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Mass concentration and health risk assessment of heavy metals in size-segregated airborne particulate matter in Changsha

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HIGHLIGHTS

- Size-segregated APM was collected using an 8 Stage Non-Viable Cascade Impactor.
- Concentrations of size-segregated APM and HMs in size-segregated APM were measured.
- Health risk of HMs in APM was assessed by hazard quotient and cancer risk.
- Non-carcinogenic health effect existed in the APM.
- Cancer risks of Cd, Ni and Cr were all below the safe level.

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ABSTRACT

This study was performed to investigate the concentration and the health risk of heavy metals (HMs: Zn, Pb, Cd, Ni, Fe, Mn, Cr and Cu) in size-segregated airborne particulate matter (APM). APM samples were collected into 9 size fractions (>9.0 μm, 5.8–9.0 μm, 4.7–5.8 μm, 3.3–4.7 μm, 2.1–3.3 μm, 1.1–2.1 μm, 0.7–1.1 μm, 0.4–0.7 μm, <0.4 μm) by an 8 Stage Non-Viable Cascade Impactor in the campus of Hunan University in Changsha. And then 9 fractions of APM were analyzed for HMs by ICP–OES. The total size-segregated APM concentration in the campus of Hunan University ranged from 120.24 to 271.15 μg/m^3, and the concentration of HMs in APM was in the range of 38.08–13955.14 ng/m^3. The health risk of HMs in APM was evaluated by hazard quotient (HQ) and hazard index (HI) and the results showed that dermal contact and ingestion of APM were the major exposure pathways to human health. The HI values of Cd, Mn, Pb and Cr for children and Cd, Mn and Pb for adults exhibited to be higher than 1 indicating that a non-carcinogenic health effect existed in the APM of the campus of Hunan University. The carcinogenic risks of Cd, Ni and Cr were all bellow the safe value.

1. Introduction

According to China's environmental bulletin in 2013, the days with an air quality level of "excellent" take only 40% of the total in Changsha in the first season of 2014 and the primary pollutant is $PM_{2.5}$. The main pollution sources of airborne particulate matter (APM) in Changsha are automobile exhaust, industrial production, reentrainment of dust, coal burning, cooking oil fume, biomass burning and other unknown sources (Zhai et al., 2014). APM is a key marker of air quality which highly relates to human health. As it is known, the adverse influences of APM on the human body and environment usually associate with their sizes (Donaldson and MacNee, 2001; Kappos et al., 2004; Martins et al., 2004). Fine particles are easy to penetrate into lungs and stay there for a long time and then enter the blood circulation system. APM is associated with cardiovascular deaths, myocardial infarctions, ventricular fibrillation and autonomic function of the heart (Mohanraj and Azeez, 2004). The presence of chemical and biological contaminants of indoor dust might pose health effects, such as some HMs in dust including lead, cadmium, mercury and arsenic may pose carcinogenic effects (Järup, 2003; Kurt-Karakus, 2012). Otherwise the APM could exert ecological effects on vegetation and ecosystems by light absorption (Horvath, 1995) virtue of the mass loading of its chemical constituents (Grantz et al., 2003).

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Literatures about the size-segregated APM and HMs in the size-segregated APM are mainly from European countries (Brüggemann et al., 2009; Chuersuwan et al., 2008; Contini et al., 2014; Filippo et al., 2010; Pennanen et al., 2007; Scheinhardt et al., 2013) and a few from China which are all about the chemical composition of size-segregated APM (Li et al., 2012; Sun et al., 2013). Investigations about the health risk assessment of APM are even less and few of them are about the health risk assessment of size-segregated APM. Greene and Morris (2006) investigated that $PM_{2.5}$ in the Washington, DC area posed notable deleterious health risk to subpopulations. Bartoš et al. (2009) studied that polyaromatic hydrocarbons (PAHs) in the atmosphere contributed most to human health risk at the urban sites. Cao et al. (2012) found that the particle size had a significant influence on human exposure risk assessment. Du et al. (2013) assessed the health risk of Cr, Ni, Cu, Zn, Cd and Pb in road dust.

In this study, mass concentrations of size-segregated APM and HMs in the size-segregated APM were measured. Moreover, the assessment of human health risks associated with HMs in size-segregated APM was performed. The size distribution of APM is useful for controlling strategy and policy making of government department. The study results described the air quality of the campus of Hunan University Changsha city and could help the physicians, public health officials and the general public to get a better understanding about the health risks of HMs in size-segregated APM via ingestion, dermal contact and inhalation exposure. This study also provides useful information as a basis for further research on risk assessment of APM and it suggests that effective measures should be taken to control the discharge of pollutants.

2. Experiment

2.1. Sampling

Changsha is located in the south central of China and northeastern of Hunan Province (Fig. 1). It is surrounded by mountains in the south, east and west. Changsha has a subtropical humid monsoon climate. The sampling site is situated in the campus of Hunan University in Changsha (28.12° N latitude, 112.59° E longitude). It is a tourist and educational area, where it has little industrial emission but a large amount of automobiles. Additionally the sampling site is close to a bus station (about 10 m away) and there are some scattered small restaurants and construction sites around the sampling site. The sampling site is close to a four-lane road with a traffic density of approximately 5000 vehicles/day and it increases on weekends due to the large number of tourists.

Size-segregated APM was collected by an 8 Stage Non-Viable Cascade Impactor (*Westech Instrument Services Ltd*) in a building of Hunan University. Ambient gases enter the inlet cone and through the succeeding orifice stages with successively higher velocities from Stage 0 to Stage 7. And whether a particle is impacted on any given stage depends on the jet velocity of the stage and the cut-off of the previous stage. Each sampling period was performed uninterruptedly for 48 h with 9 glass-fiber filters (diameter of 81 mm, first two have open centers of 7/8 in.) on sunny days during April 13th to May 6th of 2014. 36 samples were collected during the total four periods. The sampler was operated at a constant flow rate of 28.3 l/min, and APM size ranges were: >9.0 μm, 5.8–9.0 μm, 4.7–5.8 μm, 3.3–4.7 μm, 2.1–3.3 μm, 1.1–2.1 μm, 0.7–1.1 μm, 0.4–0.7 μm, and <0.4 μm.

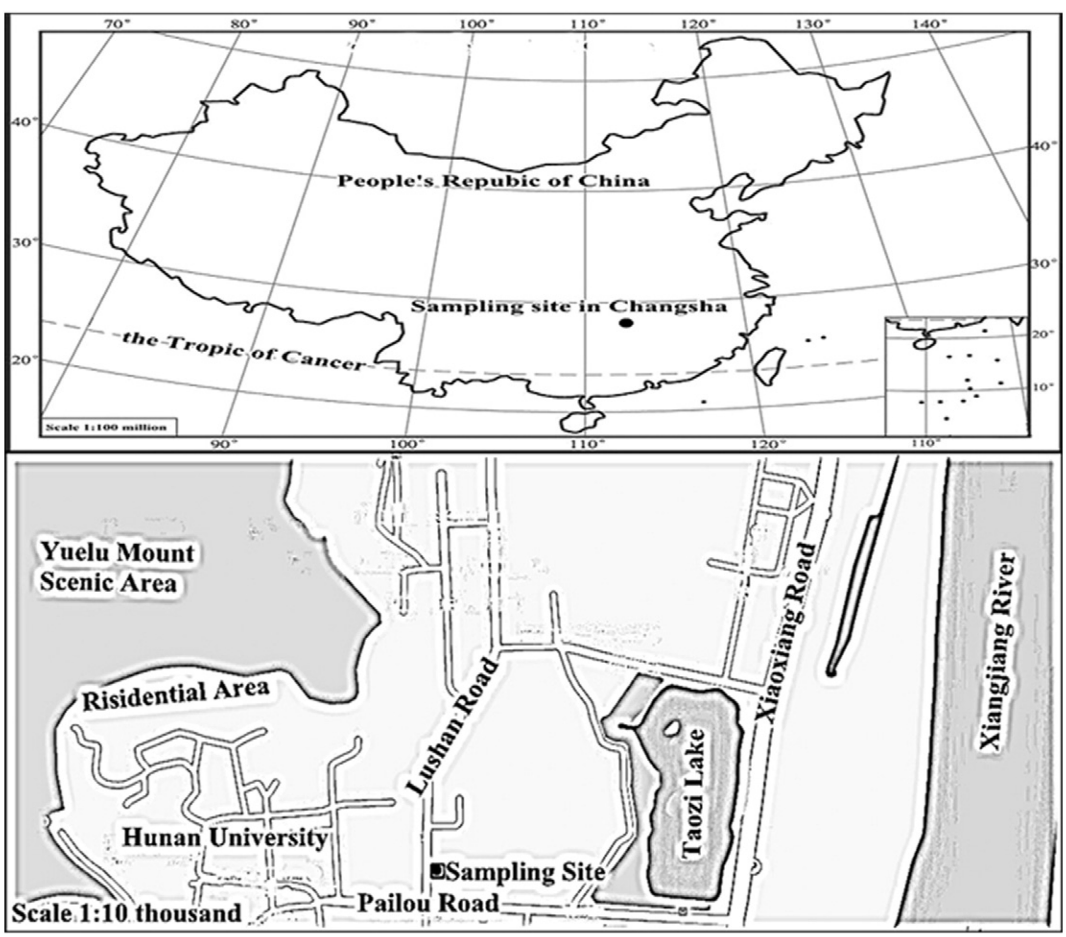

Fig. 1. The sampling site location.