Total concentrations, fractionation and mobility of heavy metals in soils of urban area of Guwahati, India

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Abstract This work describes the results of assessment of the heavy metals, Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn in urban soil of Guwahati City, India from 31 sites of five different land use types covering residential, commercial, industrial, public utilities, and roadside. Sequential extraction procedure was used to evaluate the relative distribution of the eight metals in exchangeable, carbonate, reducible (Fe–Mn oxide), organic and sulfide, and residual fractions. Of the eight metals, Cd and Co occur in lower concentrations (Cd << Co) in all types of land, and concentration variation from one type of land use to another is not much significant for both the metals. Ni presence is more than Co, and the concentrations show some variation depending on land use status. Average Cr and Cu concentrations are ≥100 mg/kg, but Cr has a significantly higher presence in industrial land use. The results are similar in case of Pb. The two metals, Mn and Zn have domination over the other metals, and the values are ≥300 mg/kg. Industrial and roadside soil contains much more Mn, while commercial soil is most enriched with Zn. Of the metals, Ni has the largest proportion (∼42%) bound to the exchangeable fraction and Co, Cr, and Pb also have appreciable proportion bound to the same fraction. A significant amount of Co is associated with carbonates. The reducible fraction has bound considerable quantity of Mn and Zn, while most of Cu is associated with the organic and sulfide fraction. Both Cd and Pb are dominantly associated with the residual fraction. Computation of the mobility factor of the metals indicates Mn to be the most mobile metal present in the soil samples.

Keywords Heavy metals · Chemical fractionation · Mobility of heavy metals · Urban soil

Introduction

Urbanization and migration of people to towns and cities in search of livelihood has progressed very rapidly all over the world. It is estimated that there is an equal divide with respect to population distribution between the urban conglomerations and the vast rural areas when the world as a whole is considered, and in the developed regions, nearly three fourths of the people make their homes in urban areas (United Nations 2006). The human health is related to the environment in these areas, and since urbanization and its associated issues adversely affect the quality of the environment, the people living in the towns and cities have had
the largest impact of the changes (Chen et al. 1998; Sauva et al. 2000). The emissions from the vehicles, accumulation of garbage and other solid wastes, effluents from households, as well as various amenities like dry cleaners, dye houses, etc. pollute air, water, and soil. Urban soil is a major receptor of these pollutants and is considered as an important factor in determining sustainable development in the towns and cities (Lu et al. 2007).

Preponderance of heavy metals in urban soil has always been a serious environmental concern. The metals enter soil through a variety of natural and anthropogenic processes, such as weathering of rocks, atmospheric deposition of particles from industrial emissions, and the application of fertilizers (Chen et al. 2001). Heavy metals, like Cd, Ni, Pb, etc., with potential high toxicity (Balasubramanian et al. 2009) have been found in urban soil to various extents. However, the toxicity of the metals depend on how they are associated with different soil fractions and whether they can be easily given off to pollute drinking water sources and get mixed up with phases that may have some effect on human health (Prack and Bastiaans 1983).

Soil serves both as a sink and as a source for heavy metals, and monitoring the soil contamination levels provides a good indicator of the overall environmental quality (Li et al. 2009; Krishna and Govil 2005). The heavy metals tend to preferentially accumulate on the clay fraction of the soil because of its large surface area. Determining the distribution and potential availability of metals within this fraction therefore give useful information (Sparks 2000). Metals that bind strongly to the colloidal fraction can, in many cases, be considered to be largely immobile (Chen et al. 2001). In the case of both street dusts and roadside soils, the environmental mobility and bioavailability of the metal is dependent upon the physicochemical forms with which the metal is associated (Harrison et al. 1981). Sub-surface soils and sediments are naturally isolated from the oxidizing influence of air and water, and such anoxic material must be protected from the atmosphere at all times following sampling as exposure to air leads to a rapid redistribution of metal species (Baxter and Frech 1995).

While the total concentration of metals in a soil sample can be a useful parameter to denote contamination intensity, the particular behavior of the metals in the environment will not be understood unless the chemical phases are determined to find the distribution of a particular metal among them (Harrison et al. 1981; Jaradat et al. 2006). Along with the determination of baseline concentrations of the potentially toxic metals, speciation studies provide important input into the labile nature or otherwise of the metals and hence their possible impacts on health.

Several extraction schemes are available for separating different chemical phases with which the metals are associated in different proportions (McGrath and Cegarra 1992; Lindsay and Norvell 1978; Tessier et al. 1979). For example, dilute acetic acid (0.11 M) may be used to identify heavy metals associated with acid-soluble phases, such as calcium carbonate, or held on weak adsorption sites such as the plant available elements in acidic soil (Bulletin 1, Aberdeen, 1985). Similarly, hydroxylamine hydrochloride (0.1 M) in HCl (pH $\sim$ 2) is used to identify heavy metals associated with reducible phases. Such procedures were also reported by Davidson et al. (1994) and Thomas et al. (1994) for the analysis of river sediments. Hydrogen peroxide ($\text{H}_2\text{O}_2$) in acidic condition in presence of ammonium acetate ($\text{NH}_4\text{OAc}$) has been broadly used for extracting the heavy metals bound to organic phases (Harrison et al. 1981). Tri acid mixture (1:2:4 v/v concentrated HCl/HNO$_3$/H$_2$SO$_4$) is often used to release most metals in soil and sediment samples, except those in the lattice of very stable silicate and aluminosilicate minerals (Davidson et al. 1994).

**Materials and methods**

**Site description and sample collection**

In the present study, the area chosen for monitoring of urban soil with respect to trace metal composition is Guwahati ($91^\circ33'E$–$91^\circ52'E$ and $26^\circ08'N$–$26^\circ14'N$), Assam, India. The city is surrounded by the river Brahmaputra, one of the largest rivers of the world, in the north and small