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MAPPING HEAVY METALS CONTAMINATION IN URBAN TOPSOIL OF FAISALABAD CITY, PAKISTAN

MUHAMMAD NASAR-U-MINALLAH*, NUSRAT PARVEEN**

*Department of Geography, Govt. Graduate College Gojra, Pakistan
**Department of Geography, Govt. College University Faisalabad, Pakistan
*Corresponding: nasarbhalli@gmail.com

ABSTRACT

This study explores the spatial distribution, patterns, and degree of heavy metal pollution in 48 soil sample sites from the urban area of Faisalabad-Pakistan. This research is based on an extensive urban topsoil survey conducted in the second largest industrial city of Pakistan. The present study analyzes the heavy metals contents (Zn, Cu, Pb, Ni, As, and Cd) by ICP (inductively coupled plasma spectroscopy) in the City's topsoil with various land use such as solid waste sites, urban parks, and roadside soils. Moreover, nutrients contents such as Na, K, Ca, and Mg have also been determined through the Flame photometer and buffer analysis respectively. The multivariate geostatistical analysis has been performed through Arc GIS and SPSS. It has been recognized through the geochemical maps based on the IDW (Inverse distance weight) analysis that there were many hotspots for Zn, Cu, Ni, and Pb in the soil of solid waste, urban parks and roadside soil sites with mean concentration ranged from 21.9-200.1, 12.03-109.85, 12.32-33.90 and 0.00-30.25 mg/Kg, 25.02-111.15, 13.83-53.23, 9.30-26.00, 0.00-18.93 mg/Kg and 19.2-336.8, 11.25-73.20, 13.38-29.70, 0.00-27.05 mg/kg respectively. Moreover, the nutrients such as K and Na's mean concentration in the solid waste sites, urban parks, and roadside soil ranged from, 1.357-3.50, 0.7619-1.924mg/g, and 1.357-3.142, 0.4762-1.4762mg/g, and 0.786-3.392, 0.4762-1.5238 mg/g respectively. Similarity index was calculated and the decreasing order for the calculated variance about the analyzed parameters is Zn>Cu>Ni>Pb. The monitoring and soil quality assessment are fruitful for sustainable development of the urban environment of Faisalabad-Pakistan.

KEYWORDS: Geo-statistics, Heavy Metals, IDW, Urban Top Soil, SPSS, ICP

INTRODUCTION

The processes of industrialization and urbanization have added certain contaminants into the urban environment of many cities in the world (Tume et al. 2008; Ali and Malik 2010). Since the onset of the Industrial Revolution contamination by heavy metals has become a global concern, the heavy metal's flux has amplified in recent years and began to enter into the water, air, and soil sphere of the earth (Yang et al. 2011). The addition of chemical contaminants into the soil is of major concern for geographers, soil scientists, agronomists, and environmentalists. These heavy metals are most often added to the soil through natural and anthropogenic processes. Additionally plentiful point and non-point bases of heavy metals recurrently linked to the transportation network, urban growth, economic and industrial complex. Furthermore extremely toxic rudiments and radioactive stuff (Yesilonis et al. 2008; Lourenco et al., 2010) such as vehicular emission, commercial fertilizers, paper pulp, tire, the organic industry, and atmospheric deposition of pollutants in the course of dust, aerosols, industrial and domestic waste (Zubillaga et al. 2008; Yisa 2010). The heavy metal contents in urban soil have long biological persistence in the pedosphere (Zhang et al. 2009) and later on through the dermal contacts, inhaling and ingestion induce threat of certain diseases and predominantly act as a carcinogenic (Chen et al. 2005; Odewande et al. 2008).

The state of the physical environment and its quality management in a region can be studied easily with the availability of the data regarding the rock, soil types, contaminants, green spaces, and other natural and human incidents (Da-Silva et al. 2010). The present research is an attempt to provide a better evaluation and identification of heavy metals found in topsoil in the city of Faisalabad and to identify the hot spots for serious thinking and ultimate provoking to the environmentalists, pedologists, and urban planners. This will help them to formulate strategies to protect the soil. Since the soils are predetermined, increasingly sparse, and non-renewable resource, therefore, findings of the present research can be advantageous for urban ecosystem efficiency as well as for risk appraisal about human health. In this paper, the interpolation spatial analyst method of Geographic Information System has been applied (Li et al. 2001). This technique is found useful for analyzing the presence of heavy metals and their spatial variations in different urban landscapes i.e. road dust with intense traffic, municipal solid waste sites, and urban green areas (Bhattarai, 2006). Thus current research aiming at to evaluate spatial patterns of heavy metals contamination mapping in urban topsoil of Faisalabad and also to discuss and compare the contamination patterns in solid waste sites and urban parks as well as road dust of Faisalabad city.

MATERIALS AND METHODS

Study area

Faisalabad city is a metropolitan part of district Faisalabad and one of the first planned cities of Pakistan. It is in the middle of the Punjab province (Figure 1). This city has very important transportation junctions such as railways and roads. This planned city has played a vital role in the country's development due to its industrial growth, especially in the cotton-textile sector. This is an important industrial hub after Karachi. The city has experienced a rapid population growth of about 2.5 million and is 3rd largest metropolitan city of Pakistan in terms of population after Karachi and Lahore. It is bordered on the north side by the districts of Chiniot and Hafiz Abad while the east side is surrounded by Nankana Sahib and the south is bounded by Toba Tek Singh & Sahiwal.

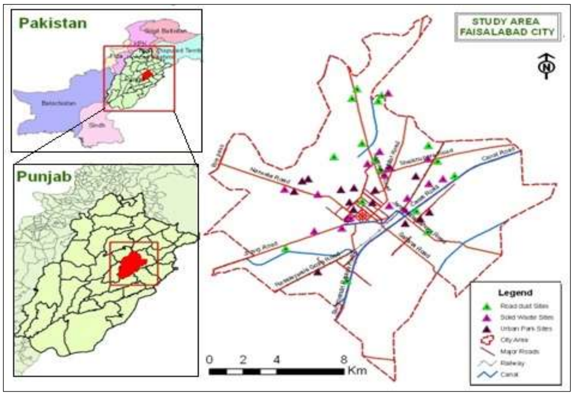

Figure 1. Faisalabad city, depicting soil sample sites

Data and Analysis

A total of 48 soil samples have been collected by taking randomly selected. A 15cm long iron trowel was utilized for sampling purposes and accumulated in polyethylene bags. Heavy metals contamination were analyzed through the Optical Emission Spectroscopy and PerkinElmer 2100 DV and Inductively Coupled Plasma (ICP) (Bhattarai 2006; Lee et al., 2006) at the laboratory of Nuclear Institute of Agriculture and Biology (NIAB) for Cd, As, Ni, Zn, Pb, Cu. Sodium, Potassium, Calcium, and Magnesium were detected by buffer analysis. Maps of pollution assessment were designed by using a geographic information system. Spatial mapping of heavy metals in urban topsoil was carried out for three types of land use by interpolation method of IDW (inverse distance weight analysis), while statistical measures of multivariate approach such as PCA (Principal Component Analysis, Cluster analysis, Correlation analysis) have also been incorporated in the final analysis. Correlation among the heavy metals contaminants and their comparison within a particular land use were also developed.

RESULTS AND DISCUSSIONS

Spatial and statistical analyses along with contamination permissible levels and comparisons in selected urban land use have been discussed. The spatial division of Zn in the solid waste site's soil range from 20mg/Kg to 200mg/Kg. Zn Amount in the topsoil is connected to human activities. The Zn presence has powerfully been allied with solid and liquid discharge from industrial and domestic waste (Tume et al. 2008). While in the 2nd class which is urban park Zn (mg/Kg) contamination ranges from 25mg/Kg to 111mg/Kg). 3rd class of land use which is road dust has a level of Zn contamination range from 19mg/Kg to 87mg/Kg. Zn emission is linked with transportation and human activities (Akbar et al. 2006; Yesilonis et al. 2008; Lourenico et al. 2010). The highest quantity of Zn 336.75 mg/Kg larger than the tolerance level was in the soil of open drain on the Sheikhupura road (Table 1, Figure 2).

Table 1. Values of heavy metals comparison with the adequate range

Elements	Acceptable Limits (mg/Kg)	Mean Urban land use value (mg/kg)		
		Solid Waste Sites	Urban Parks	Road Dust
Zn	135-150	21.9-200	25.02-111	19.2-336.8
Cu	30-40	12.03-110	13.83-53.23	11.25-73.2
Pb	85-450	0.00-30.25	0.00-18.93	0.00-27.05
Ni	30-70	12.32-33.9	9.30-26.00	13.38-29.7

Source: Warmate, 2011; Pervee, 2011; Perveen et al., 2012; 2012a

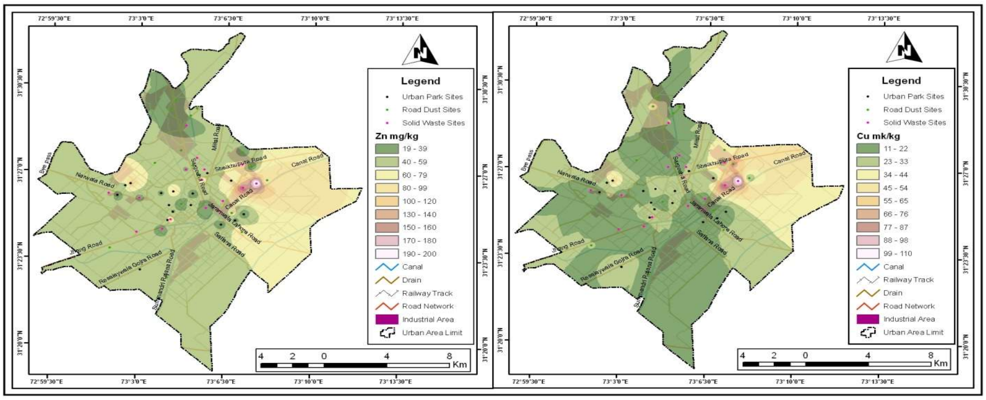

Figure 2: Z, Cu contamination in three types of urban land use

The amount of Cu in the solid waste site's soil ranged from 12mg/kg to 109mg/kg and has strong human influence. On the other hand, the subsistence of Cu has been linked with dumping from industrial and domestic waste (Tumuklu et al. 2007). The spatial disparity of Cu contamination in urban parks' soil is from 14mg/Kg to 53mg/Kg hot spot for the said parameter was reported in Go Park. While Cu in road dust has a value from 11mg/Kg to 73mg/Kg., therefore this chemical equilibrium of the urban ecosystem is a threat due to the industrial actions and road dust (Akbar et al. 2006).

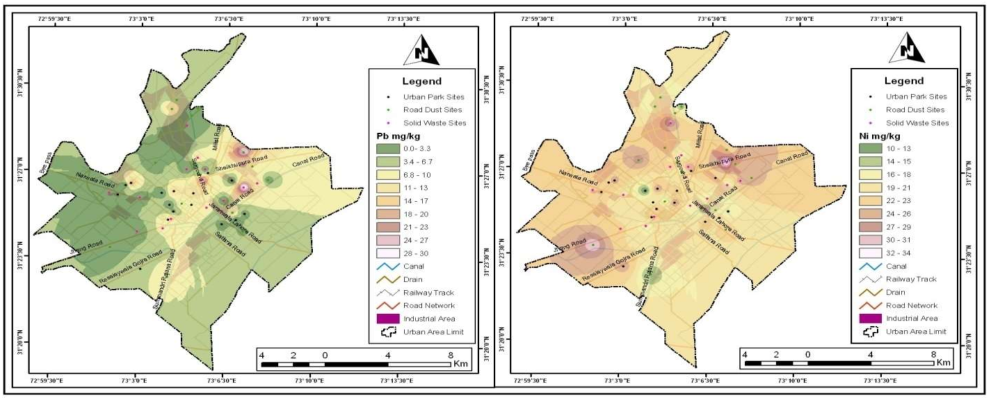

Figure 3: Pb, Ni contamination in three types of urban land use

The maximum quantity of Cu 73mg/Kg which crossed the permissible level (Table 1) was in the soil near the drained on Sheikhupura road. The highest Cu concentration was observed in Solid waste site soil with the comparatively less value in road dust and least among the three types of land use in Urban parks (Figure 2). While Pb concentration exists in the solid waste site's soil ranges from 0mg/kg to 30mg/kg. 95% of Pb release into the environment has been gradually relevant to anthropogenic influence. Pb is a toxic and non-degradable element its emission is related to gasoline use in vehicles (Esakku et al. 2003; Ali and Malik 2010). Pb contamination in the topsoil of the urban park of Faisalabad mapped by IDW and spatial variation of Pb lies from 0mg/Kg to 19mg/Kg Although Pb existence is connected to human action (Karishna and Govil, 2008) yet urban parks of Faisalabad have the least amount of Pb because of least vehicular effect. Pb has been an influx into the soil through industries and transportation (Jankiewicz and Adamczyk 2007; Adija et al. 2008; Maas et al. 2010). Road dust has Pb values from 0mg/Kg to 27mg/Kg. The maximum amount of Pb 27 mg/Kg was observed in the soil of Club road near Ibrahim Group of Industry. Interpolation of data by IDW provides a comparison between the soil sample points of three types of land use although maximum concentration reported in solid waste site yet the road dust is enriched with Pb as many sites experiencing the value from 23-29mg/kg. Urban parks stand least in the category of Pb Concentration (Figure 3).

Table 2: Eigen analysis of the correlation Matrix (Zn, Pb, Cu, Ni (mg/kg)

Eigen analysis of the correlation matrix				
Eigen value	2.2360	1.0755	0.5429	0.1457
Proportion	0.559	0.269	0.136	0.036
Cumulative	0.559	0.828	0.964	1.000
Variables	**PC1**	**PC2**	**PC3**	**PC4**
Zn	0.589	0.113	-0.517	0.544
Pb	0.494	-0.368	-0.743	0.264
Cu	0.635	0.073	0.117	-0.760
Ni	0.075	0.920	-0.372	0.093

The presence and extent of Ni in the soil have not been related to anthropogenic activities. It is usually considered an ingredient of rock natural geology (Wong et al. 2006). The IDW maps depict maximum soil solid waste samples with have Ni value range from 15-23mg/kg. while Ni contamination found in urban parks' soil range from 9.3mg/Kg to 25.75mg/Kg and road dust has varied from 13mg/Kg to 30mg/Kg highest of the three selected land use (Figure 3). Na is a natural constituent of parent rock material and its presence in the soil the naturally related to rock geochemical composition (Ali and Malik, 2010).

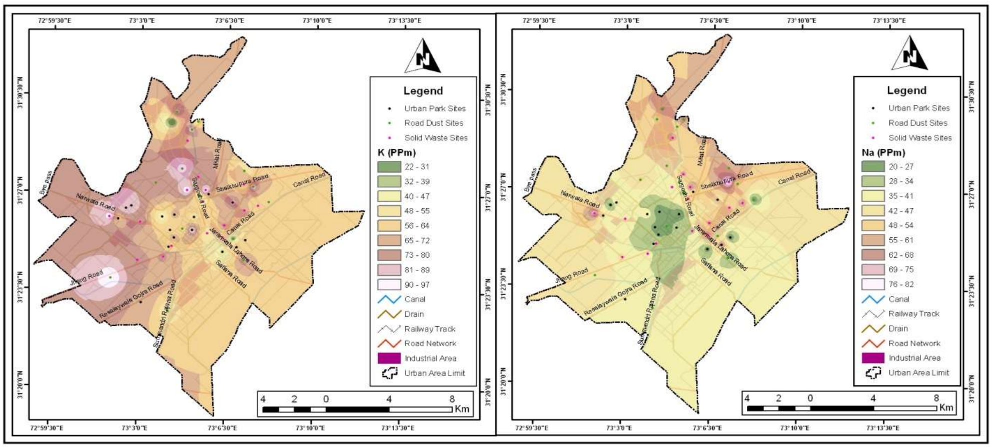

Fig 4: k, Na in concentration in three types of urban land use

For solid waste site soil 32PPm to 82PPm, road dust has 20mg/Kg to 64mg/Kg and urban parks Na value range 20mg/g to 62mg/g. K concentration in the solid waste site's soil ranges from 22PPm to 95PPm, urban parks have ranged from 38mg/Kg to 88mg/Kg and roadside soil contains 22mg/Kg to 95mg/kg of contamination.

Table 3: Zn, Pb, Cu, and Ni (mg/Kg) variable cluster analysis

Step	No. Of Cluster	Similarity level	Distance level	Clusters Joined		New Clusters	NO. of Observation in the new cluster
1	3	90.7493	0.185015	1	3	1	2
2	2	75.1357	0.497287	1	2	1	3
3	1	52.0869	0.958262	1	4	1	4

Source: Pervee, 2011; Perveen et al., 2012.

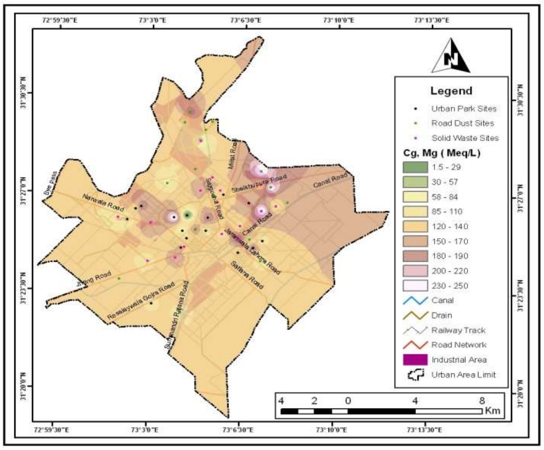

Fig 5: Ca, Mg concentration in three types of urban land use

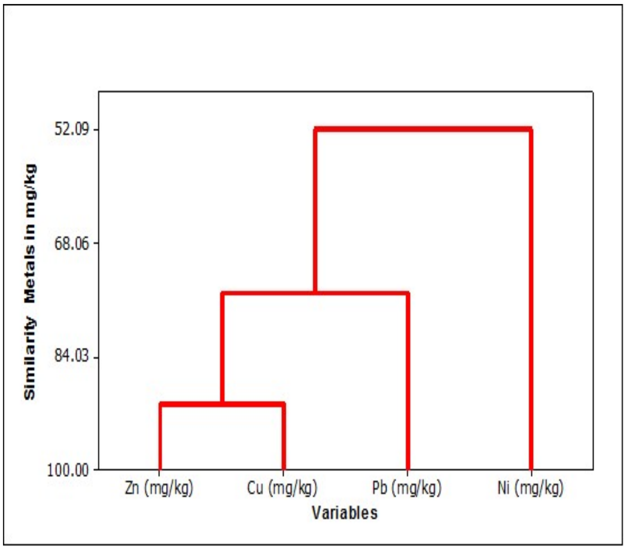

Figure 6: Correlation Coefficient Distance of Zn, Cu, Pb, Ni Dendrogram

The calcium and magnesium level in the solid waste site's soil ranges from 50 to 250Meq/L, urban parks from 60 to 250Meq/L, and road dust 80 to 250 Meq/L (Figure 5). Cluster 1 and 3 were coupled with 90.7% of similarity level whereas 0.185015 was distance level. mg/Kg) with the similarity level 75.1 along with distance level 0.497287. Furthermore, cluster 1 (Zn mg/kg) also coupled with cluster 4 (Ni mg/kg) with 0.958262 distance level between them, 52.01 the corresponding similarity level (Figure 6 & Table 2).

CONCLUSION

The polluted and contaminated site identification would be the first step to control contamination initiative processes and formulate remedy action. Moreover, the average concentration of Zn road dust > solid waste sites> urban parks. The maximum average concentration for Pb follows an order of the solid waste sites soil >urban parks >road dust respectively. The average concentration of Cu is ordered as solid waste sites soil>urban parks>road dust. Urban soil average concentration for the Ni follows an order urban parks> solid waste > road dust. The average quantity of Na (PPm) observed in an order of solid waste sites> road dust> urban Parks. The average concentration order for K is Solid waste sites soils> road dust> urban parks. The average concentration of Ca and Mg for the three types of urban land use soil is road dust> urban parks > solid waste sites soil. The reducing order for the computed variance about the evaluated parameters is Zn>Cu>Ni>Pb. Regular observing of heavy metal contamination in urban topsoil is indispensable for the safeguard of the millions of people living in

Faisalabad city. Similarly, to diminish the extent and scale of future pollution problems in the city, regular topsoil survey should be carried out by respective administration of each union council. In addition, more health impact analysis of heavy metals can be conducted in future studies in the domain of urban environmental stability perspectives. The analytical results of the research should be made available to stakeholder involved in monitoring, management and appraisal of soil contamination for a better city.

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