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Heavy metal content in urban soils as an indicator of anthropogenic and natural influences on landscape of Karachi—A multivariate spatio-temporal analysis

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ABSTRACT

Urban soil is influenced by both the natural and anthropogenic factors. Their impacts, therefore, amend the concentration of heavy metals in urban soils. In this study, the concentration of selected heavy metals including Cu, Zn, Pb, Fe and Cr in urban soils was assessed in the megacity of Karachi, Pakistan. Variability of metal concentration across distinct urban land uses, and through seasonal interventions was used as an indicator of the factors involved. For spatial analysis, soil samples were collected from 30 different locations, belonging to 6 distinct land uses dominant in the megacity. For temporal investigations, the samples were collected in both pre-monsoon (PRM) and post-monsoon (POM) conditions. The results revealed that the mean concentrations were in the order Fe ≫ Zn > Pb > Cu > Cr, in both the seasons. Increase in concentration of Pb and Fe, after rain, seems to be the result of sinking of aerial metal and relocation by flood runoffs. The concentration of Cu and Zn decreased in the POM season possibly due to dilution by rainwater. The spatial variation in the concentration of Cu, Zn and Pb metals seemed to be the result of point sources and vehicle emissions. Fe, despite of its very high average concentration in soil, shows moderate spatial variation (Variance <50%) which indicates the non-point nature of its sources. Cu, Zn and Pb showed their common sources (through anthropogenic activities) and the relationship have been proved by both the multivariate and spatial analyses. However, Cr seemed to have least affected by anthropogenic activities due to weaker and/or no correlation.

1. Introduction

Urban ecosystem is characterized as a complex composite of both the natural and anthropogenic factors. The local climate, geology and the geographical characteristics are regarded as the main natural factors that influence the urban environment. Whereas the anthropogenic factors may include population and settlement patterns, use and misuse of resources and behavior of the human inhabitants primarily governed by their socio-economic conditions. The mega-urbanization in form of increased population density, intense industrialization and excessive exploitation of natural resources characterize a megacity as a unique system but has its consequential deteriorating impacts on the overall structures and functions of the ecosystem (Antrop, 2000; Qureshi et al., 2010).

Soil is a dynamic natural resource for the survival of human life and due to its complex matrix is the prime receiver of the relentless pollutants such as heavy metals (Goulding and Blake, 1998; Luo et al., 2007). Every soil contains some natural amounts of heavy metals, at concentrations called backgrounds. The magnitude of a metal's background depends upon the composition of the parent rock material from which the soil was derived (De Temmerman et al., 2003; Ojanuga et al., 1996; Scazzola et al., 2003). Human activities that add waste material to the urban soils also influence its metal concentration; examples of such activities include soil excavation and land filling at dump-sites and construction sites by domestic or industrial wastes or with natural or disturbed soils and demolition wastes, incineration wastes and crushed rocks etc. (Anikwe and Nwobodo, 2002; Pastor and Hernandez, 2012; Wang et al., 2012). It also includes inappropriate drainage of waste-fluids from metallurgic or metallic artifact manufacturing industries, power generation and distribution, transportation etc. One of the most important anthropogenic source of a group of heavy metals including Zn, Cu and Pb in urban environment is the automobile traffic (Wei and Yang, 2010). The engine exhausts produced by the fuel combustion, engine wear, the wear of tires and the associated moving parts, leaks and spills from batteries and radiators – all contribute these heavy metals to the immediate environment (Denier van der Gon and Appelman, 2009). Due to their abundance and the

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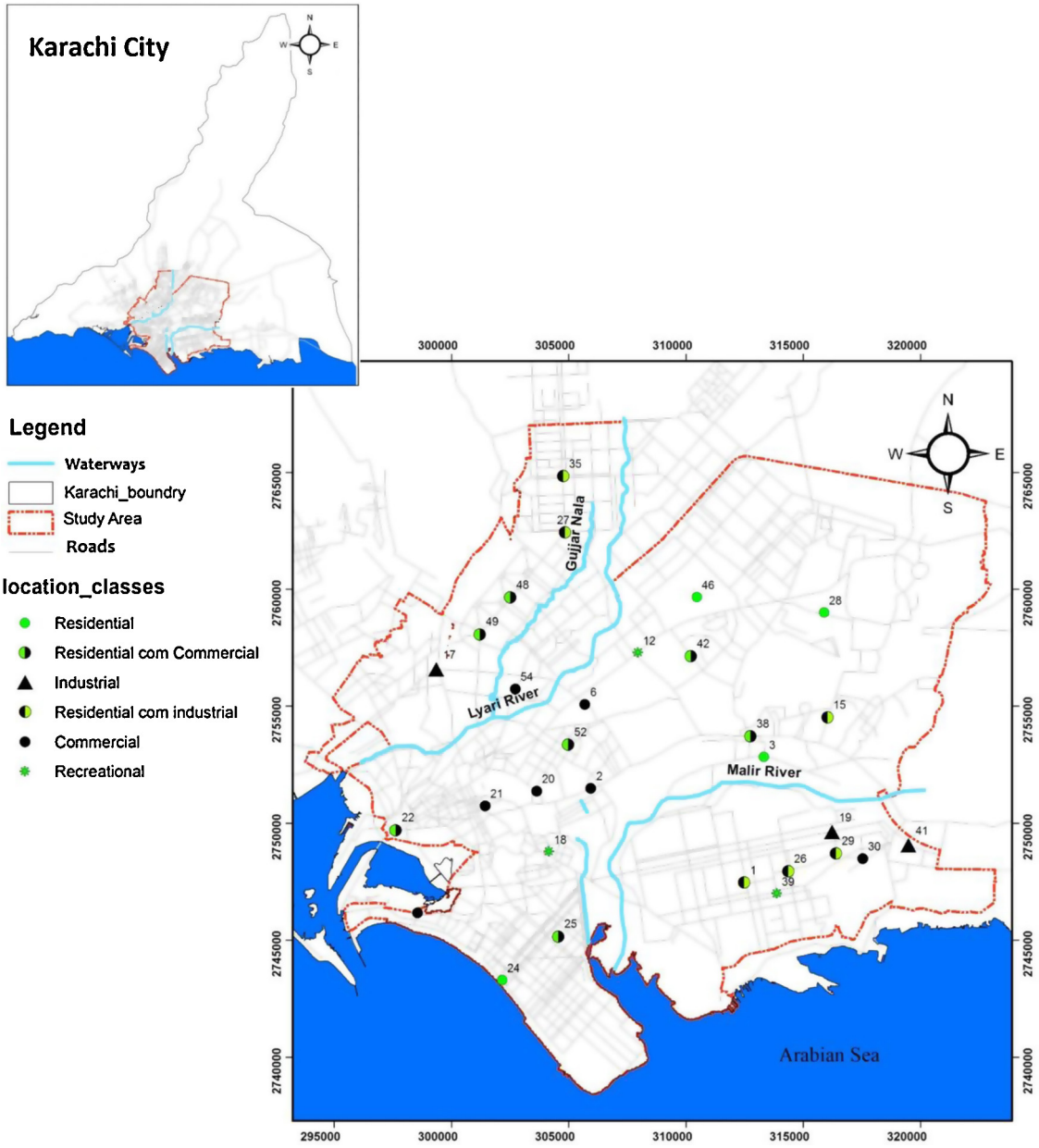

Fig. 1. Map of Karachi, study area, sampling locations and corresponding land use.

consequential environmental hazards, the above-mentioned group of metals, along with Cr and Fe are the most frequently reported heavy metals in the context of contaminated urban soils.

Karachi is one of the most populated urban agglomerations in the world. In semi-arid cities like Karachi, the airborne metal in industrial and vehicular aerosol finally sinks into the city's soil, principally at roadsides and their immediate neighborhoods (Velea et al., 2009; Davis and Birch, 2011). The average annual precipitation of around 200 mm and the yearly monsoon rainfall of 150 mm in Karachi can influence the average concentration and spatial distribution of the metals in soil by facilitating the sinking of airborne metal and elution via floodwater runoffs (Legret and Pegotto, 1999; Viard et al., 2004).

Several studies have reported the accumulation of heavy metals in the soils of Karachi (e.g. Yousufzai et al., 1998; Sharif et al., 2010). Karim and Qureshi (2013) estimated the human health risk associated with Pb, Cu, Fe, Cr and Zn in urban soils of Karachi. Nevertheless, these studies do not considered the land use aspect as an indicator having strong influence on the metal concentration in urban soils. Therefore, in this study, the variation in heavy metal concentration of urban soils was investigated in both the spatial and temporal contexts. Different multivariate statistical methods were used to evaluate the variation patterns of heavy metal contents of the soil for the seasonal transition of pre-monsoon (PRM) to post-monsoon (POM), across distinct urban land uses. The objective was to study the cause–effect relationship between human and natural impacts and soil quality in the urban environment.

2. Materials and methods

2.1. Study area and problem

Karachi is geographically located at 24°45′ N–25°37′ N and 66°42′ E to 67°34′ E. It is the largest city of Pakistan, and among the fastest growing cities of the world both in terms of population