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Preliminary assessment on exposure of four typical populations to potentially toxic metals by means of skin wipes under the influence of haze pollution

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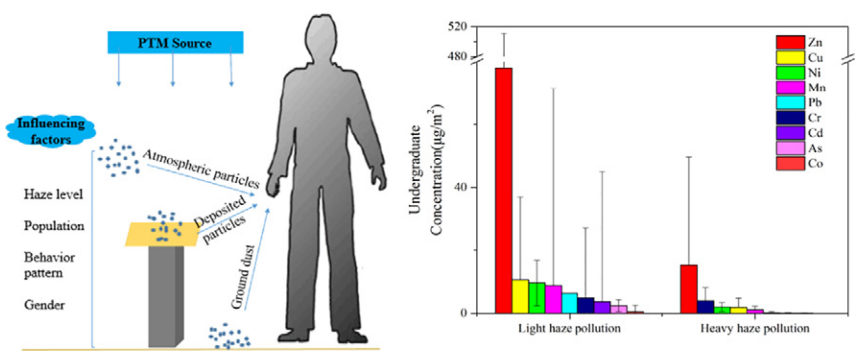
HIGHLIGHTS

- PTMs in dust adhered on human hands were determined by means of skin wipes.
- PTM occurrence varied among populations and was influenced by haze level, gender and individual behavior patterns.
- Ground dust was deduced to be the dominant exposure source of PTMs on hands for children.
- Human exposure to PTMs in dust particles via dermal contact and ingestion were assessed.

GRAPHICAL ABSTRACT



The concentration of nine PTMs in light haze pollution is higher than that of heavy haze pollution.

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ABSTRACT

To investigate the exposure risk of human beings to nine potentially toxic metals (PTMs), namely, Cu, Cr, Zn, As, Cd, Pb, Ni, Mn, and Co, skin wipe samples were collected from four types of populations, namely, children, undergraduates, security guards, and professional drivers, under different haze pollution levels in Xinxiang, China by using Ghost wipes. The Ghost wipes were quantitatively analyzed by inductively coupled plasma mass spectrometry (ICP-MS) after microwave digestion. Generally, Zn (ND-1350 μg/m^2 for undergraduates, ND-2660 μg/m^2 for security guards, ND-2460 μg/m^2 for children, and ND-2530 μg/m^2 for professional drivers) showed the highest concentration among the four populations, followed by Cu (0.02–83.4 μg/m^2 for undergraduates, ND-70.2 μg/m^2 for security guards, 23.2–487 μg/m^2 for children, and ND-116 μg/m^2 for professional drivers). As (ND-5.7 μg/m^2 for undergraduates, ND-2.3 μg/m^2 for security guards, ND-21.1 μg/m^2 for children, and ND-11.0 μg/m^2 for professional drivers) and Co (ND-6.0 μg/m^2 for undergraduates, ND-7.9 μg/m^2 for security guards, ND-13.4 μg/m^2 for children, and ND-2.1 μg/m^2 for professional drivers) showed the lowest concentrations in all populations. Remarkable differences were found among the four populations and PTM levels decreased in the following order: children, professional drivers, security guards, and undergraduates. Gender variation was discovered for undergraduates and children. Generally, PTM contamination in skin wipes collected during a light haze pollution level was generally higher than that during a heavy haze pollution level, but PTM contamination

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was comparable between the two haze pollution levels for children. Non-carcinogenic exposure risks to As, Cd, and Pb for all populations were higher than those for the other six elements but all of them were within the acceptable safety threshold, indicating no apparent non-carcinogenic risk.

1. Introduction

In China, potentially toxic metals (PTMs) in urban dust and atmospheric particles are considered to be a major source of pollution in urban areas and have a significant impact on the environment and public health due to their toxic and non-degradable nature (Maas et al., 2010; Wei and Yang, 2010). PTMs are deposited and accumulate on urban surfaces and are transported by natural or human forces, such as blowing wind, weathering (Shi et al., 2008), and gravity (Zhao et al., 2006). They can enter the human body via direct inhalation, ingestion, and dermal absorption (Lu et al., 2009a; Pereira et al., 2007; Shi et al., 2008; Wei and Yang, 2010), affecting the central nervous system and acting as cofactors in other diseases (Faiz et al., 2009; Han et al., 2006), especially for young children who are more sensitive than adults (Ajmone et al., 2008; Maas et al., 2010; Meza-Figueroa et al., 2007; Shi et al., 2008).

Many studies have evaluated the human exposure risk of PTMs through three exposure pathways using settled dust samples; however, few studies have been conducted using skin wipe sampling (Ali et al., 2017; Li et al., 2017; Masto et al., 2017; Yan et al., 2016), which has recently been applied to measure the contamination levels of toxic chemicals on the skin surface. Generally, dust ingestion occurs through hand-to-mouth contact and dermal exposure occurs when dust particles adhere to human skin. As a result, dust particles on human hands can reflect PTM contamination characteristics more accurately than settled dust. Additionally, recent publications have demonstrated that the components and particle size distribution of settled dust and particles on human skin are remarkably variable (Cao and Yu, 2014; Cao et al., 2013; Cao et al., 2012). Therefore, skin wipes are more feasible for evaluating the human exposure risk of PTMs and the potential danger of PTMs found should draw more attention (Pereira et al., 2007).

In recent years, China has faced the world's most serious air pollution problem and Xinxiang has become one of the top ranked cities with respect to haze contamination in China (Liu et al., 2016). With increasingly severe air pollution, the increase in the number of suspended particles in the atmosphere may increase human exposure risk of PTMs through dermal absorption and ingestion (Luo et al., 2014). However, how air quality affects human exposure to PTMs from atmospheric particles is unclear. Though some studies have been conducted to investigate the exposure risks PTMs in settled dust in children (Sulaiman et al., 2017; Sun et al., 2017), research on the variation of PTM exposure among different populations, analyzed by skin wipes, is rather limited.

In the present study, children, professional drivers, and security guards were selected due to their potential higher exposure risks to PTMs in dust or atmospheric particles. Undergraduates were also selected as a reference population because of their non-professional characteristics. Hence, the objectives of this study were (1) to explore the levels of PTMs in skin wipes, (2) to examine factors that may influence the amounts of PTMs measured, and (3) to assess human exposure to PTMs via dermal absorption and ingestion and assess the corresponding health risk. This study can provide new insights into human exposure to PTMs in dust or atmospheric particles through skin contact and ingestion.

2. Materials and methods

2.1. Sampling area description

This study was conducted in Xinxiang, a medium-sized city in central China with approximately 1.2 million inhabitants in its urban area. It has experienced rapid urbanization and industrialization in the past decades and is now one of the most important production bases in China for batteries and relevant raw materials. In recent years, Xinxiang has become one of the top-ranked cities suffering from severe haze contamination in China.

2.2. Dust sampling and pretreatment

Ghost wipes, made of polyethylene fiber that can be completely digested in acid, were used for sampling (Taylor et al., 2013). The Ghost wipes were cleaned in an ultrasonic bath for 30 min, dried in a vacuum desiccator, and immersed in 4 mL of isopropyl alcohol (reagent grade) in a 60-mL, cleaned (combusted at 450 °C for 6 h), brown glass jar. For each participant, the entire hand surface was wiped over two times using one surface of a Ghost wipe and then wiped two additional times using the other side. The Ghost wipe was then put back into the same brown glass jar. The skin area of the sampled hands was approximately estimated with a coordinate paper (Liu et al., 2017).

Skin wipe samples were collected from the skin surface of four populations, namely, children ($n = 10$), professional drivers ($n = 10$), security guards working at gates ($n = 10$), and undergraduates ($n = 10$) from November to December 2015. Two rounds of sampling were conducted on the same subjects under two different amounts of haze pollution. Light pollution was defined as when the AQI (air quality index) ranged from 90 to 120, PM_{10} ranged from 74 to 114 μg/m^3, and $PM_{2.5}$ ranged from 67 to 90 μg/m^3. Heavy pollution was defined as when the AQI ranged from 280 to 330, PM_{10} ranged from 245 to 290 μg/m^3, and $PM_{2.5}$ ranged from 233 to 271 μg/m^3. The different pollution levels were obtained by sampling on different days. All participants were required to not wash their hands for at least 2 h prior to sampling, and before sampling, all of the participants were working or playing normally. Participants were also asked to fill out a simple questionnaire about their age, gender, height, weight, activities before sampling, last time washing hands prior to sampling, and whether they were using any skincare products. All 80 samples were stored in a refrigerator at −4 °C until analysis.

Samples were dried at 30 °C for 20 min in a dryer to remove moisture. After drying, samples were accurately weighed, 2 mL of high purity water was placed in a 100-mL polyfluortetraethylene tank to wet the sample, and 8 mL of nitric acid and 1 mL of hydrofluoric acid were added in sequence before the microwave digestion program was conducted. The samples were digested in a microwave digestion system for 10 min at 130 °C, then 10 min at 150 °C, followed by 10 min at 180 °C, and finally 10 min at 210 °C. After cooling, the extracts were filtered and dissolved in 50 mL high-purity water. Finally, the PTM concentration of the samples was determined by an inductively coupled plasma mass spectrometry (ICP-MS).

One standard sample (Geochemistry reference matter (GSS-2)) was analyzed per 10 skin wipe samples to assure the accuracy and repeatability of the analysis procedure. For these 8 standard samples, the recoveries of all elements were in the range of 80% to 120%, the relative standard deviations were 3.10%, 7.00%, 3.61%, 2.96%, 7.22%, 8.25%, 7.44%, 6.74%, and 2.05% for Zn, Cu, Cr, Mn, Pb, Cd, Ni, As, and Co, respectively. Field blank skin wipes were collected during sampling and processed simultaneously with field samples. All of the blank skin wipes were below the detection limit. Further, each skin wipe sample was analyzed three times for 10 samples to assure that relative errors were <20%.