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Urban park soil contamination by potentially harmful elements and human health risk in Peshawar City, Khyber Pakhtunkhwa, Pakistan

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ABSTRACT

Urban soils may be highly contaminated with potentially harmful elements because of intensive anthropogenic activities. This study aimed to investigate the concentrations, sources, pollution levels and human health risk of potentially harmful elements in the soil of urban parks present in Peshawar, Khyber Pakhtunkhwa, Pakistan. For this purpose, the soil samples ($n = 85$) were collected from different parks ($n = 8$) and playgrounds ($n = 3$) and analyzed for total and bioavailable (EDTA extracted) potentially harmful elements (Cd, Cr, Cu, Pb, Ni and Zn) using an atomic absorption spectrophotometer. The basic soil properties such pH, electrical conductivity, organic matter, and soil particle size were also determined. The data revealed a significant ($P = 0.01$) variation in the concentrations of selected harmful elements among the different parks. The mean concentrations of Cd exceeded its maximum permissible limit (MPL) in all sites set by China (1995), India (2000), UK (1989) and EU (2000), while Ni concentrations exceeded its MPL in 5 sites. However, observed Zn, Cu, Cr and Pb concentrations were within their respective MPLs. Pollution indices (PI) of potentially harmful elements indicated low, moderate or high level of contamination in park soils linked with vehicular emissions, waste disposal and wastewater irrigation. The health risk was calculated using health quotient (for children) and total risk (for adults). Both non-carcinogenic and carcinogenic vulnerability were also calculated. The health risk data indicated that the main exposure pathway of potentially harmful elements to both children and adults was ingestion followed by dermal contacts. Hazard index (HI) values were lower than safe level ($=1$) but few parks showed the health risk existence. Children showed higher possible health risk than adults in the studied parks/playgrounds. The results of this study are important for the development of proper management strategies to decrease soil contamination with potentially harmful elements in the urban parks.

1. Introduction

Soil is one of the foremost constituents of the environment, therefore a great interest has been paid to its contamination with potentially harmful elements in the urban environment (Waqas et al., 2015; Zacháry et al., 2015). In urban areas the most imperative sink for pollutants is soil (Cheng et al., 2014; Marcussen et al., 2014). It also acts as source of both essential and non essential elements and transforms them in to air, water and other living organisms (Iqbal and Shah, 2011). Among the contaminants, potentially harmful elements are of foremost importance due to their toxicity and persistency in the environment (Guagliardi et al., 2012; Khan et al., 2015a).

Globally, serious environmental problems are associated with high concentrations of toxic metals present in urban soil (Cheng et al., 2014; Luo et al., 2012; Thornton et al., 2008; Wong et al., 2006). These toxic metals have adverse effects on humans, flora, fauna and even microorganisms (Khan et al., 2015b; Rehman et al., 2016). In city areas, anthropogenic activities (vehicular emissions, industrial discharges, wastewater irrigation, coal and fuel combustion, waste dumping and developmental activities) are severely concentrated, due to high urban population (Iqbal and Shah, 2011; Rashed, 2010) that lead to increase the contamination of environment (Martin et al., 2015). Due to urbanization and industrialization potentially harmful elements are frequently released to the urban environment and finally reach to soil (Bavec et al., 2015; Chen et al., 2013). The presence of harmful elements in soil is reported as a sign of great threat to ecological resources and humans (Guagliardi et al., 2012).

Urban park soils are not used for cultivation but have direct effects on the health of humans primarily children (Chen et al., 2005). In city, the soils of parks and grounds have high contamination of toxic metals (e.g. Pb) and health risk. The data regarding harmful elements in park

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soil showed that the concentrations of Pb, Zn and Cu have frequently exceeded the limits set for institutional, entertaining and residential sites (Mass et al., 2010). The application of metals is higher in the developed landscape than undeveloped areas (Li et al., 2013).

The discharge of potentially harmful elements badly disturbs the values of the metropolitan surroundings and causes threats to human beings. Children and adults are exposed to soil contaminants through incidental soil ingestion, re-suspension and consequent contact (Mitchell et al., 2014). USEPA (2003) suggested a value of 100 mg for soil ingestion per day for children of 1–6 years of age. Later on, USEPA (2008) suggested of the intake value of 50 mg/d for soil, 100 mg/d for soil and dirt and 1 g/d for soil through pica behavior. The children are exposed to soil particle smaller than 2 mm because of potential gripping to the skin of their hands. Consequently it is paramount important to estimate potentially harmful element levels in urban areas, metal ingestion rates and their threats to health.

In fact, individual well-being is strongly correlated to the worth and quality of soil and mainly to its level of contamination. Potentially harmful elements can be unsafe and cause hazardous impacts after their accumulation in body of the humans and other living organism (Duruible et al., 2007; Guagliardi et al., 2012). They badly affect the physical growth and inhibit the mental development of children. Organisms exposed to these pollutants were reported to have a wide range of problems including acute effects, endocrine disruption, reproduction dysfunction and cancer (Zhao et al., 2014). Furthermore, the intake of potentially harmful elements can also cause impacts on several vital nutrients within the body of consumers, decline the immunological defenses, stop development, cause psychosocial destruction, cause disabilities related with undernourishment and even upper gastrointestinal cancer (Khan et al., 2011). Pb through ingestion and contact can be harmful to enzymatic systems, affects the brainpower of humans (Babula et al., 2008) and causes various anemia, neurological disorders and hyperactivity (Marsden, 2003). Toxic metals (Cd, Ni, Cr, Cu and Zn) cause stomach pains, ulcers, vomiting, nausea, diarrhea, damages to liver, kidney, central nervous system and immune system, cancer growth, reproductive failure, modification of genetic material, melanoma, skin problem, bone crack, cardiovascular and respiratory diseases, lung cancer, liver demolition, kidney disorder and reduce the body weight (Agarwal et al., 1993; Barrento et al., 2009; Elinder, 1986; Oliver, 1997).

Several authors have indicated the need for a better understanding of urban soil contamination (De Kimple and Morel, 2000). Differences among cities regarding population, livelihood, traffic load and industrial behavior cause great differences in the concentrations of potentially harmful elements. Not only for biologists and ecologists but also for environmentalists these harmful elements in soil have been an issue of great concern. Thus the present study was designed to investigate the contamination load of potentially harmful elements (Cd, Cr, Cu, Ni, Pb and Zn) in the soil of urban parks and playgrounds present in Peshawar City because the children and young generation are exposed to it through hand to mouth and dermal contacts. To our knowledge, this is the first study focuses on parks/playgrounds' soil contamination with potentially harmful elements and associated health risk. This paper may play a great role to protect the young generation and children from the adverse impacts of these harmful elements. The findings of this study can facilitate the decision makers to manage the soil contamination and minimize health risks of urban inhabitants through stopping wastewater irrigation and other contributing factors.

2. Material and methods

2.1. Area description

Peshawar is the capital city of Khyber Pakhtunkhwa Province and lies between 33° 44′ and 34° 15′ north latitudes, 71° 22′ and 71° 42′ east longitude (Fig. 1). The total area is 1257 km^2 with total population of 2.019 million. Peshawar basin is an intermontane basin present at the southern margin of the Himalayas. The basin is mainly composed of the Quaternary deposits such as fanglomerates, fluvial and lacustrine sediments (Burbank and Raynolds, 1984). It is bounded by the Attock-Cherat Range on the south, Gandghar Range on the east and Khyber Range on the west. The ranges of Gandghar and Khyber contain rocks of metasediments and unmetamorphosed foreland basin sediments of Kohat-Potwar Plateau. The metasedimentary rocks are intruded by granites are present in the north and northwest of the Peshawar basin (Hussain et al., 1991). Above-mentioned city is highly developed and populous area as compared to other cities in the province. Several industrial units such as leather, outfits, soap, hosiery, footwear, ghee, miniature arm, flourmills, match factories and steel re-rolling units are present in the region. The temperature is ranged from 25 to 42 °C, while relative humidity is changed from 46 to 76%. The mean annual rainfall is 400 mm in the study area (DCR, 1998). The lawns, parks and gardens are mostly irrigated with wastewater due to shortage of canal water.

2.2. Sampling sites and procedure

Soil samples ($n = 85$) were collected from major public parks (Baghe Naran Park, Chacha Younas Park, Jinnah Park, Khyber Park, Parda Bagh, Shahi Bagh, Sher Khan Shaheed Stadium and Tatara Park; 8 samples from each) of Peshawar and main playgrounds (Cricket, Hockey and Volleyball grounds; 7 samples from each) present in the campus of University of Peshawar, Pakistan. Soil samples were collected from the top soil (0–15 cm) in triplicates. The samples were collected with stainless shovel and were placed in airtight polythene bags and were properly labeled and brought to laboratory for further processing. The materials such as stones or debris were removed by hand and air dried in room temperature. The soils were grounded into powder, separately labeled in polythene bags and used for further analyses.

2.3. Soil chemical analyses

Soil samples of the urban parks were analyzed for basic properties such as pH, electrical conductivity (EC), organic matter, particle sizes and texture (Table 1). Soil particle sizes were determined using Fritsch Analysette 3 PRO Sieve Machine. The air dried samples were used and the soil retained by every mesh was weighed and particle size in fraction for sand, silt and clay was measured (Liu et al., 2007). Soil sample (<2 mm) was used to determine the pH and EC using respective electrodes. Briefly the soil was mixed with deionized water (1:5 weight:volume) and shaken for 30 min and then pH and EC were measured using respective electrodes. Organic matter was determined through loss on ignition (LOI) technique adopted from Storer (1984).

For total concentrations of potentially harmful elements, the soil samples were digested with strong acids using the method adopted by Khan et al. (2008). Briefly, 1.0 g soil was taken into acidified rinsed digestion tube and 10 ml aqua regia (HCl: HNO_3) was added into it. Next morning, the tubes were put in the digestion block and temperature was raised to 80 °C for 1 h, then cooled and 5 ml of $HClO_4$ was added and finally heated to 160 °C until the solution in the tubes become clear. After cooling, the suspensions were filtered into acid rinse volumetric flasks and diluted to 50 ml with deionized water. The concentrations of Cd, Cr, Cu, Ni, Pb and Zn, were determined using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer 700).

For determination of available potentially harmful elements, the air dried sample (5.0 g) was taken into a 125 ml Erlenmeyer flask. 25 ml of 0.05 M EDTA was added and shaken at 120 rpm for 1 h and then filtered through filter paper (Merry et al., 1981). The filtrates were analyzed for available concentrations of potentially harmful elements such as Cd, Cu, Cr, Ni, Pb, and Zn using AAS, (Perkin Elmer 700). All the samples were analyzed in triplicates.