Spatial distribution of metals in top soils of Islamabad City, Pakistan

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Abstract Present study was conducted in rapidly growing city Islamabad, and surface soils were collected from three major land cover types viz., built-up, drain side, and green areas. A total of seven physicochemical parameters and 11 metals were determined in surface soils. Factor analysis based on principal component analysis explained total variance of 68.0%, 64.5%, and 60.2% of three land cover types and showed high loadings for major elements (Mg and K) in built-up and green area and Fe in drain side. Top soil pollution index was carried out by using geo-accumulation index and metal pollution index (MPI). Concentration of major elements (Ca, Mg, Na, K) in surface soils is derived by parent material, whereas concentration of Fe, Ni, Pb, and Zn were mainly related with anthropogenic sources. Geostatistical methods such as kriging identified hotspot areas of metal contamination by Pb, Ni, and Zn in built-up areas influenced mainly by vehicular emissions and waste disposal. The results stresses that land clearing should be avoided to reduce contamination and management of urban soils.

Keywords Cluster analysis · Heavy metals · Kriging method · Spatial distribution · Urban soil properties

Introduction

The soil forms chief component of an ecosystem and is the most endangered due to influence of various human activities related to industrial, agricultural, urban development (Coskun et al. 2006). Urban soils vary spatially due to soil composition (Burghardt 2002) and determine the quality of the urban environment (Madrid et al. 2006). Urban areas are expanding all over the world utilizing more and more agricultural and natural areas (Norra and Stuben 2003). Changes in land use and land cover are gaining wide recognition as a key driver responsible for environmental change (Imbernon 1999). In the last two decades, reduction of land cover is attributed to accelerated rate of urbanization along with explosive economic growth (Chen 2007). Land converted to urban land use such as housing, parks, industrial, and disposal sites has resulted in loss of cultivated and green land and arouses special attention (Zhang et al. 2003). Land use drew attention towards possible impacts on soils and becomes an important point source controlling metal distribution in urban catchments (Snowdown and Birch 2004). Foley et al. (2005) reviewed the global...
significance of land use which indicates that although in short term, modern land use practices have given increased supplies of material goods, they have also undermined many ecosystem services in the long term. Additional input of waste materials, landscaping, and rapid change of land use also contributes towards an unpredictable modification of soil properties and poor soil structure increasing concentrations of heavy metals (Tiller 1992). Change in land use has important consequences for many biological, chemical, and physical processes in soils and indirectly to the environment (Goulding et al. 1995; Sverdrup et al. 1995). Due to land use changes, soil pollution has become important environmental issue in developing countries (Adriano 2001).

Urban soils act as a sink for heavy metals and other pollutants, possible sources of which are mainly from anthropogenic activities such as vehicular emissions (Sutherland et al. 2000), waste water sludges, and industrial wastes (Jin et al. 2005). Uncontrolled development and urbanization has also resulted in accelerating input of heavy metals in urban soils. In the last few decades, anthropogenic activities like industrial and energy production, construction, waste disposal, domestic heating system, and motor vehicles are continuously contributing towards an increase in the level of heavy metals in urban soils (Li et al. 2004). Heavy metal contents in soil are highly dependent on geochemical nature of parent material (Lee et al. 1997), and their presence in the soil is due to natural weathering of parent rock material and pedogenic processes. Conversely, their accumulation in the soils is of considerable importance because they are persistent, nonbiodegradable, and toxic to biota if it exceeds threshold values (Massas et al. 2008).

Owing to environmental and health concerns, distribution of heavy metals in urban soils have been studied in many big cities such as Glasgow (Farmer and Lyon 1977), London (Kelly et al. 1996), Hong Kong (Li et al. 2001, 2004), New Orleans (Mielke et al. 2000), and Oslo (Tijhuis et al. 2002). Many scientific studies have focused on the determination of sources, types, and degree of heavy metal pollution in soils (Einax and Soldt 1998; Plant et al. 2001; Brus et al. 2002). Spatial variability of urban soils has also been studied using geostatistic approaches (Brike and Rauch 1997; Norra 2001; Cattle et al. 2002).

Like other metropolises, Islamabad also faces a rapid urban and industrial growth resulting in degradation of soil ecosystem. The population of the city was around 950,000 (Islamabad Census Report 1998) that has resulted in conversion of farmlands/open areas to covered area, posing high risk of polluting the soil with heavy metals and other harmful substances. Developmental, increasing urbanization, and industrialization are important environmental concerns in the city. Increasing economic activities have given birth to high-rise buildings, residential apartments, housing schemes, educational institutions, industrial units, and new markets. These pressures have resulted in altering of basic physical infrastructure of the city. Due to increased pressure on land in the study area, soils are highly susceptible to pollution from different sources. Open spaces have been converted into constructed land in recent years resulting in disturbed natural soils (Zhang 2005). There is a need to better understand the relationship between land use changes and regional environmental change that drive them.

Status of urban soils and heavy metal contamination in Pakistan in terms of is not predominantly focused, and an attempt to produce an extensive survey using a systematic sampling strategy of urban soils has been limited. An understanding of the modifications of soil characteristics and their spatial variation in Islamabad is needed to combine traditionally based soil survey approach and associated soil interpretations. GIS-based approach refines and confirms geochemical interpretation of statistical output (Mielke et al. 2000; Facchinelli et al. 2001; Gritzner et al. 2001). Focus on such lines in terms of soil status is limited and has never been conducted. Analysis of the effects of land use on metal concentrations in soils is, therefore, critical for the making of policies aimed at reducing metal inputs to the soils and maintenance of soil functions. Therefore, this study attempts to report the spatial variability of soil physicochemical properties. The aims of the present work were (1) to measure the total (acid extractable) and available (water soluble) physicochemical concentrations in top soils of three land use, (2) to define possible pollution sources in top