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Bioaccessibility, sources and health risk assessment of trace metals in urban park dust in Nanjing, Southeast China

Jinhua Wang [a], Shiwei Li [a], Xinyi Cui [a], Huiming Li [a,*], Xin Qian [a,b,**], Cheng Wang [a], Yixuan Sun [a]

[a] State Key Laboratory of Pollution Control and Resources Reuse, School of the Environment, Nanjing University, Nanjing 210023, PR China
[b] Collaborative Innovation Center of Atmospheric Environment and Equipment Technology (CICAEET), Nanjing University of Information Science & Technology, Nanjing 210044, PR China

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ABSTRACTS

Arsenic, Cd, Co, Cr, Cu, Mn, Ni, Pb, V, and Zn total concentrations and bioaccessibilities in 15 urban park dust samples were determined. The oral bioaccessibility measured by the Simple Bioaccessibility Extraction Test (SBET) decreased in the order of Pb > Cd > Zn > Mn > Cu > Co > V > Ni > As > Cr. The Tomlinson pollution load index (*PLI*) and geoaccumulation index (I_{geo}) were calculated to evaluate the pollution extent to which the samples were contaminated. Sources were identified using principal component analysis and Pb isotope compositions. Most elements except Co and V were considered to mainly originate from anthropogenic sources. Non-carcinogenic and carcinogenic risks to humans through urban park dust exposure were assessed using the oral bioaccessibilities of the elements. Ingestion was the main pathway for non-carcinogenic risk. The hazard quotients were below the safe level (=1) for all elements, however, Pb (0.154) and As (0.184) posed potential higher risks to children than adults. The carcinogenic effects occurring were below the acceptable level (10^{-4}) for As and $< 10^{-6}$ for Cd, Co, Cr, and Ni.

1. Introduction

Urban dust has been reported in many countries which contain toxic organic and inorganic pollutants, especially trace metals (Saeedi et al., 2012; Shi et al., 2008; Ahmed and Ishiga, 2006). It is known that urban parks are one of the limited playgrounds where urban dwellers pay frequent visits (Li et al., 2011). Moreover, there are great population and heavy burden of human activities in urban parks which are associated with people's daily life and health (Du et al., 2013). Many related studies have focused on urban park soils (Hou et al. 2015; Sarah et al. 2015; Aguilar Reyes et al. 2013; Luo et al., 2012; Li et al., 2011; Guney et al., 2010; Poggio et al., 2009; Lee et al., 2006; Chen et al., 2005). Compared with the urban soils, urban park dusts can easily be re-suspended by the wind and exposed to urban dwellers, potentially having a negative influence on their health (Du et al., 2013). Few studies exist about trace metal contamination in urban park dust and the associated health risk (Liu et al., 2015; Guo et al., 2014; Ma and Wichitra, 2012; Du et al., 2013).

Exposure to trace metals above certain concentrations can lead to acute and chronic toxicity (Poggio et al., 2009; Leung et al., 2008). The actual health risks posed by trace metals depends on the soluble fraction in the gastrointestinal environment and available for absorption (i.e., bioaccessibility, Ruby et al. (1999)). Many recent studies have focused on the total trace metals contents without considering their bioaccessibilities (Turner and Ip, 2007; Zheng et al., 2010).For example, the physiologically based extraction test (PBET) and the simple bioaccessibility extraction test (SBET) have been widely used for estimating the oral bioaccessibility of trace metals in soils or dusts (Hu et al., 2011; Sialelli et al., 2010; Madrid et al., 2008). So far, only the bioaccessibility and health risks of trace metals in urban street dusts and park soils were investigated (Guney et al., 2010; Hu et al., 2011). The oral bioaccessibility of trace metals in park dust has seldom been investigated. It's therefore necessary to characterize the health risks of trace metals in urban park dust through multi-pathways (ingestion, inhalation, dermal) containing oral bioaccessibility.

Trace metals in urban dust may come from various mobile and stationary anthropogenic and natural sources (Manasreh, 2010; Rossini Oliva and Fernandez Espinosa, 2007). Traditional approaches rely on multivariate statistical analyses (e.g., principal component analysis (PCA), correlation analysis) of large databases of environmental samples to characterize sources (Qishlaqi and

* Corresponding author.
** Corresponding author at: State Key Laboratory of Pollution Control and Resources Reuse, School of the Environment, Nanjing University, Nanjing 210023, PR China.
E-mail addresses: valen222@126.com (H. Li), xqian@nju.edu.cn (X. Qian).

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Moore, 2007; Facchinelli et al., 2001). Pb isotopic fingerprinting technology has been used to identify Pb source (Cheng and Hu, 2010). However, few studies have combined the Pb isotopic fingerprinting technology with the statistical analyses to identify the source of trace metals in urban dusts (Liu et al., 2104; Zhu et al., 2013).

Nanjing is an important industrial zone and transportation hub in southeastern China. There are more than 100 urban parks in Nanjing. Urban parks can be used as realistic places to analyze pollutant concentrations and sources of trace metals. As such, the objectives of this study were to: (1) determine the concentrations, spatial variabilities, and bioaccessibilities of As, Cd, Cr, Co, Cu, Mn, Ni, Pb, V, and Zn in urban parks dust samples; (2) characterize the non-cancer and cancer risks through exposure to urban park dust by three exposure pathways taking the bioaccessibilities of the elements studied into account; and (3) identify the main sources of trace metals present in urban park dust using PCA and Pb isotope compositions.

2. Materials and methods

2.1. Study area

Nanjing (118° 46′ E, 32° 03′ N) is the second largest city in the Yangtze River Delta region, with an area of approximately 6600 km^2 and a population of 8.19 million in 2013. Nanjing is the main transportation hub in eastern China and its five main industries are the automobile, electrical power production, electronics, petrochemical, and steel industries. Nanjing is one of China's most famous garden cities and there are approximately 120 parks in Nanjing located in the 11 administrative districts. We selected 15 parks in the center of Nanjing and the sampling sites are marked in Fig. 1 by using ArcGIS 10.2. The sampling sites were in the districts of Xuanwu, Baixia, Qinhuai, Jianye, Gulou, Xiaguan, and Qixia, which contained most of the traditional residential areas. Some of the parks were established hundreds or even thousands of years ago. The descriptions of the urban parks in which dust samples were collected are presented in Supporting Information (SI) Table A1.

2.2. Sample collection and preparation

A total of 60 dust samples were collected in June of 2014 during periods when no rain had occurred over the previous 2 weeks. The areas of most parks are not very large, thus, four sampling sites were selected for each park. Four to six subsamples were collected at each site and mixed thoroughly to give a representative bulk sample. Each urban park dust sample was collected by sweeping roofs, corners of landscape buildings, windowsills, steps and pavements with a clean brush. At least 5 g of dust was collected and transferred into a coded self-sealing polyethylene bag before being taken to the laboratory. Each sample was air-dried and sieved through a 1 mm nylon sieve to remove stones, coarse material, and other impurities. Dust with particle diameters of <63 μm is thought to mainly arise from atmospheric deposition and to be transported by re-suspension (Hu et al., 2011). Because of this, each sample was passed through a 63 μm nylon sieve for analysis.

2.3. Bioaccessibility tests and total trace metal concentration determination

Digestion using a mixture of HNO_3 and $HClO_4$ was performed on each sample to allow the total As, Cd, Co, Cr, Cu, Mn Ni, Pb, V, and Zn concentrations to be determined (Lee et al., 2006;

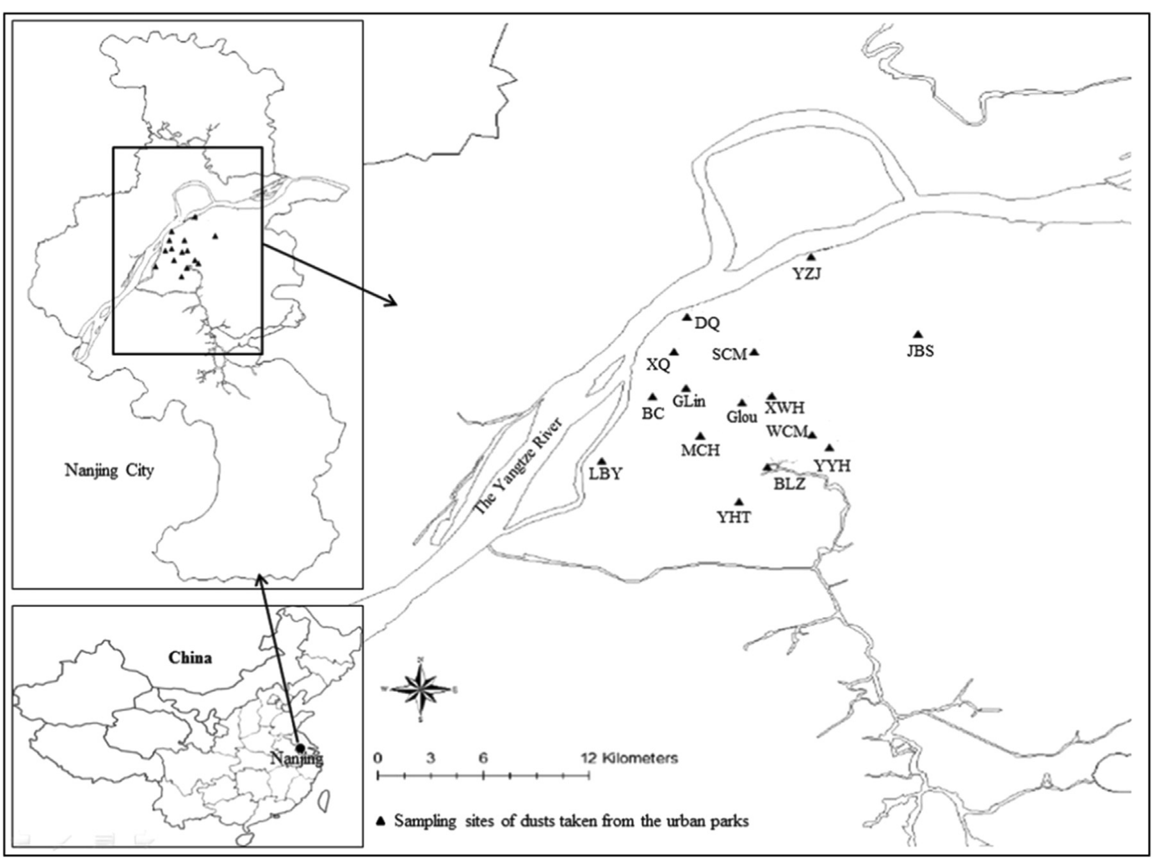

Fig.1. Location of sampling.