

DOCTORAL THESIS

Risk assessments of human exposure to metal(loid)s via urban dust and airborne particles in Guangzhou, South China

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**Risk Assessments of Human Exposure to Metal(loid)s
via Urban Dust and Airborne Particles in Guangzhou,
South China**

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**A thesis submitted in partial fulfillment of the requirements for
the degree of
Doctor of Philosophy**

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Hong Kong Baptist University**

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ABSTRACT

The major objectives of the research were to investigate the contamination of metal(loid)s (Cr, Mn, Ni, Cu, Zn, As, Cd, Sn, Sb, Hg and Pb) in dust and airborne particles, and identify typical metal(loid)s contained in them which might lead to hazardous effects on human health. Road dust, household air-conditioning (AC) filter dust and PM_{2.5} were collected in outdoor and indoor urban environments of Guangzhou. Enrichment factors (EFs) were used to assess the influence of human activity on the contamination of these metal(loid)s. Physiologically based extraction test (PBET), an *in-vitro* gastrointestinal method, was employed to estimate the oral bioaccessibilities of metal(loid)s. Moreover, a composite lung simulating serum, consisting of salts of sodium, ammonium and calcium as well as amino acids, was used to mimic the pulmonary condition to extract the respiratory bioaccessible metal(loid)s in PM_{2.5}. On the other hand, this study also attempted to investigate the accumulation of the metal(loid)s in human scalp hair, and associated it with the individual daily intakes (DIs) via dust and airborne particles. Eighty-eight scalp hair samples were collected from Guangzhou urban population. Demographic information (body weight, height, age, gender, habits of smoking and drinking, types of drinking water, duration of stay in Guangzhou, days of stay in Guangzhou per year, and hours spent in indoor environment per day) was also recorded during hair sampling. The resident's individual DIs of metal(loid)s were calculated based on their body weights, duration of stay in Guangzhou, days of stay in Guangzhou per year, and hours spent in indoor environment per day. Lastly, hepatocellular liver carcinoma (HepG2), dermal

keratinocyte (KERTr,) and lung epithelial carcinoma (A549) were employed in MTT assay to evaluate the cytotoxicity of water-soluble fraction of road dust, AC filter dust and PM_{2.5}. Spike solutions of detected metal(loid)s were employed to compared their cytotoxicity with the aqueous extracts of dust and airborne particles.

Zinc was found to be one of the most abundant elements. Cu, Zn, Cd, Sb and Pb in road dust, Zn, Cd, Sb, Hg and Pb in AC filter dust, Cr, Zn, As, Cd, Sb, Hg, and Pb in PM_{2.5}, with their EFs larger than 5, showed significantly contaminated. In the case of non-carcinogenic risk, both ingestion of AC filter dust and inhalation of PM_{2.5} were significantly hazardous to human health, especially for children (HIs>1). Furthermore, household AC filter dust and PM_{2.5} could also cause potential carcinogenic risks (CRs>1.0×10⁻⁰⁶). Arsenic was found to be the most risky element.

Speciation (iAs^{III}, iAs^V, MMA and DMA) of total arsenic (As) content and its bioaccessible fractions (oral bioaccessibility and respiratory bioaccessibility) contained in road dust, household AC filter dust and PM_{2.5} was further investigated. Inorganic As, especially inorganic pentavalent arsenical (iAs^V), was observed as the dominant species. Reduction of iAs^V to inorganic trivalent arsenical (iAs^{III}) occurred in both *in-vitro* gastrointestinal and lung simulating extraction models. The inorganic As species was found to be the exclusive species for absorption through ingestion and inhalation of dust and airborne particles, which was the other important sources of exposure to inorganic As, in addition to drinking water and food consumption.

As another heavy metal of human health concern, total Hg (THg) and methyl Hg (MeHg) were also analyzed in the dust and airborne particles. The concentrations of

THg and MeHg were observed relatively lower in peri-urban district, compared with other urban districts (such as scenic parks, educational districts, traffic pivotal districts, residential districts and commercial districts) in Guangzhou. The significantly higher THg concentration ($p < 0.05$) in household AC filter dust than that in road dust indicated that the household environment provided other pollution sources of Hg. Although the proportion of MeHg in THg contained in each type of particles was extraordinarily low (less than 0.5%), the DIs of MeHg accounted for 2.7-14.4% of THg via ingestion and inhalation of dust and airborne particles.

The concentrations of Cr, Ni and As in human scalp hair showed at the upper extreme around the world. Inorganic As^{III} was the most abundant As species. Body mass index (BMI) and body area surface (BAS) were found to be associated with the accumulation of metal(loid)s in human hair interactively with age or duration, based on the multiple linear regression analysis. Additionally, nutritional and physical status, reflected by BMI and BAS, were observed as the exclusive factors associating As speciation in human hair. The environmental exposures to urban dust and airborne particles were significantly correlated to the concentrations of Cd ($R^2=0.306$, $p=0.005$) and Ni ($R^2=0.333$, $p=0.002$) in human scalp hair.

The effects of aqueous extracts of dust and PM on cell growth were dependent on exposure time and the exposed concentration. The LC_{20s} of PM_{2.5} for A549 cell were about one order of magnitude lower than those of road dust and AC filter dust for KERTr cell and HepG2 cell. The LC_{20s} of dust aqueous extract was negatively correlated to the water-soluble metal(loid)s contained in dust particles (KERTr:

p=0.004; HepG2: p<0.001). However, no significant correlation was observed between the soluble metal(loid)s in PM_{2.5} and LC₂₀s for A549 cell (p>0.05). The LC₂₀s for dust and airborne particles were much lower than those caused by spike solutions.

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