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Pollution characteristics and human health risks of potentially (eco) toxic elements (PTEs) in road dust from metropolitan area of Hefei, China

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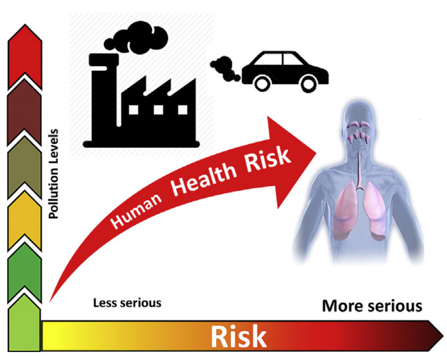
HIGHLIGHTS

- Pollution characteristics of PTEs in roadside dust were assessed.
- Exposures to PTEs in road dust and their potential health risks were estimated.
- Distribution of most PTEs was affected by the industrial activities.
- As, Cu, Pb, Sn and Zn concentrations in urban areas were found to be higher than industrial areas.
- Potential health risks of PTEs were lower than regulatory guideline levels.

GRAPHICAL ABSTRACT



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ABSTRACT

This study aims to investigate the pollution characteristics of road dust and their associated health risks of potentially toxic elements (PTEs) to humans using array-based risk assessment models described by United States Environmental Protection Agency (USEPA) in a metropolitan area of Hefei, China. Geo-accumulation index (I_{geo}) was used to describe pollution characteristics of roadside dust in urban, per-iurban and industrial areas. Results indicate that industrial roadside dust was contaminated with Fe, Ni, Cu, Ti, V, Pb, Ba, Sb, Cr, Sn, Pb, As and Ga showing I_{geo} value ($log_2(x)$) between I_{geo} class 3 to 4. In other hand, urban roadside dust contamination with Cu, Zn, Sb and Ga ranged between I_{geo} classes 2 to 3 and with As and Pb ranged between I_{geo} classes 4 to 5. Furthermore, health risk assessment revealed negligible non-cancerous health hazard in all sites including urban, periurban and industrial areas. The hazard quotient (HQ) and hazard Index (HI) values for all exposure routes (ingestion, inhalation, and dermal contact) were <1 except for chromium with HI value of 1.06E+00 in industrial areas. Moreover,

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the most prominent exposure route was ingestion (HQ_{ing}) and the non-carcinogenic health risks were found to be high in case of children compared to the adults. The cancer risk from As, Co, Cr, Ni, and Pb was found to be in safe levels as the RI (carcinogenic risks) values were below the limits for carcinogens (1.00E-6 to 1.00E-4).

1. Introduction

Roadside dust is a non-exhaust source of origin for the atmospheric particulate matter by the process of re-suspension (Lu et al., 2009). It is a heterogeneous mixture of different environmental pollutants originated from a series of miscellaneous sources and identification of these sources may be very complex (Wong et al., 2006). It can originate through both natural and anthropogenic activities. Among the natural sources, the most important contributors are soil erosion, re-suspension of soil particles, weathering of materials and atmospheric deposition (Fergusson and Kim, 1991; Amato et al., 2009). While in case of human activates the main contributors are increased urbanization, industries, transport activities (tire, brake, and asphalt wear), generation of power, household use of fossil fuel, construction and demolition (Saeedi et al., 2012; Bi et al., 2013; Ordóñez et al., 2003). The composition, distribution, and source can differ from one city to another depending upon the type of activities going on a specific city (Duzgoren-Aydin et al., 2006). Roadside dust have a series of toxic element attached to it, these elements can easily be remobilized and enter into a different environment in many ways i.e. re-suspension and leaching through precipitation into our water systems (Rogge et al., 1993; Kreider et al., 2010; Joshi et al., 2009). Due to high surface area road dust can easily be re-suspended, transported and re-deposited carrying a load of an environmental toxic element (Martuzevicius et al., 2011; Joshi et al., 2009), and these toxic elements can affect human health in many ways (Duzgoren-Aydin et al., 2006).

Trace element in the road dust come from a variety of sources which including mobile or stationary human sources and/or natural (Ferreira-Baptista and De Miguel, 2005). The presence of these potentially toxic elements (PTEs) in roadside dust can have a great deal of risk to human health due to minute particle size of dust and its inherent moment from one place to another through the wind that can increase the probability of direct and indirect human exposure. The direct pathways for exposure are ingestion and inhalation while indirect ways of exposure are dermal contact and outfits which can be incidentally ingested (Roels et al., 1980; Ferreira-Baptista and De Miguel, 2005; Zheng et al., 2010). Trace elemental exposure beyond a specific limit can cause chronic toxicity and risk posed depends upon their solubility in the gastro-intestine and its absorption in the body (Ferreira-Baptista and De Miguel, 2005; Yousaf et al., 2016a). In addition, trace elements can easily enter to the circulatory system and can also get accumulated into fatty body tissues containing fatty acids because of toxic and non-biodegradable nature (Tang et al., 2013; Sezgin et al., 2004). They can interfere with the function of body organs, malfunction the endocrine system and can disrupt the nervous system or they can act as the secondary factor for other diseases (Roels et al., 1980; Ferreira-Baptista and De Miguel, 2005; Zheng et al., 2010).

In addition, exposure to PTEs in soil, road and street dust can cause nervous disorder, renal problems and it can also be responsible for cardiovascular and reproductive malfunctions (Christoforidis and Stamatis, 2009). Trace elemental exposure can be severe in infants and young children because of their rapid growth capabilities. The exposure to children is also higher as compared to adults because of their playing activities, hand to mouth habit and licking objects which may be contaminated (Mohmand et al., 2015; Acosta et al., 2009). Normally, geo-accumulation index (I_{geo}) of PTEs in dust is good indicators of environmental pollution (Wong et al., 2006). Human health risk assessment (HQ, HI and RI) studies on various exposure routes in urban, urban periurban and industrial environments have recently been given great importance. The adverse health effects during life can be evaluated by using threshold R_fD value. The chances of severe health effects will be minimum if the average value of average daily dose (ADD) is lower than that of the reference dose (R_FD) and the chances will be maximum if the average value of ADD is higher than that of R_fD (USEPA, 1993; USEPA, 2001b; Lim et al., 2008).

Due to persistence in nature, trace elements in road dust and their associated negative health effects have been highly endured for the pollution status of urban environment during last decade (Duggan, 1980; Shi et al., 2011; Wei and Yang, 2010). The PTEs pollution is one of the important issue, researchers are concerned about especially in China where in the past 3 decades urbanizations and industrialization increased at a very high and extraordinary pace (Faiz et al., 2009; Ahmed and Ishiga, 2006; Al-Khashman, 2007). Most of the studies conducted in China have focused on a very few elements that are the most toxic like Pb, Zn, As and Cr.

Keeping in view the importance of health risk assessment, the current study aimed elaborate the following objectives. (1) To assess and evaluate the current status of eighteen potentially (eco) toxic elements concentration in road dust from three distinct zones of provincial capital (Hefei) of Anhui, China. (2) Use of geo-accumulation index method in order to find the pollution level of selected element in road dust of urban, peri-urban and industrial zones. (3) To investigate potential adverse health effects due to PTEs exposure in children and adults by using health risk assessment models described by United states Environmental protection agency (USEPA).

2. Methodology

2.1. Sample collection

The study was conducted in Hefei metropolitan area, the capital of Anhui province with an area of 11,408 km^2 which is situated in upper limits of Yangtze delta of China. Its population is around about 4.86 million. In the last decades, there was a rapid increase in urbanization and agricultural activities, which have a considerable impact on the urban environment, and air quality especially in the region of Hefei. A total of 91 samples of road dust were collected from urban (35), periurban (31) and industrial (25) areas during May and June 2016 (Fig. 1). Central city and most populated area was considered as urban, industrial zone including all heavy and small industry considered as industrial area and the area between the main city and countryside was considered as peri urban area. The sampling campaign was started in summer because Hefei receives high rainfall and snow in winter season which makes it