

Short communication

Potentially harmful metals and metalloids in urban street dusts of Urumqi City: Comparison with Taipei City

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ABSTRACT

Urumqi City is the farthest metropolis from an ocean in the world. This communication measured the concentrations of eight potentially harmful metals Cr, Pb, Hg, Ni, Cd, Zn, Cu, and Sr and metalloids As and Sb in the street dusts collected from Urumqi City and compared them with those noted in Taipei City. Although the geological environments of Taipei and Urumqi differ markedly; however, the potential harmful metals and metalloids studied are surprisingly similar in their distributions in these two cities. Particularly, As is a common pollutant that poses severe health risks to residents in both cities. Hence, the anthropogenic rather than geogenic factors pre-dominate the formation and distributions of street dusts. This finding suggests common control strategy may be applicable to different metropolis on the confinement of adverse health effects by the street dusts.

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1. Introduction

Urban street dust is produced in cities, which composed of solid particles with complex compositions. High levels of potentially harmful metals in street dust, after entering the human body, can have adverse effects on the health of individuals [1,2]. Taipei City is a coastal metropolis with high population density (9600 per km²) and high vehicle density (6786 per km²). Zhang et al. [3] sampled the street dusts in Taipei City and demonstrated the concentrations of eight metals and two metalloids in the collected samples. These authors noted that the studied potential harmful metals and metalloids in Taipei street dusts were mainly from traffic emissions, with adverse health effects from exposure to As, Sb, Cr and Pb by children.

Urumqi, the capital city of China's Xinjiang Uygur Autonomous Region, is the metropolis farthest from an ocean in the world, whose geological characteristics limit the removal of produced pollutants in and near the city. Urumqi has a continental and arid

climate and was rated as 4th in the 15 most heavily polluted cities worldwide by the World Health Organization (WHO) [4]. Wei et al. [5–7] reported the levels of heavy metals in street dust of Urumqi.

Literature works on street dusts in Urumqi neglected the impacts of potentially harmful metals (Hg and Sr) and metalloids (As and Sb). Also, these studies did not conduct health risk analysis using the obtained data. The objectives of this communication are to measure the concentrations of eight potential harmful metals (Cr, Pb, Hg, Ni, Cd, Zn, Cu and Sr) and two metalloids (As, Sb) in street dust samples from Urumqi using the same protocols by [3] on Taipei City and then make comparisons of the results between these two cities.

2. Materials and method

2.1. Study areas and sampling

Fig. S1 and Table S1 in Supplementary materials shows the sampling sites. 63 street dust samples were collected in Urumqi during of July 2011. Dust samples were not collected adjacent to specific pollution sources such as industrial sites. At each sampling site, approximately 250 g of dust that accumulated on impervious surfaces was collected with a plastic brush and dustpan. Samples were kept in sealed polyethylene bags and transported to the

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laboratory. They were then dried at room temperature for 5 d with grids being removed.

2.2. Sample treatment and analysis

The sampling, treatment and analysis protocols of street dusts from Urumqi City were the same as those in Zhang et al. [3]. Statistical analyses were performed with SPSS 11.5. Descriptive analysis, correlation analysis (CA), and principal component analysis (PCA) were used. The exposure assessment of the studied metals and metalloids to human bodies was conducted according to Ref. [3]. Details of the exposure assessment are also listed in the Supplementary materials.

Quantitative risk characterization requires the evaluation of exposure (or intake) estimates, such as a cancer SFAn HQ is a ratio of the daily exposure level to the reference dose (RfD). A Hazard Index (HI) equals the sum of HQs. For carcinogens, the dose is multiplied by the corresponding SF to produce a degree of cancer risk. The general equations used to calculate risk from street dust are Eqs. (S7)–(S9) [8].

Enrichment factors (EFs) were used to highlight the origin of elements in soil. The EF was calculated based on methods proposed by Lim et al. [9] and Zhang et al. [3].

3. Results and discussion

3.1. Potential harmful metal concentrations in street dust

Fig. 1 shows the metal and metalloid concentrations in street dust samples from Urumqi. In Urumqi, the mean concentrations of potential harmful metals in street dust samples were as follows: As, 229 mg/kg; Cu, 179 mg/kg; Cd 1.97 mg/kg; Cr 186 mg/kg; Hg 1.50 mg/kg; Ni 289.7 mg/kg; Pb 187 mg/kg; Zn 227 mg/kg; Sb 73.5 mg/kg; and Sr 226 mg/kg. The average concentrations of potential harmful metals and metalloids in the street dust followed $Ni > As \approx Zn \approx Sr > Pb \approx Cr \approx Cu > Sb > Cd > Hg$. Overall, heavy metals contents in the road dust of Taipei were much higher than those in Urumqi except for As and Sb, with those being 60% and 70% of those in Urumqi, respectively.

3.2. Correlation studies

The Pearson correlation coefficient (r) was used to quantify the linear relationship between two quantitative variables. Table S2 lists the coefficients for inter-element correlations in street dust in Urumqi. In Urumqi, only Cr–Cu concentrations were strongly

correlated. The Cr–Pb, Pb–Cu, and Sb–Hg concentrations were weakly correlated. Fig. S2 shows the dendrograms for potential harmful metals and metalloids in Urumqi. In Urumqi, 4 clusters are noted: (1) Hg, Cd, and Sb; (2) Cu, Cr, Zn, and Pb; (3) As and Sr; and (4) Ni.

Table S3 shows PCA results and Varimax rotation matrix. Four principle components were extracted. In Urumqi, Factor 1 was extracted by loadings of Cu, Zn, Cr and Pb, which may be related to vehicle emissions [10,11]. Factor 2 was loaded primarily by Hg and Sb, which obviously originated from anthropogenic activities such as incineration of municipal solid waste. Factor 3 was dominated by Cd and Ni. Traffic emissions and oil combustion can contribute to some extent to Cd and Ni concentrations in street dust. Nickel pollution is caused by emissions from vehicle engines that use gasoline containing Ni and by the abrasion and corrosion of Ni from vehicle parts [12]. Factor 4 was explained by As and Sr. Metal As was likely from the combustion of fossil fuels such as waste oil and coal [1,10,13].

3.3. Health risk assessment and potential sources

The exposure assessment is listed in Table 1. In Urumqi, all exposure routes for non-carcinogenic effect by Ni, As, Zn, Sr, Pb, Cr, Cu, Sb and Cd in road dusts have the following risk order for both children and adult ingestion > dermal contact > inhalation. In particular, the ingestion exposure is the main route for heavy metals and metalloids in road dust to human, correlating with [14,15]. Conversely, the inhaling Hg vapor was higher than those of ingestion and dermal exposures. Also, the exposure of studied metals and metalloids for children exceeded those for adult, which is attributable to the hand-to-mouth activity of children [3,15].

On carcinogenic effects, intakes of As, Cr, Cd and Ni in the road dust through three exposure routes were listed Table 1. The As in road dust has higher carcinogenic effect on children than on adults.

The noted metal or metalloids in street dust may be of geogenic or anthropogenic origins. Only the EF value of Sr (7.3) in street dust from Urumqi was in the range of 1–10, suggesting that Sr in street dust in Urumqi is mainly from crustal sources.

In Urumqi, only the Cr–Cu concentrations were strongly correlated. The Cr–Pb, Pb–Cu, and Sb–Hg concentrations were weakly correlated (Table S2). Cluster analysis identified correlations among studied potential harmful metals and metalloids (Fig. S2 and Table S3). Street dust samples from Urumqi had much higher As concentrations than those for other cities [16,17]. Some gasoline reportedly contains 30–120 ng/g of As [18]. However, since the vehicle density of Urumqi is low (557 km⁻²) and since

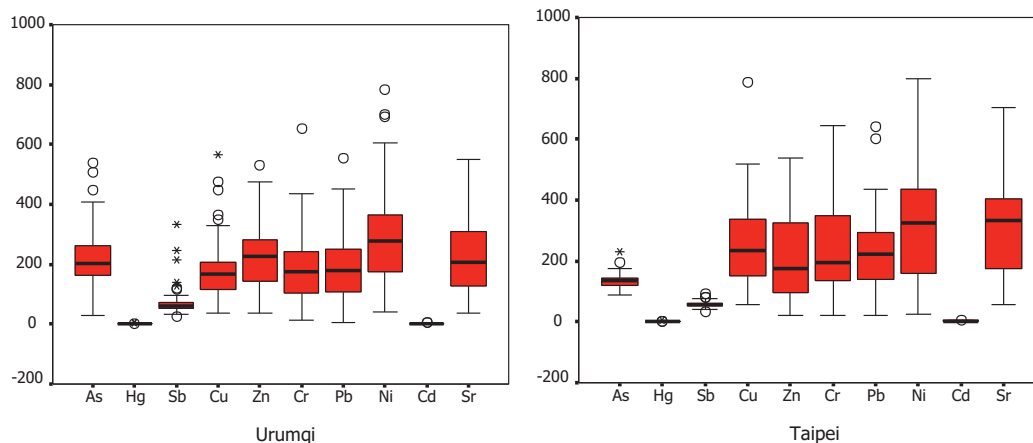


Fig. 1. The contents of the heavy metals in the road dust. (a) Urumqi and (b) Taipei [3]; boxes delineate interquartile range (25–75%) with indication of median; whiskers indicate range excluding outliers; dots are outliers.

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