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Characteristics and health risk assessment of heavy metals exposure via household dust from urban area in Chengdu, China

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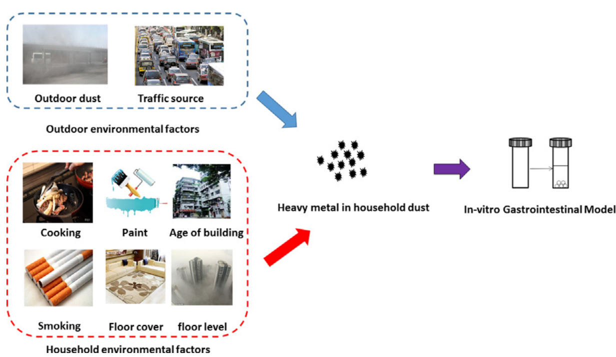
HIGHLIGHTS

- Heavy metal concentrations in household dust collected from 6 urban districts.
- Health risks were evaluated for the metals combined with oral bioaccessibility.
- There was negative correlation between the metals concentrations and floor levels.

GRAPHICAL ABSTRACT



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ABSTRACT

To investigate the characteristics of heavy metals (Cr, Cd, Pb, Zn, Cu and Ni) in household dust in urban household environment of Chengdu, China, 90 household dust samples were collected from 6 districts of the city. The information of houses and residents were also recorded during dust sampling to identify the correlations between heavy metals in household dust and the house attributes. And also the principal component analysis and cluster analysis for sources and impactor factors. The concentrations of Pb (123 $mg\cdot kg^{-1}$), Zn (675 $mg\cdot kg^{-1}$), Cu (190 $mg\cdot kg^{-1}$), Cr (82.7 $mg\cdot kg^{-1}$), Cd (2.37 $mg\cdot kg^{-1}$) and Ni (52.6 $mg\cdot kg^{-1}$) in household dust are in low or moderate levels when compare with that from other counties or areas. The heavy metals of household dust samples from Chengdu is higher concentrations than that in the street dust from Chengdu, except for Cr. Statistical analysis result showed traffic sources and corrosion of alloys are important factors contributing to the rise concentrations of heavy metals in household dust. In addition, there is negative correlation ($p < 0.05$) between the heavy metals concentrations and floor levels. The ingestion is the important pathway for Pb, Zn, Cu and Ni via household dust exposure to the residents, and the dermal contact was identified as a main route for Cr and Cd in household dust exposure to the residents. There are minor non-carcinogenic and carcinogenic risks from the heavy metals in household dust for the residents in Chengdu.

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1. Introduction

Urban dust as sink and source of air pollution, which can indicate the characteristics of heavy metals distribution and accumulation in urban environment (Hu et al., 2011; Huang et al., 2014c; Wei and Yang, 2010). Household dust is heterogeneous and complex mixture of organic and inorganic particles (Maertens et al., 2004), which could absorb and accumulate heavy metals (eg: lead, Pb; zinc, Zn; copper, Cu; chromium, Cr; nickel, Ni; cadmium, Cd) (Rasmussen, 2004). It is reported that adults and children have approximately 88% and 75% of the day time stay at indoor environment, respectively (US EPA, 1997). Therefore, household dust maybe a major pathway of heavy metals exposure to the residents (Hassan, 2012; Hogervorst et al., 2007; Yoshinaga et al., 2014). In recent years, the content of heavy metal in household dust has become the focus of social concern (He et al., 2017; Li et al., 2014; Olujimi et al., 2015).

Previous studies indicated there were two major way of heavy metals from the outdoor to the indoor: the soil or dust that stick to footwear is brought into room, and the suspended particulate matter in outdoor air drift in house (Hunt et al., 2006; Thatcher and Layton, 1995). The soil and outdoor dust in residential area could be enriched heavy metals by anthropogenic activities (vehicular traffic, industrial plants, city construction) and other activities with the process of urbanization (Wang et al., 2016; Wei et al., 2015). In addition, the number of storey and height of the building, the frequency and time of windows opened, the number of residents and pets in house could also affect to the concentrations of heavy metals in household dust (Kurt-Karakus, 2012). On the other hand, the household environment and activities are also the important factors which can affect the content of heavy metals in household. Previous studies showed the color of the wall paints was an important source of heavy metals in household dust, eg, yellow color was connected with the relative higher concentrations of Cd, Cu, Pb, and Zn, purple paint was correlated with the higher levels of Zn and Pb and green paint had elevated the content of Cu (Chattopadhyay et al., 2003; Tong and Lam, 2000). The daily fuel combustion for domestic cooking play also a crucial factor on the heavy metals accumulated in household dust (Hassan, 2000). Furthermore, heavy metals in household dust also related to smoking, sweeping frequency, the use of air conditioning and rubber carpet products, paint and cooking frequency (Kim and Fergusson, 1993; Kurt-Karakus, 2012; Rasmussen et al., 2013). However, the living habits of residents in different countries and areas are vary greatly, the data of questionnaire and correspondingly analyzed with the statistical methods could reflect more reliable relationship between the household attributes and heavy metals concentration in household dust from the study area.

In recent years, lots of studies on heavy metals in indoor dust were focused on concentrations, source, particle diameter, spatial characteristics and pollution assessment (Akinwunmi et al., 2017; He et al., 2017; Olujimi et al., 2015). The results showed dust which <63 μm in particle size can be easily re-suspended into atmosphere and have a higher tendency to absorb by humans via ingestion, inhalation and dermal adsorption than the dust in other particle size (Mohmand et al., 2015; Shilton et al., 2005; Zheng et al., 2010). In addition, the fine particles dust also have relatively high surface area and were detected higher concentrations of heavy metals (Hassan, 2012). Therefore, the fine particles dust is the research focus of heavy metals in household dust.

Due to the toxicity, persistence and bioaccumulation, long-term exposure to heavy metals contaminated dust can affect the human health. Pb has a half-life of 4 years in the human body, and up to 10 years in the bones, and Pb is found to be destructive to the nervous system, kidney, circulatory and reproductive systems, especially for children (Needleman, 2009). The half-life of Cd is 6.2 to 18 years in the human body, and Cd is also neurotoxic for living organisms including humans, and toxic to kidney (Thomas et al., 2009). Zn and Cu are essential element for human, but they are initiators or promoters of carcinogenic activities in animals (Nriagu, 1988). Health risk assessment of exposure to heavy metals in indoor dust has been attempted in lots of cities in the world, such as Istanbul, Turkey (Kurt-Karakus, 2012), Lahore and Sargodha, Pakistan (Mohmand et al., 2015), Japan (Yoshinaga et al., 2014), Ogun State, Nigeria (Olujimi et al., 2015), Rouen, France (Marcotte et al., 2017), Guangzhou, China (Huang et al., 2014c). In general, the studies showed that oral ingestion is the primary exposure route to household dust for humans, compared with inhalation and dermal contact. The ingested dusts reach the gastrointestinal tract where heavy metals are partly dissolved (Butte and Heinzow, 2002), then heavy metal are transported by the circulatory system and finally accumulated in tissues and organs of the human body. Physiologically based extraction test (PBET), an in-vitro gastrointestinal method, has been widely applied to assess the bioaccessibility of heavy metals in the stomach and intestinal tract (Turner and Hefzi, 2010; Turner and Ip, 2007). However, there are few studies on the health risks associated with the actual situation of the local resident (eg: exposure frequency, exposure duration, body weight).

Chengdu, as a large central city in China, has an urban population of 15.7 million in 2015 and a huge of living emissions (Chen et al., 2016). The main industries in Chengdu including machinery, automobile, medicine, food, and information technology. With the rapid economic growth, the number of motor vehicles were 4.64 million (included 243,000 trucks) and the annual growth rate was >14% in Chengdu (Qiao et al., 2013). In addition, there are about 2600 urban construction sites (including housing, municipal and rail transit), and >800 of them in the central of city (Qiao et al., 2013), which have generated a lot of pollutant emissions. Chengdu is located in the central area of the Sichuan Basin, which is difficult to diffuse the urban atmospheric pollutants and prone to haze weather (Tao et al., 2013). Fang et al. (2016) showed that the annual average concentration of $PM_{2.5}$ is 75–100 μg/m^3 and about 3% mortality rate were associated with air particulate matter in Chengdu. Air pollution has become a public health concern in this city. Previous studies on heavy metals in dust from Chengdu were focused on the outdoor dust of content, particle size, pollution, source identification and health risk assessment (Chen et al., 2016; Qiao et al., 2013). However, there is few studies are related to the heavy metals in household dust from Chengdu. The major objectives of current study were as follows (1) to determine the heavy metals (Lead, Pb; Zinc, Zn; Copper, Cu; Chromium, Cr; Cadmium, Cd; Nickel, Ni) concentrations in household dust from Chengdu; (2) identify the correlations between heavy metals in household dust and the house attributes (such as resident habits, house age, paint and cooking frequency); and (3) to evaluate the human health risks (based on oral bioaccessibility) posed by heavy metal exposure through the three exposure ways of household dust.

2. Material and methods

2.1. Samples collection

A total of 90 combined household dust samples (3 sub-samples were acquired randomly and combined with equal weight in each site) were collected in six urban districts in Chengdu from November 2014 to July 2015. There are geographic differences between samples. The household dust samples were obtained by a plastic brush and a dust collector from floor surfaces in all living areas and connecting rooms, avoiding potentially wet areas (kitchen and bathroom) to protect the integrity of the sample. Before each sampling, brushes, dustpans and dust collector were cleaned. These households were located in Wuhou (WH, $n = 21$), Chenghua (CH, $n = 18$), Jinniu (JN, $n = 15$), Jinjiang (JJ, $n = 12$), Gaoxin (GX, $n = 12$), and Qingyang (QY, $n = 12$). The dust samples were wrapped in aluminum foil, placed in zip-lock bags and transported to the laboratory. The samples were freeze-dried and homogenized by passing through a stainless steel 63 μm sieve. A questionnaire was designed for collect information from the resident volunteers to assess household attributes and resident personal habits. The data covered the following information: age of building, floor cover, smoking, open