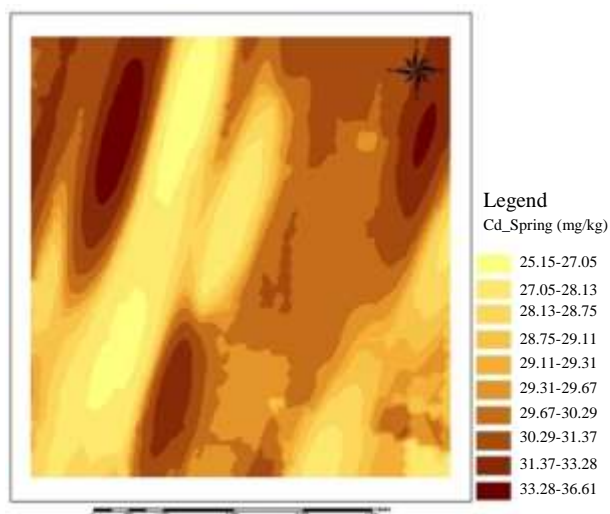

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(b)

(c)
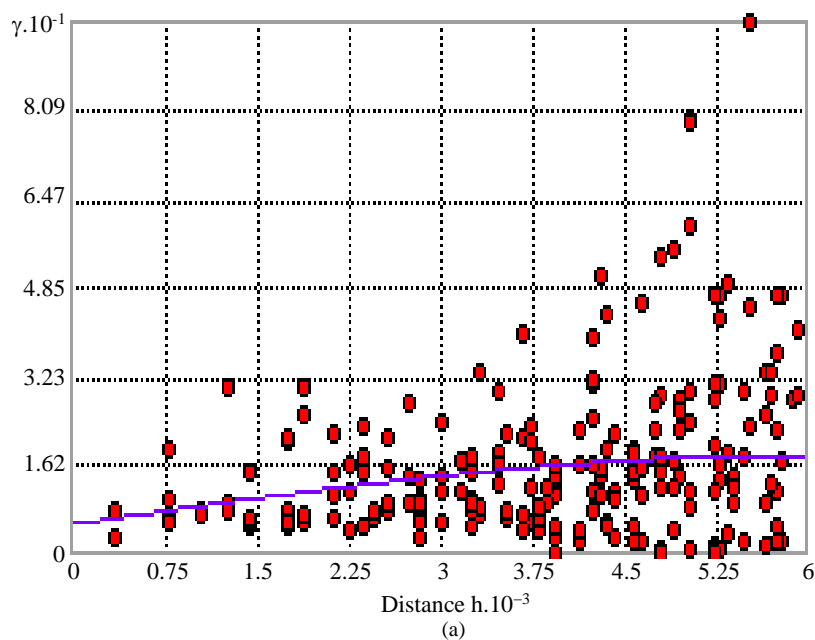
Fig. 2: Half the change of empirical views and models fitted to them, (a) lead (b) copper (c) cadmium
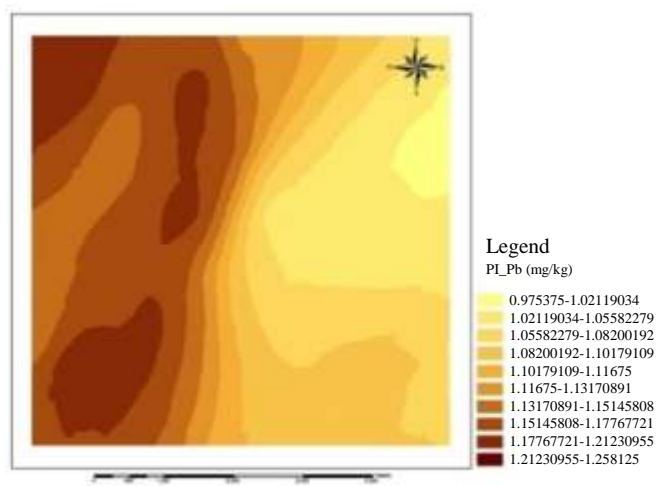

(a)

(b)

(c)

Fig. 3: Krigingmap: The concentration of total heavy metals (mg/kg) (a) lead (b) copper (c) cadmium
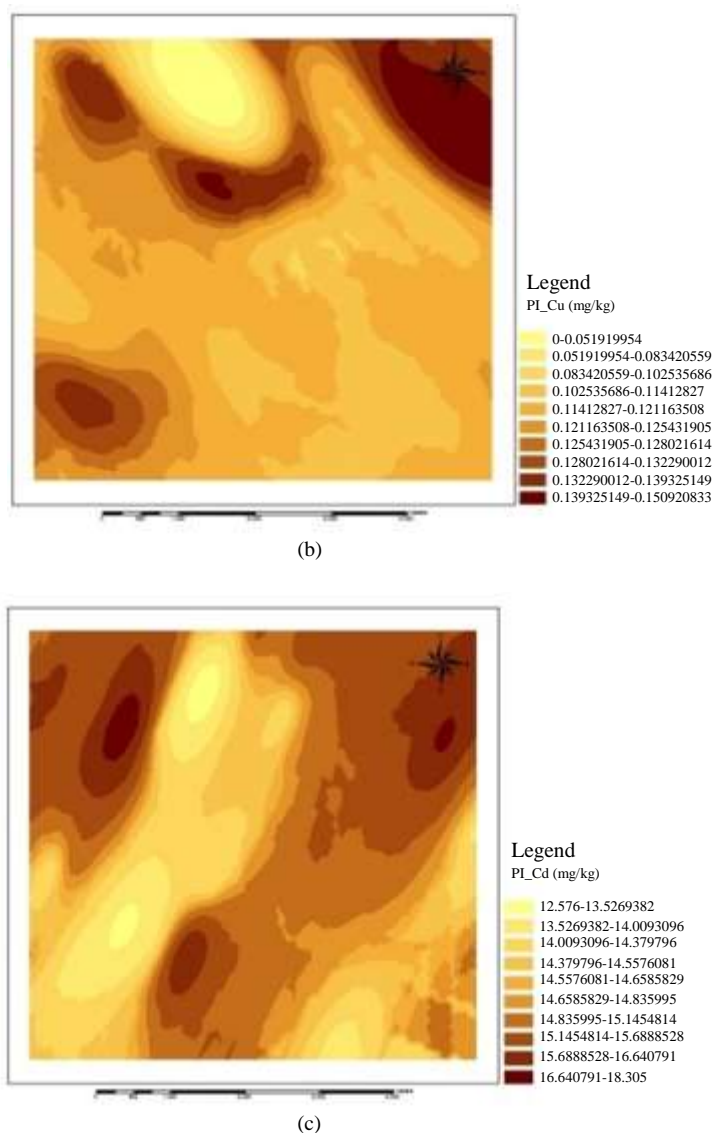

(a)

(b)

(c)

Fig. 4: Infiltration index zoning map (PI) (a) lead (b) copper (c) cadmium

Discussion

In this study, the concentration of Pb, Cd and Cu heavy elements in Zahedan was studied and analyzed statistically. Investigating the results of heavy metal scrubbing showed that lead concentration is more than other elements, which requires more accurate inspections. Using the analysis of heavy metals mapping map with the help of geological map, it seems that material the main factor is the high concentration of heavy metals in the soil. Also, by investigating the area and the absence of industries, factories and agricultural activities in the study area, it seems that the presence of traffics is the most important human factor affecting the increase of heavy metals concentration. Poggio and Vrscaj (2009) as well as (Wang *et al.*, 2012) reported similar results on the effect of the road on increasing the concentration of heavy metals in the soil. Spatial Distribution Model The concentration of heavy elements shows that factors such as wind and direction of local dominant winds in the region cause and extend the spatial distribution of pollution, as well as the continuation of the phenomenon of atmospheric development and the emission of pollutants to urban and residential areas. Therefore, in areas where the concentration of the elements is greater, measures should be taken to reduce the entry of heavy elements into the soil.

Conclusion

In this study, it was tried to investigate the distribution of spatial concentration and pollution

index of heavy lead, copper and cadmium elements in Lutheran dust in Zahedan using GIS and Earth statistics. It is suggested that other elements such as nickel, zinc and chromium, imported through industrial activities into the soil and atmosphere, are also studied, in order to obtain information about their environmental hazards.

Due to the fact that in some places the concentration of elements is excessive, it is recommended that during future research the origin of the production of these elements should be determined and methods for controlling, reducing and preventing its effects should be investigated. In this case, by reducing the consumption of organic and chemical pollutants, the control of some of the elements of the heavy metal can be controlled.

Due to the specific climate and climate conditions in this area, it is suggested that more extensive studies be carried out on the whole territory of the province regarding the pollution of dust and soil to heavy metals and the results of this study are based on the results of the research. In other provinces, comparisons and measures are needed to reduce pollution.

Acknowledgment

Notes:

- Geo accumulation index
- Enrichment factor
- Pollution index
- Pollution load index
- Marble dust collector
- Potential environment risk index
- Ecological risk
- Gaussian
- Spherical
- Mean squared error
- Nugget
- Sill

Author's Contributions

All authors equally contributed in this work.

Ethics

This study was approved by Department of Environmental Science, Yazd University, Yazd, Iran.

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