Evaluating the relation between heavy metal contamination of air and surface soils in city of Isfahan (Iran)

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Abstract: The presence of heavy metals in urban air is an important environmental issue and the sources of these contaminants should, if possible, be identified and controlled. One of the major sources of heavy metals in air is the consumption of leaded gasoline. In many countries of the world, as a result of the consumption of unleaded gasoline, the concentration of lead in air has sharply decreased. This has not been observed in the city of Isfahan, Iran, where the small decrease in lead in air from 600 ng/m^3 to 400ng/m^3 indicates that there may be other sources of lead in the air, and it was considered that these sources should be identified. Geologically the city of Isfahan is located in a mineralized zone containing rich veins of lead and zinc, and this study evaluates and compares the relationship in the concentrations of lead (Pb), Zinc (Zn) and Cadmium (Cd) in the soil and air in and around the city.

The results indicated that high concentrations of Pb, Zn and Cd in the air of Isfahan closely correlate with high concentrations of these metals in soil in the north-central part of the city. The results also indicated that the average concentrations of Pb, Zn and Cd in the air of Isfahan are 1 to 4 times higher in comparison to the cities of Manchester and London, England.

Résumé: La présence des métaux lourds en air urbain est une issue environnementale importante et les sources de ces contaminants devraient, si possible, être identifié et commandé. Une des sources principales des métaux lourds en air est la consommation de l'essence plombée. Dans beaucoup de pays du monde, en raison de la consommation de l'essence sans plomb, la concentration du plomb dans l'air a brusquement diminué. Dans beaucoup de pays du monde, en raison de la consommation de l'essence sans plomb, la concentration du plomb dans l'air a brusquement diminué. Ceci n'a pas été observé dans la ville d'Isphahan, Iran, où la petite diminution en plomb dans l'air de 600 ng/m3 à 400ng/m3 indique qu'il peut y avoir d'autres sources de fil dans le ciel, et on l'a considéré que ces sources devraient être identifiées. Géologiquement la ville d'Isphahan est située dans une zone minéralisée contenant les veines riches du fil et du zinc, et cette étude évalue et compare le rapport dans les concentrations du fil (Pb), du zinc (Zn) et du cadmium (Cd) dans le sol et de l'air dans et autour de la ville.

Les résultats ont indiqué que les concentrations élevées du Pb, du Zn et du Cd dans le ciel d'Isphahan se corrèlent étroitement avec des concentrations élevées de ces métaux dans le sol dans la partie du centre-nord de la ville. Les résultats ont également indiqué que les concentrations moyennes du Pb, du Zn et du Cd dans le ciel d'Isphahan sont 1 à 4 fois plus haut par rapport aux villes de Manchester et Londres, Angleterre.

Keywords: contaminated land, geoenvironmental engineering, heavy metals, Isfahan

INTRODUCTION

When heavy metals are released into the environment either naturally or by human activities, they have the potential to harm human health. The cessation in the consumption of leaded gasoline in the city of Isfahan did not have a major effect on the reduction of concentrations of heavy metals in air, and preliminary investigations indicated higher than reported ranges of heavy metals in air in comparison to other major cities of the world. Consequently other sources of the identified heavy metals in the air of Isfahan required further investigation. Given that the city of Isfahan is located in south-central Iran near a mineralized zone of the Irankuh Mountain which is rich in lead and zinc veins, it is considered possible that the major sources of the heavy metals Pb, Zn and Cd in the air in Isfahan, could be from contaminated soil and resulting dust which is transferred into the air by wind and moving automobiles (Momenzadeh & Ziserman, 1973; Nriagu, 1978). Thus, the purpose of this study is to determine the relationship between the concentrations of three heavy metals, Pb, Zn and Cd in soil and air in the city of Isfahan, and to compare the results with other cities in the world and with current WHO guidelines.

MATERIALS AND METHODS

For the sampling of soil in the city of Isfahan, a rectangular grid (7×5 km) with 750-metre intervals was prepared (figure 1). Surface topsoil samples (0-15 cm surface layer) were collected at grid points and were taken from un-made and uncontaminated ground. At each sampling point, ten samples were collected at a 5 m radius and mixed in a polyethylene sample bag. In the laboratory, soil samples were air dried and crushed by an acid washed mortar and pestle and were then dry sieved through a number 10 mesh stainless steel screen. Three grams of the fine portion of the soil sample was dried at $104^{\circ}c$ and then to remove organic matter, the sample was heated at $400^{\circ}c$. Duplicate samples were dissolved by heating with aqua regia for two hours and diluted to 100 ml by 0.1 M HNO_3 and filtered

using whatman 42 filter paper (Davies, 1980). The concentrations of heavy metals in the solutions were determined by a Phillips atomic absorption spectrometer (Pu 9100).

In order to determine the concentration of Pb, Zn and Cd in the air, airborne particulate matter from the atmosphere of the city of Isfahan was collected on quartz fibre filters (Whatman QM-A) using a high-volume air sampler at 18 sampling points with different traffic densities. Samples were collected from a height of 1.5m above the ground level with a flow rate of 1 m^3min^{-1}. In order to collect sufficient material and obtain accurate data, each air sampling exercise was conducted for 12 hours. Two samplers were used in each sampling site and simultaneous sampling was performed. The exposed filters were extracted with a mixture of nitric and hydrofluoric (HF) acids in a PTFE beaker at $90^{\circ}c$ for 1 hour. The remainder of the HF was removed from the mixture by adding HNO_3 and heating. The digest was then transferred into a 25ml volumetric flask and made to the required volume using deionized distilled water. Determination of heavy metal concentrations was conducted using a Phillips atomic absorption spectrometer (Pu 9100). The wavelengths used for absorption of Pb, Zn and Cd were 217.0 nm, 213.9 nm and 228.8 nm respectively.

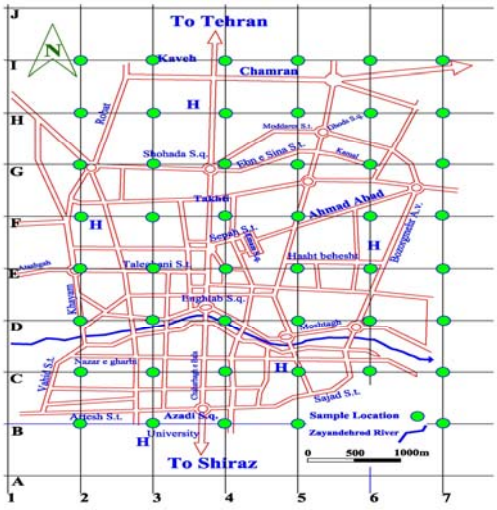

Figure 1. General location map of the study area and sampling points

RESULTS AND DISCUSSION

For presentation of the results of the soil and air analysis, the data from the 60 soil samples and 18 air samples were processed using the Surfer™ program for Windows 2000, and the isopleths of heavy metal concentrations in soils and air were plotted. The results of Pb, Zn and Cd concentrations in soil are shown in figures 2, 3 and 4 respectively. It is evident that the total concentration of Zn is higher than Pb and Cd and the overall concentration of all of the metals is higher in the northern parts of the city which could relate to the presence of zinc and lead mines in the Irankuh mountain located 15 Km south-west of the city. According to Alloway (1999), the typical normal ranges of Pb, Zn and Cd in soil are 2 to 300, 10 to 300 and 0.01 to 2.4 mg/kg of dry weight respectively (Table 1). These results indicate that the average concentrations of Pb, Zn and Cd in the soils of Isfahan are within the normal ranges of world soils and are also less than the allowable limits. It is surprising that the results indicate that the concentrations of Pb and Zn in the soil of Isfahan are not very high, because the city is located in an arid area and the wind can easily erode soils, and a proportion of heavy metals in soils could be easily transferred into the air though the mobilization of dust resulting from soil erosion.

The results of air sample analysis for the heavy metals Pb, Zn and Cd are shown in figures 5 to 7. The results indicate that the concentrations of Pb in air range from approximately 200 ng/m^3 to over 400 ng/m^3, with an average concentration of 298 ng/m^3. As is shown in figure 5, the highest concentrations of Pb are at the southern and north-central parts of the city. These results indicate that high concentrations of Pb in air correlate only with high concentrations of Pb in soil in the northern part of city. Table 2 shows the average concentration of heavy metals in air in the city of Isfahan with a comparison to the cities of Manchester and London, England, and World Health Organization (WHO) guidelines (WHO, 1995). The concentration of Pb in the air of the cities of Manchester and London is 130.0 and 130.8 ng/m^3 respectively, which are approximately $^1/_3$ to $^1/_4$ of the Pb concentration in the air of Isfahan (4). The high concentration of Pb in the air of Isfahan could be a result of soils polluted either naturally or anthropogenically, and given that leaded gasoline is no longer being used in Isfahan, the high concentration of Pb in soil and dust which enters the air as a result of traffic and wind movements could be the major source of Pb in the city.

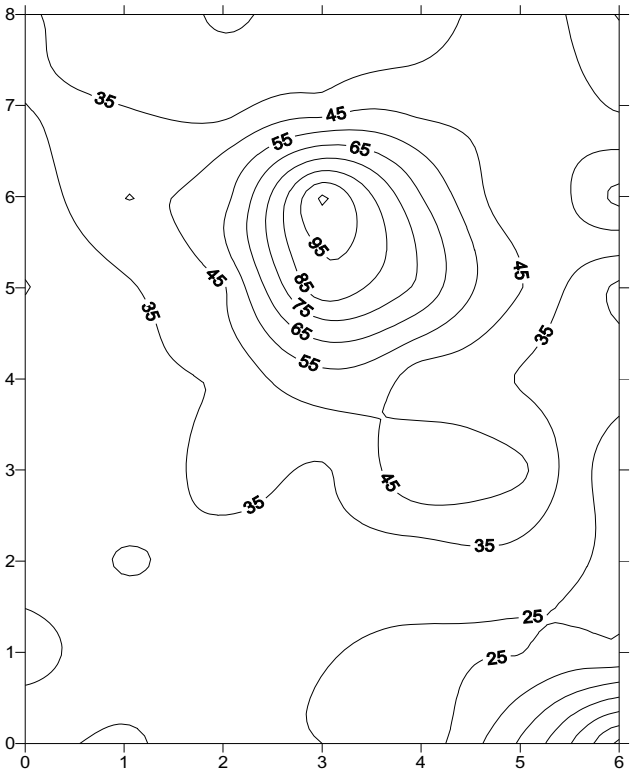

Figure 2. Isopleth plot of soil lead concentration in Isfahan (mg/ kg)

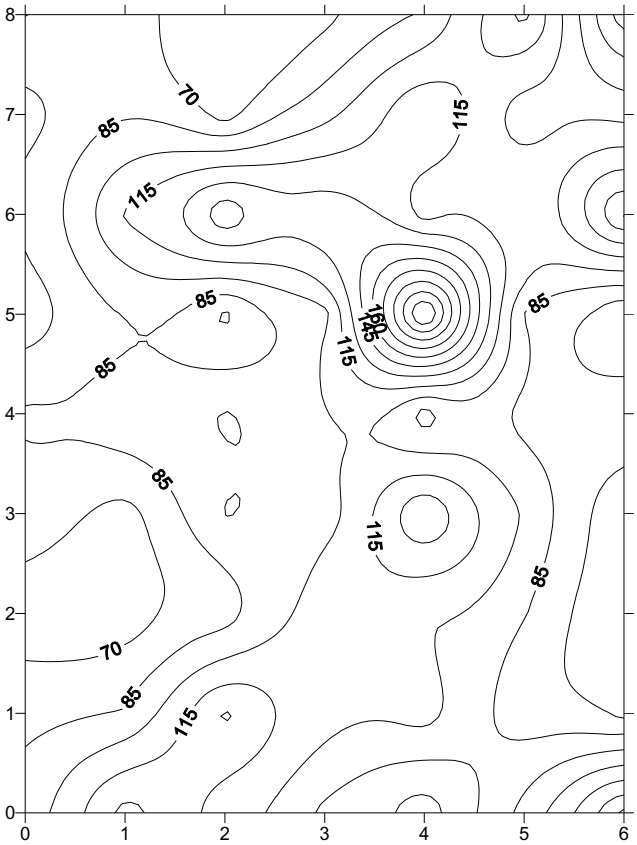

Figure 3. Isopleth plot of soil zinc concentration in Isfahan (mg/ kg)

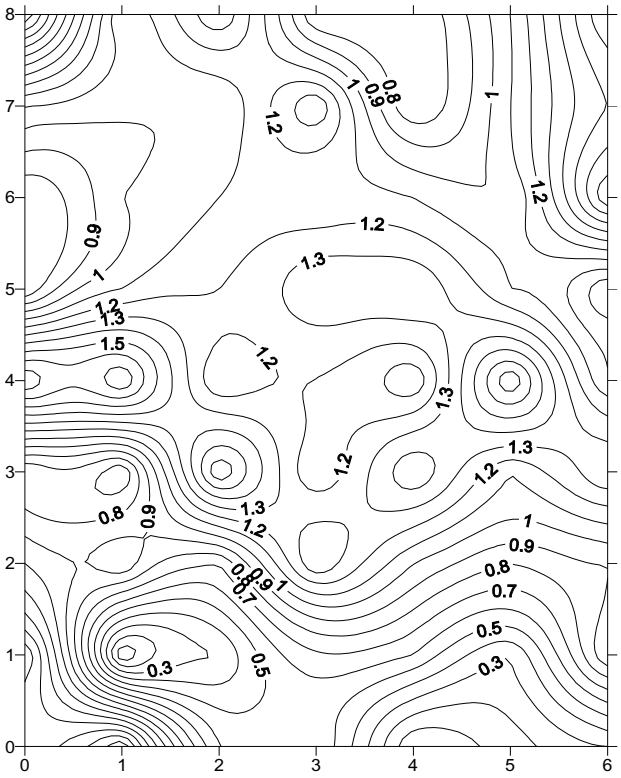

Figure 4. Isopleth plot of soil cadmium concentration in Isfahan (mg/ kg)

Table 1. Average concentration of heavy metals in soils of Isfahan compare to their typical normal ranges of soil as mg/kg dry soil (Source: 1,3,6)

	Isfahan		World	
Metals	Range	Average	Normal Range	Allowable Limits
Pb	17- 107	37.4	2-300	100
Zn	56-242	94.3	10-300	300
Cd	0.3- 1.7	1.05	0.01- 2.4	3

Table 2. Average concentration of heavy metals in the air of Isfahan, Manchester and London compared to WHO guidelines (ng/m^3)

Metals	Isfahan	Manchester	London	WHO
Pb	297.5	130.0	130.8	500
Zn	498.0	126.0	339.0	No guideline
Cd	6.0	6.5	4.2	5

Figure 6 shows the concentration of Zn in the air of Isfahan and indicates that the average concentration of Zn is approximately 500 ng/m^3 and the highest concentrations were observed in the southern part of the city around 600 ng/m^3 and the next most elevated concentrations were observed in the north-central part of the city at around 560 ng/m^3. The concentration of Zn in the air of Manchester was reported as 339 ng/m^3 and in the city of London was 126 ng/m^3. Therefore the Zn concentration in the air of Isfahan is approximately 1.5 to 4 times higher than these cities in England. This high concentration of Zn in the air of Isfahan correlates with high Zn concentrations in soils in the northern parts of the city, but in the southern parts of the city the results do not correlate with the Zn concentration in soils. The high Zn concentration in the air in the southern parts of the city could also be due to windblown dust from mining activities in the Irankuh mountain located approximately 15km southwest of the city, which contains rich veins of zinc and lead ores. Alternatively they could be derived from heavy industrial activities such as two large steel plants located southwest of Isfahan. According to Nriagu (1978), after leaded gasoline, the steel plants have the highest anthropogenic effect on heavy metals concentration in air.

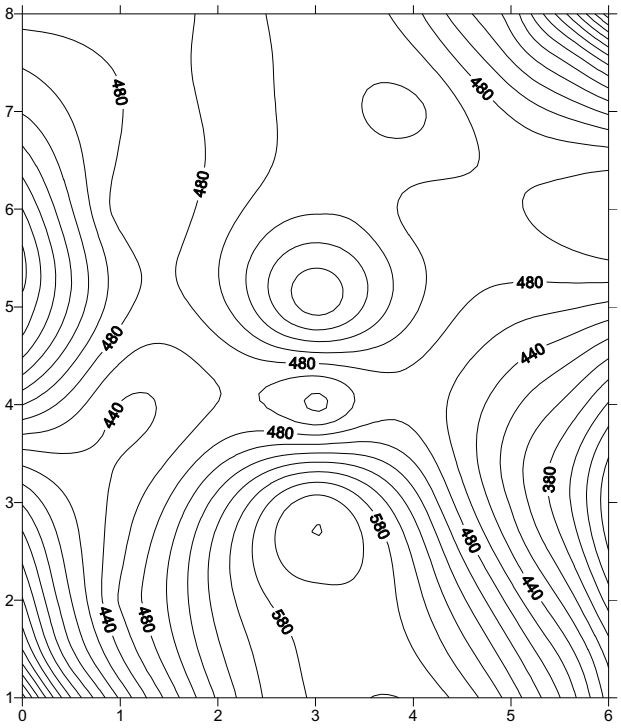

Figure 5. Isopleth plot of lead in the air of Isfahan (ng/m^3)

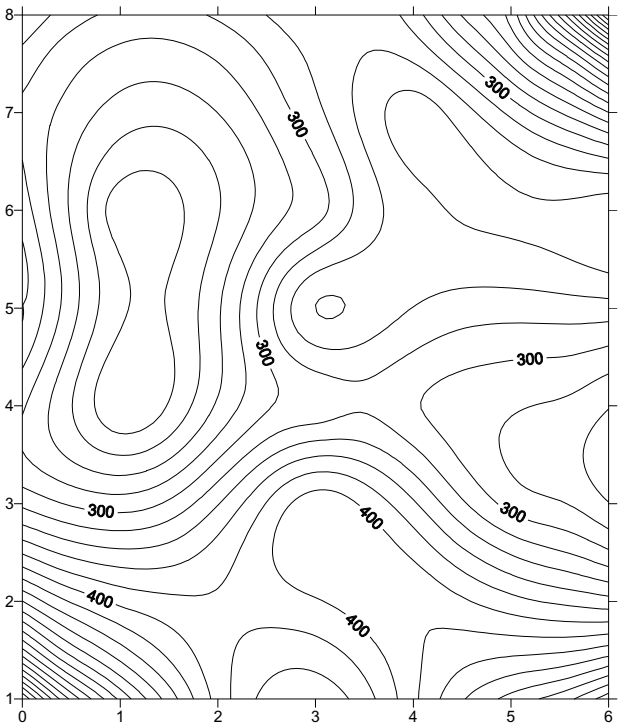

Figure 6. Isopleth plot of zinc in the air of Isfahan (ng/m^3)

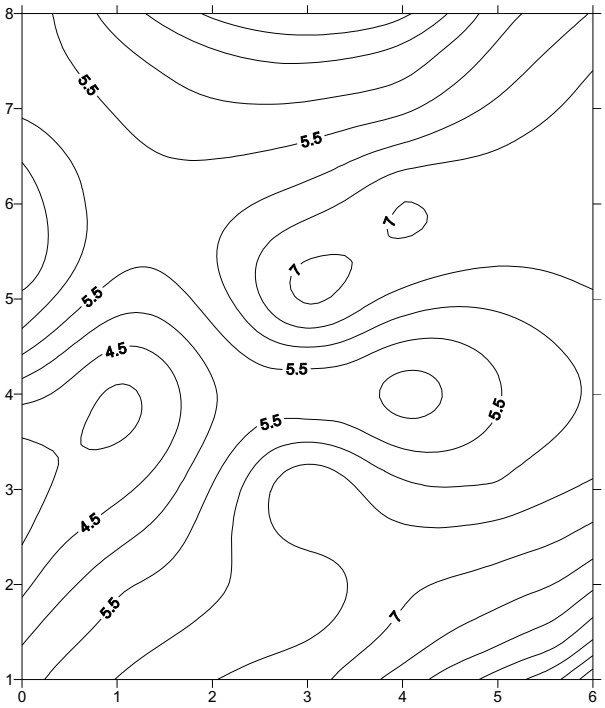

Figure 7. Isopleth plot of cadmium in the air of Isfahan (ng/m^3)

Figure 7 shows the isopleths for Cd in the air of Isfahan. The results indicate that the average concentration of Cd is about 6.0 ng/m^3 and the highest concentration is in the north-central part of the city around 7.0 ng/m^3. The concentrations of Cd in the air of the cities of Manchester and London were 6.5 and 4.2 ng/m^3 respectively, and the concentration of Cd in the air of city of Isfahan is not very high in comparison, and when compared to the WHO guidelines it is observed to be at a near acceptable level. It should be noted that the highest concentration of Cd in the air in the north-central part of the city closely correlates with a high concentration of Cd in soil in the same part of the city which indicates that soils polluted with Cd could be a major source of Cd in the air of Isfahan.

In order to further assess the correlation between the concentration of Pb, Zn and Cd in air and soil, the concentration of total suspended particulates (TSP) in air was also investigated. The results of the TSP measurements are shown in figure 8. The highest concentration of TSP was observed in the north-central part of the city and this correlates very well with the high concentration of Pb, Zn and Cd observed in air. These results indicated that although higher concentrations of metals in soil may not directly affect the concentration of metals in air, the dust from polluted soils will have a direct effect on presence of metals in air.

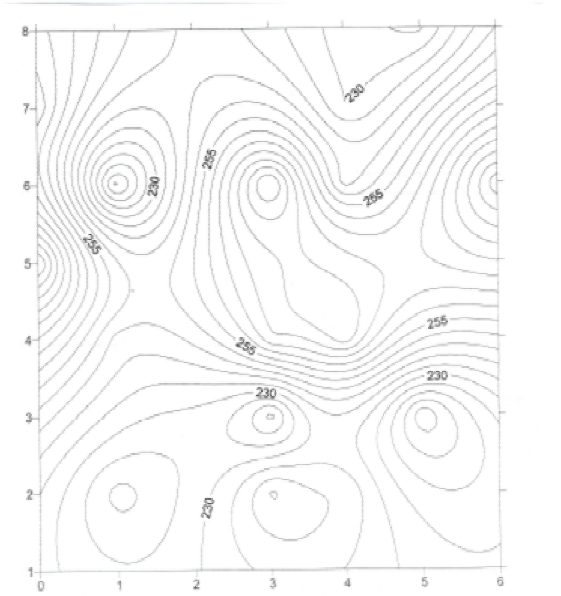

Figure 8. Isoline plot of TSP in air of Isfahan (µg/m^3)

CONCLUSIONS

The highest concentration of Pb, Zn and Cd in surface soils are found in the north-central parts of the city of Isfahan and are less than the normal ranges of world soils.

- The highest concentrations of Pb and Zn in the air of Isfahan are in the southern and north-central parts of the city, while the highest concentration of Cd in air is in the north-central part of city.
- The average concentrations of Pb and Zn in the air of Isfahan are less than the WHO guidelines but when compared to the cities of Manchester and London are 3 to 4 times higher for Pb, and 1.5 to 4 times higher for Zn.
- The concentration of Cd in air is higher than the WHO guideline but approximately equal to the cities of Manchester and London.
- High concentrations of Pb, Zn and Cd in the air of Isfahan closely correlate with high concentrations of Pb, Zn and Cd of soil in north-central part of city, but in the southern parts of the city further investigations are needed.
- The high concentration of heavy metals are well correlated with an increase in TSP in air, which indicates that the higher dust content in air, potentially resulting from polluted soils, will have direct effect on increase of heavy metals in air.

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