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Sources apportionment and spatio-temporal changes in metal pollution in surface and sub-surface soils of a mixed type industrial area in India

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ABSTRACT

Metals in the urban soils of industrial townships adversely affect human health and ecosystem. In the present work, surface and sub-surface soils collected at 0–10 cm and 10–20 cm depth, respectively, in pre and post monsoon seasons from twenty sites in an urban industrial area adjoining New Delhi are studied for the total metal concentrations (Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn) seasonal changes and pollution sources. Both surface and sub-surface soils are affected by high metal pollution with the contamination factor (CF) > 2 and the average pollution load index (PLI) of 2.77. The geo-accumulation index values of 6.6–8.2 (pre and post monsoon samples) for Zn, 6.7–8.2 for Cr and 5.6–5.1 for Cd in surface soils indicate extreme levels of pollution in the region. A total four metal sources, industrial emissions for Fe, Mn, Cu, Ni, Co and Cd, electroplating industry for Zn and Cr, geogenic for Al and V, and vehicular and biomass burning for Ba and Pb in the surface soils were identified using the principal component analysis. Industrial emissions, explaining 46% of data variance, are the major source of metals. Surface soils around small scale industries are more polluted with Zn, Cr and Cd (CFs = 25–31), and Cu and Pb (CFs = 7–11) and have high PLI (range: 3.28–8.77) compared to other sampling sites. Higher geo-accumulation indices and pollution load of metals in the urban soils are expected to have long term impact on human health, plants and crop productivity in this area.

1. Introduction

The surface soils, an important part of terrestrial ecosystems, receive pollutants from a variety of sources including industries in urban areas. Soil quality in the urban area is deteriorating rapidly due the ongoing rapid urbanization and industrialization and the changes in land use patterns (Cheng et al., 2014; Tume et al., 2011). The metal contaminated surface soils adversely affect the human health and ecosystem in the towns and cities (Cheng et al., 2014). In addition, the metal enriched surface soils contaminate atmosphere through re-suspension (Cyrys et al., 2003; Tandon et al., 2008) and surface/ground water via leaching (Bhuiyan et al., 2010; Chen et al., 2005; Liu et al., 2011). Metals like Pb, Cu, Zn, Ni, Cr and Cd cause serious environmental and health hazards due to their mobility in the environmental compartments (soil, air and water) (Dao et al., 2010; Nagajyoti et al., 2010; Wei and Yang, 2010). These potentially toxic metals enter into the food chain through plant uptake (Liu et al., 2011; Nagajyoti et al., 2010; Sharma et al., 2007) and can also accumulate in the human body via direct ingestion, inhalation and hand to mouth pathways (De Miguel et al., 1998, 2007; Madrid et al., 2002; Simon et al., 2013; Velea et al., 2009). Metals, unlike organic compounds, are non-biodegradable in nature and persist for years in the environment (Bailey et al., 1999). Thus, there is a need for the studies on metal pollution/accumulation in urban soils in order to safe guard human health, particularly children and old age persons and ecosystems (Dao et al., 2010; De Kimple and Morel, 2000; Wei and Yang, 2010).

Industrial and vehicular emissions are the potential sources of metals in urban soils (Bhuiyan et al., 2010; Dao et al., 2010; Li et al., 2001, 2008; Moller et al., 2005; Nagajyoti et al., 2010; Wei and Yang 2010; Zhang et al., 2009; Zheng et al., 2002). The urban soils are also affected by the direct dumping of urban and industrial waste, open discharge of untreated effluents, agricultural runoff and atmospheric depositions (Chen et al., 2005; Nriagu 1989; Nriagu and Pacyna, 1988; Wei and Yang, 2010). These sources and pathways of metal contamination in the urban soils are very common and frequently observed in India (Nagajyoti et al., 2010; Rawat et al., 2009). In some cities, the vegetables and crops grown on the urban soils carry high amounts of potentially toxic metals and therefore, are not safe for consumption (Sharma et al., 2007, 2008; Khillare et al., 2012). In the Faridabad township, located adjacent to New Delhi, small and medium scale industries like electroplating, metal coating, tyre, tractor, and power plants are being run in the residential parts of the city without any effluent treatment facility. Pathak et al. (2013) have reported high levels of potentially toxic metals in the surface dust collected from this area. However, the surface soils are good proxy for assessing the metal pollution levels in urban areas (Dao et al., 2010; Manta et al., 2002), urban environmental quality (Cheng et al., 2014) as the metal contamination/ accumulation in urban soils takes place in surface layers (De Miguel et al., 1998). In this study,

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we examined the total metal content in the surface and sub-surface soils collected at 0–10 cm and 10–20 cm depth, respectively, in pre and post monsoon season from twenty sites in Faridabad city adjoining the national capital of India. The data are discussed to understand the sources and the levels of metal pollution in surface and sub-surface soils and associated spatio-temporal changes. The geo-accumulation index and pollution load index of metals in urban soils are also discussed.

2. Study area

Present work on metal pollution of urban surface and sub-surface soils was undertaken in Faridabad Industrial Township, located in state of Haryana, adjoining New Delhi (Fig. 1). This township has emerged as the ninth largest industrial hub in Asia during last decade after Honorable Supreme Court of India's order to shift very large numbers of industries from New Delhi to nearby areas. At present about 15,000 small, medium and large scale industrial units are functional in Faridabad employing half a million people and generating 1500 billion rupees revenue per year (http://www.faridabad.nic.in/industri1.html). As per Haryana government directives, industrial units having capital value of 1–10 million, 10–50 million and more than 50 million Indian rupees are considered as small, medium and large scale industries, respectively. The large scale industries are situated in industry specific zones and have pollution control devices in place, but small scale industries, which includes motor winding, metal alloy, metal electro-plating and many more, are operating in the residential areas in an unorganized manner with no means for pollution control. Dumping of solid industrial discards on empty and open places, including roadsides, is a prevalent practice in this area. Effluents are drained directly into small channels which finally enter into river Yamuna flowing along eastern side of the city. Detailed description of the study area and industries with their respective products is reported elsewhere (Pathak et al., 2013).

3. Experimental

3.1. Materials and methods

Surface and sub-surface soil samples were taken from 0–10 cm and 10–20 cm depths, respectively, (Dao et al., 2010; Velea et al., 2009) during pre and post monsoon season from twenty sites in the study area. Nature and scale (small to large) of industries were seriously taken into consideration before selecting a sampling site. A general description of the industries around each sampling site is provided in Table 1. At each sampling site, three samples of surface and sub-surface soils from 30 X 30 cm size surface area were taken and mixed thoroughly to get a representative composite sample. All such samples were stored

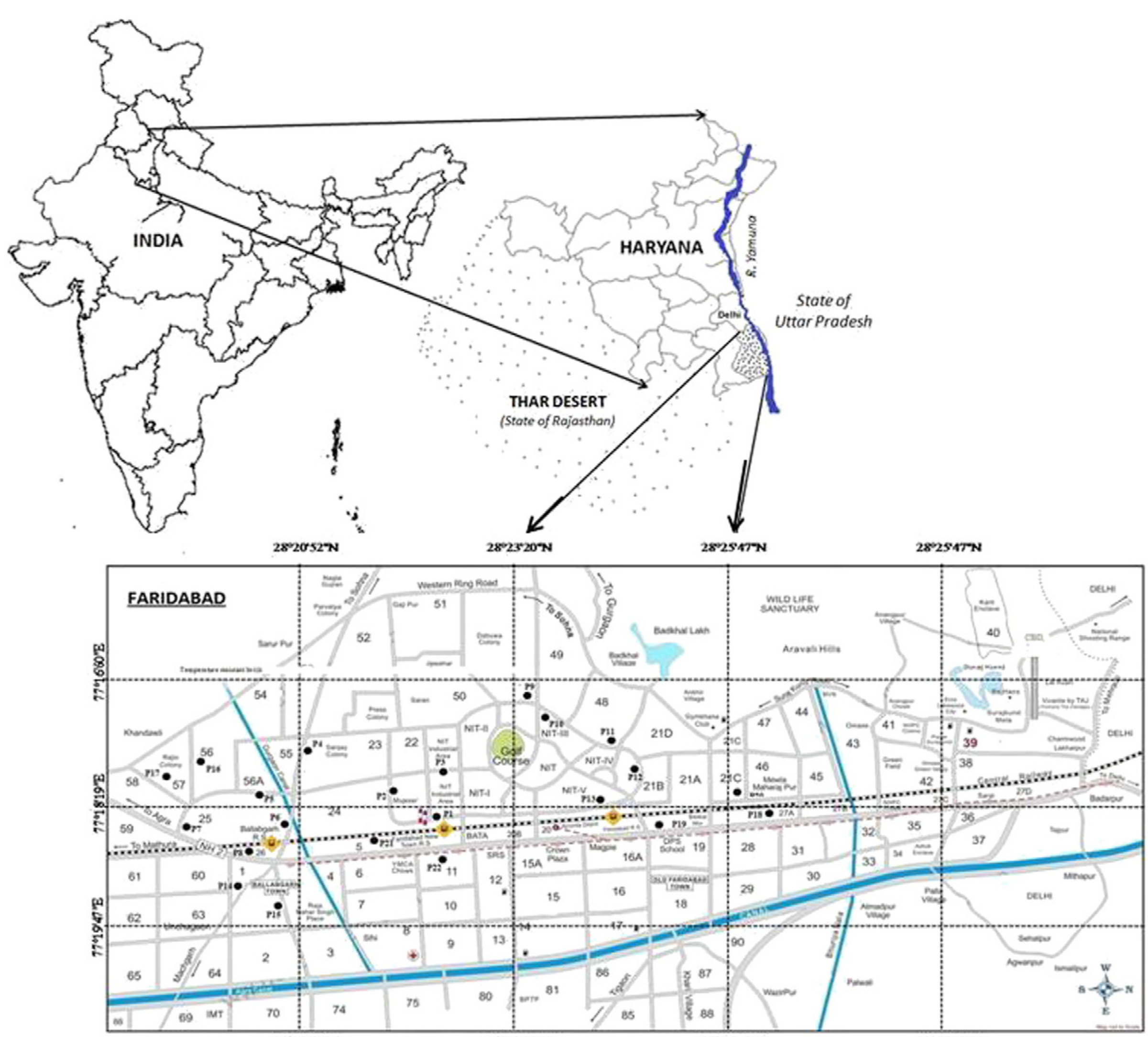

Fig. 1. Map of the study area showing Faridabad industrial area amidst the high population density residential areas. Numbers indicate residential pockets. Surface and sub-surface samples were collected near the small, medium and large scale industry in this area and are indicated by dark black dotes.