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GIS-based approach to evaluate heavy metals in urban street dusts of southwest Iran (Case study: Bushehr)

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Abstract—Thirty street dust samples were collected from all over Bushehr city, Iran, to characterize the spatial distribution and sources of two soil heavy metals (Pb, and Mn) and for the interrelation patterns of these elements, anthropogenic, the multivariate analysis was applied. Samples were collected by the random systematic method. The concentrations of Pb, and Mn were analyzed with an ICP-AES. Principal component analysis (PCA) was used, and geostatistics was conducted for the data processing. The results showed that the main source of the Pb is anthropogenic, mines of Mn natural material. The result's finding of this research showed that multivariate statistical analysis, a powerful tool for identifying and monitoring sources of heavy metals of street dust.

Index Terms—Geostatistics, Heavy metals, Principal component analysis, Spatial variability, Street dust.

1. Introduction

STREET dust, particles deposited on a road, originates from the interaction of solid, liquid and gaseous materials produced from different sources (Banerjee, 2003). Components and quantity of street dust are environmental pollution indicators (Yongming et al, 2006). Street dust receives varying inputs of heavy metals from a variety of mobile or stationary sources (Bilos et al., 2001; Manno, 2006) , such as vehicular traffic, industrial plants, power generation facilities, residential oil burning, waste incineration, construction and demolition activities and resuspension of surrounding contaminated soils (Manno, 2006), and makes a significant contribution to the pollution in the urban environment. Therefore, the study of street dust is important for determining the origin, distribution and level of heavy metal in urban surface environments.

In recent decades, more and more attention has been paid to heavy metal pollution in urban road dust in that heavy metals exert considerable impacts on human health and ecosystem. For example, lowlevel lead exposure can be harmful to enzyme systems, brain and blood production for human body; and high Pb level may affect blood Pb level and intelligence (Poon and Liu, 2001; Sezgin et al., 2003). Long-term exposure to lead can increase the probability of mentally retarded children and slow down the mentality development of children (Ahmed and. Ishiga, 2006).Some trace metals (such as Cu and Zn) at small amounts are harmless, but some (mainly Pb, As, Hg and Cd) even at extremely lowconcentrations are toxic and are potential cofactors, initiators or promoters in many diseases and cancer (Dockery and Pope, 1996; Willers et al., 2005). Young children are more likely to ingest significant quantities of dust than adults because of the behavior of mouthing non-food objects and repetitive hand/finger sucking (Bargagli, 1998). Secondly, children have a much higher absorption rate of heavy metals from digestion system and higher hemoglobin sensitivity to heavy metals than adults (Hammond, 1982).Therefore, the study of street dust is important for determining the origin, distribution and level of heavy metal in urban surface environments.

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2. Materials and methods

2.1 Study area

The study area extends from 50° 49' 6" E to 50° 56' 8" E and 28° 49' 5" N to 29° 0' 5" N, in the central city of Bushehr provenance in southwestern Iran(Fig.1) and has a space of about 1441.949 km^2 with a population of almost 225,297 in 2010. The city is boarded by the Persian Gulf on its south and west. Bushehr has a hot and humid climate, with an annual average temperature of 24°C and annual precipitation of 217 mm. The prevailing wind is northwestern. The main industries surrounding Bushehr city include the production of plastic and polymeric sheets.

2.2 Sampling and sample analysis

Thirty sites were selected in Bushehr for street dust sampling, including heavy- and low-traffic density areas, commercial areas and residential districts (Fig.1). Samples were collected using a clean plastic dustpan and a brush (Lu et al.

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2010; SalimAkhter and Madany 1993), from each 1 m2 sampling area (Wei et al. 2009). All collected dust samples were stored in sealed polyethylene bags, labeled and then transported to the laboratory. All samples were dried in a laboratory oven at 70°C, and then sieved through a 1.0mm mesh nylon sieve to remove refuse and small stones. The resulting street dust samples were used to analyze heavy metal concentration. A 0.5g of milled street dust sample was digested with 8ml of HNO_3 65%, 5ml of HCl37%, and 1.5ml of HF 40% in Milestone Microwave (Manual of Microwave). The concentrations of Mn and Pb in the street dust samples were then determined using ICP-AAS.

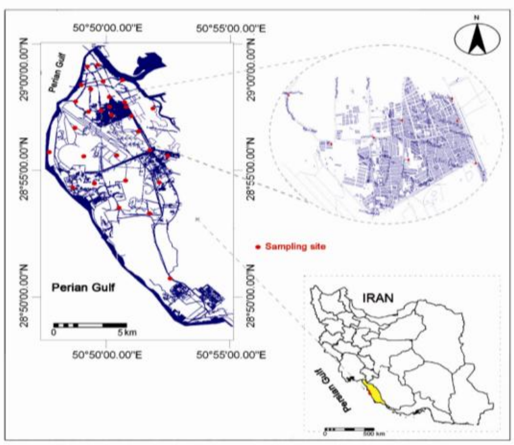

Fig. 1.Sampling site in Bushehr city

2.3 Statistical analysis

Relationships between heavy metals in the street dusts were determined using Pearson's correlation coefficient analysis, principal component analysis (PCA) using the Mosaic version 3.01 software.

2.4 Geostatistic methods and mapping of metal concentration

The maps of spatial distribution of heavy metal concentrations were produced by Kriging the interpolating data from 30 road dust samples using ILWIS 3.6. The major aim of kriging is to find the statistical weights of observations with non- skew estimations and minimum variance of estimations. So,kriging results in the best linear non- skewed estimator (Lark 2000). In this study we used ordinary kriging for evaluating the distribution of Mn and Pb concentration.

3. Results and Discussion

It is common to compare mean concentrations of heavy metals in road dusts in different urban locations (Charlesworth et al. 2003; Duzgoren-Aydin et al. 2006; Lu et al. 2009), while there are no generally accepted sampling and analytical protocols for geochemical studies of urban deposits. Results of ANOVA showed that concentration of Pb had different between stations (Fig.2a), but no difference had between stations based on concentration of Mn (Fig.2b).

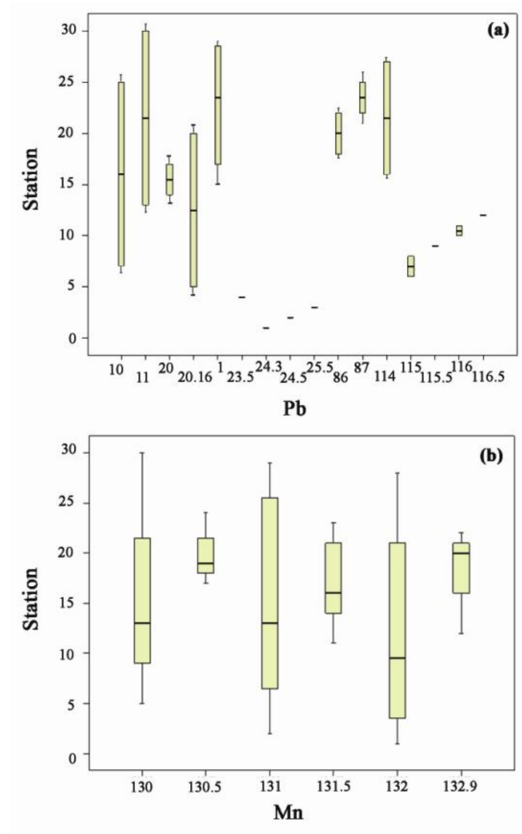

Fig.2. Concentration of Pb (a) and Mn (b) in studied stations

Concentrations of heavy metals measured in street dusts of Bushehr were compared with reports presented for other areas (Table 2), the concentration of Mn and Pb in all the cities listed in the table above were higher than Bushehr, except Converty and Birmingham where the Pb level was lower than Bushehr. The Mn concentration was less than the global average, while the Pb concentration was higher than the global average.

PCA (Principle Component Analysis) was used by applying varimax rotation with Kaiser Normalization to identify sources of heavy metals in the street dust. The eigenvalues and eigenvectors were extracted from the correlation matrix, and the number of significant factors and the percent of variance explained by each of them were calculated. Factor loadings with varimax rotation, as well as the eigenvalues indicated that there were three components with eigenvalues higher than one and that these three factors explained 99.8% of the total variance.

Table1. Comparison of heavy metal concentrations in street dust of Bushehr relative to other selected cities

City	Mn	Pb	Reference
Baoji	804.2	433.2	(Lu et al. 2010)
Kavala	-	301	(Christoforidis and Stamatis 2009)
Guangthal	481	240	(Duzgoren-Aydin et al. 2006)
Amman	-	236	(Al-Khashman 2007)
Kayseri	-	28-312	(Tokalioglu and Kartal 2006)
Yazgat	-	69	(Divrikli et al. 2003)
Calcutta	619	536	(Chatterjee and Banerjee 1999)
Luanda	258	351	(Ferreira-Baptista and De Miguel 2005)
Istanbul	-	61-383	(Sezgin et al. 2004)
Madrid	362	1927	(Miguel et al. 1997)
Birmingham	-	48	(Charlesworth et al. 2003)
Coventry	-	47	(Charlesworth et al. 2003)
Manchester	-	265	(Robertson et al. 2003)
Aviles	1661	514	(Ordonez et al. 2003)
Bahrain	-	697	(Salim Akhter and Madany 1993)
Cuenca	-	19-970	(Nicholas Hewitt and Candy 1990)
Kuala lumpur	-	2466	(Ramlan and Badri 1989)
Xian	687	230.2	(Yongming et al. 2006)
london	-	1030	(Schwar et al. 1988)
Athen	-	-	(Yassoglou et al. 1987)
Nigeria	-	4-243	(Ndiokwere 1984)
Olso	833	180	(Miguel et al. 1997)
lancaster	-	150-15000	(Harrison 1979)
Hong kong	594	120	(Lau and Wong 1982)
Bushehr	132	58.17	This work

The first factor explains 70.5% of the total variance due Pb. Factor 2, dominated by Mn, accounted for 27.06% of the total variance. Factor 3 accounted for 2.23% of the total variance. Figure 3 indicate that the origins of the metal lead and manganese were different.

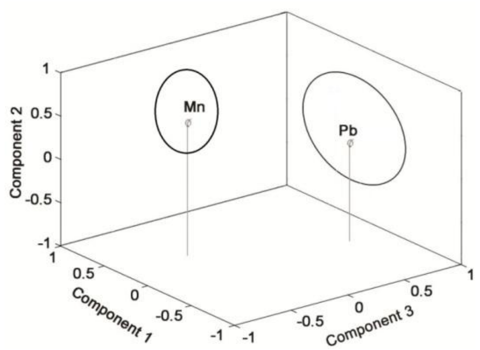

Fig.3. the three principal components in three dimensional space

The distribution patterns of the elements in the studied area are presented in Figure 4. It was evident that the pattern of spatial distribution for Pb and Mn were different. Their hot-spot areas for Pb were principally associated with stations where high traffic density was recognized. Spatial distribution of Mn showed that this element had almost similar concentrations in all stations and concentration of Mn was moderate (not too high or low). This pattern indicates that the origin of Mn is likely due to natural sources (Ferreira-Baptista and De Miguel 2005; Oliva and Espinosa 2007; Wang and Qin 2007).

4. Conclusion

The concentrations of heavy metals (as non- point pollutants) with potential effects on humans and the environment make them a global issue. The results of the street dust samples collected from Bushehr showed that concentrations Pb was higher than global values, while the concentrations for Mn was lower than global values. The heavy metals were classified into two main groups according to their sources: Pb was associated with heavy traffic, while Mn was associated with natural sources.

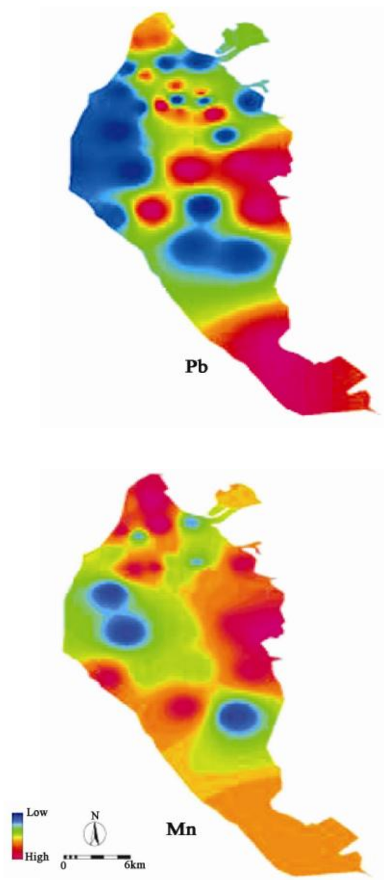

Fig.4. Geospatial distribution of the elements

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