Chin.J.Geochem.(2014)33:272–276
DOI: 10.1007/s11631-014-0687-x

Accumulation and risk assessment of heavy metals in dust in main living areas of Guiyang City, Southwest China

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Received December 2, 2013, accepted January 28, 2014

Abstract Guiyang is a famous tourist city located in southwestern China. In this study, dust from eleven residential areas, seven city squares, and nine schools was collected to measure the heavy metal levels and evaluate its risk. At each sampling site, 4–5 sub-samples were taken as a bulk sample. All samples were air-dried, ground, passed through a 0.105 mm nylon sieve, digested with HNO_3-$HClO_4$ to determine the concentrations of Cd, Cu, Ni, Pb and Zn by ICP-MS, and digested with 1:1 aqua regia to determine As by AFS. The results show that the concentrations of As, Cd, Cu, Ni, Pb and Zn in dust of Guiyang City follow normal distribution with means of 16.1, 1.54, 138, 47.7, 129 and 479 mg/kg, respectively. Levels of As, Cd, Cu, Ni, Pb and Zn exceed the background level of soil in Guizhou Province by 33%, 96%, 100%, 78%, 96%, and 100%, respectively. Cd, Cu, Pb and Zn are heavily accumulated in dust of living areas with accumulation factors of 4.10, 5.12, 4.12 and 5.51, respectively. City square possesses the highest geometric means of As, Cd, Cu, Pb, and Zn. The risks of heavy metal exposure to teenagers are not obvious and in an order of As>Pb>Cu>Ni>Zn (Cd).

Key words heavy metal; dust; main living area; Guiyang City; Southwest China

1 Introduction

The increase of heavy metals concentration caused by human activities has led to rising environment and health risks in recent years. A potential risk to humans can be urban dust, as its small particle size and re-suspension in wind can lead to the possibility of direct and indirect exposure (Okorie et al., 2012). Exposure to metal-contaminated dust may cause human health issue through skin contact and hand-mouth activity, particularly through the unintentional uptake by children in playgrounds and city streets (Saeedi et al., 2012). Girvin et al. (1998) showed that exposure to dust lead in school area was an important contributor to blood lead levels in, and hence a potential health hazard to children.

The urban area is an assembly of different land use types and the chemical composition of urban dust precipitation at different sites can show a high spatial heterogeneity (Rio-Salas et al., 2012). Some studies focused on difference of city functional areas show that the highest concentrations of heavy metals in dust are mainly found in industrial area (Han et al., 2008; Liu et al., 2012; Li et al., 2013), especially Pb and Zn, with nearly twice level higher than in other functional area (Li et al., 2013). While some studies on health risk have been conducted according to the heavy metal concentrations in whole city urban dust (Liu et al., 2009; Fang et al., 2010; Li et al., 2011), risk study based on the data for whole city may overestimate the exposure risk to heavy metal.

In this study, we choose the main living areas in Guiyang City as research area, to present the heavy metal levels and its risk to people by sampling dusts from residential area, city square, and school area.

2 Sampling and methods

2.1 Research area

Guiyang, located in the southwestern China, is a famous tourism city, awarded the title of *the Summer Capital of China*. Guiyang is under the influence of a humid climate with the mean annual temperature of 15.3℃, the mean annual relative humidity of 77% and the total mean annual precipitation of 1129.5 mm. The central urban district of Guiyang covers an area of 220 km^2, which consists of 3 districts. The central district has over 2 million urban residents with a population density of 30000 people per km^2 (Li et al., 2012).

2.2 Dust sampling and data analysis

Dusts were sampled in 2010 from main living areas in Guiyang, including eleven residential areas, seven city squares, and nine schools (Fig. 1). At each sampling site, 4–5 sub-samples were taken as a bulk sample, hence a total number of 27 samples were obtained. Collected dusts were air-dried, ground, passed through a 0.105 mm nylon sieve and digested with HNO_3-$HClO_4$ to determine the concentrations of Cd, Cu, Ni, Pb and Zn by ICP-MS, and digested with 1:1 aqua regia to determine As by AFS. Standard soil reference materials ESS-1 and GSS-4 from the Center for National Standard Reference Material of China were inserted for quality control.

The accumulated ratio obtained by the following equation,

$$R_i = \frac{C_i}{C_j} \quad (1)$$

where R_i is defined as the accumulated ratio; C_i stands for the concentration of a specific heavy metal (As, Cd, Cu, Ni, Pb and Zn) in dust, and C_j refers to the background value of the corresponding metal in Guiyang soils.

Risk assessment model from ingestion unintentional heavy metals is,

$$Q_{\text{ingestion}}\ (\mu\text{g/kg BW·d}) = \text{C (mg/kg)} \times \frac{\text{Ing}R \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \times 10^{-3} \quad (2)$$

where $Q_{\text{ingestion}}$ stands for heavy metals for unintentional ingestion dust by children, Ing R is intake/contact rate (200 mg/day in this study), EF is exposure frequency (180 days/a in this study), ED means exposure duration, which is 6 years for children, BW stands for body weight, which is 15 kg for children, AT is averaging time, value ED×320 days (Fang et al., 2010), and C is the concentration of heavy metal in dust.

The doses thus calculated for each element and exposure pathway are subsequently divided by the corresponding reference dose to a hazard quotient (H*Q*),

$$\text{H}Q = \frac{Q_{\text{ingestion}}}{R\text{fD}}$$

where *R*fD is reference dose, by EPA (Table 1).

3 Results and discussion

3.1 Heavy metal levels in dust in main living area of Guiyang

Data of As, Cd, Cu, Ni, Pb and Zn in Guiyang urban dust follow the normal distribution with Means±SDs of 16.1±5.50, 1.54±0.786, 138±90.1, 47.7±17.4, 129±67.7 and 479±266 mg/kg (Table 2), respectively. When compared with background value of heavy metals in soil of Guizhou Province, China, levels of As, Cd, Cu, Ni, Pb and Zn of our samples exceed the back ground values by 33%, 96%, 100%, 78%, 96% and 100%, respectively. Cd, Cu, Pb and Zn are heavily accumulated in dust of living areas with the accumulation factors of 7.40, 5.12, 4.12 and 5.51, respectively, and Cd is heavily accumulated in dust of the main living area. Levels of As and Ni in dust are close to their background value in soil.

Table 1 Reference dose by EPA

	HQ (ug/kg BW·d)					
	As	Cd	Cu	Ni	Pb	Zn
RfD	0.3	1.0	40	20	3.57	300

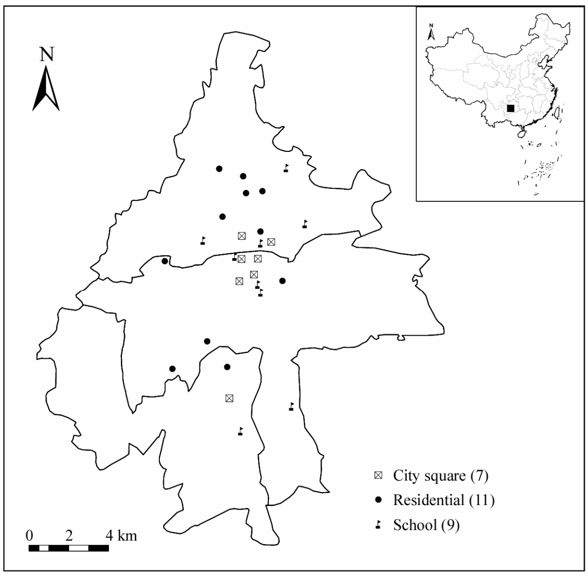

Fig. 1. Dust sampling sites in Guiyang City.

3.2 Heavy metal levels in dust of different functional areas

The concentration of metals in dust varies for each function area (Table 3). City square posses the highest mean value of As, Cd, Cu, Pb, and Zn, and As level in city square is significant higher than in school area with $P = 0.012$, while residential area having the highest mean value of Ni. School area has the lowest concentrations of Cu, Zn, and Ni and residential area owns the lowest concentrations of As, Cd, and Pb. Higher concentrations of metals for city square may due to that the city square is in the centre of city with large foot traffic each day.

3.3 Heavy metal accumulation in dust and its potential source

Fig. 2 shows that As and Ni are lightly accumulated in dust, while Cd, Cu, Pb and Zn are considerably accumulated in dust. The studied nine schools are evenly located in the urban area. We also sampled the paint chips and rubber scraps from school ground, analysis showed that the Cd concentrations of which are 3.44–4.37 and 1.51 mg/kg (Table 4), 21 and 7.3 times higher than the background value, respectively. Therefore it could infer that the Cd contained in auxiliary material in campus could be the main factors affecting Cd levels in dust.

Table 2 Heavy metal levels of dusts of the main living area in Guiyang

	Heavy metal (mg/kg)					
	As	Cd	Cu	Ni	Pb	Zn
Mean	16.10	1.54	138.00	47.70	129.00	479
Median	15.30	1.43	114.00	44.20	114.00	451
Minimum	7.80	0.31	29.90	23.20	26.80	157
Maximum	29.50	3.57	3810.00	92.50	294.00	1493
Std. deviation	5.50	0.79	90.10	17.40	67.70	266
Background value in Guiyang soil (NEPA, 1990)	16	0.208	26.90	32.90	31.30	86.90
R	1.01	7.40	5.13	1.45	4.12	5.51

Table 3 Heavy metal levels for different functional areas

		Heavy metal (mg/kg)					
		As	Cd	Cu	Ni	Pb	Zn
Residential	Range	7.80–29.50	0.31–2.32	33–381	32.70–90.60	26.80–294	157–1493
	Median	14.30	1.25	158	53.60	107	419
	Mean	14.70	1.08	124	52.10	103	423
	R	0.92	5.19	4.62	1.58	3.31	4.31
City square	Range	8.30–29.50	0.93–3.57	64.90–363	23.20–92.50	65.60–265	223–930
	Median	16	1.97	142	49.20	116	484
	Mean	17	1.74	137	46.30	127	487
	R	1.06	8.36	5.09	1.41	4.05	4.96
School	Range	10.80–19.50	0.76–3.12	29.90–218	27.10–50.60	47.90–236	213–553
	Median	15.30	1.51	87	35.50	107	432
	Mean	14.70	1.48	87.10	36.90	112	384
	R	0.92	7.12	3.24	1.12	3.57	3.92

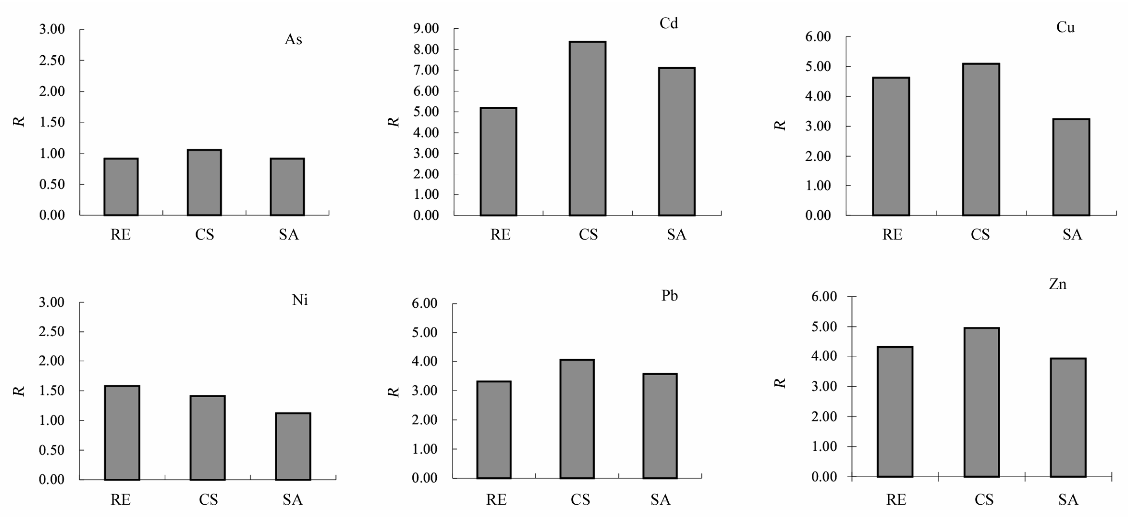

Fig. 2. Heavy metal accumulated in dust of different functional area in Guiyang City. RE. Residential; CS. city square; SA. school.

Table 4 Level of Cd of materials from school

Material	Cd (mg/kg)		
	Result 1	Result 2	Mean
Paint chips-1	4.37	/	4.37
Paint scrap-2	3.60	3.28	3.44
Plastic scrap	1.57	1.45	1.51

Pb remains the metal of the greatest concern from a human health perspective (Turner et al., 2012). Fig. 2 shows that Pb is accumulated in dust in the main living area of Guiyang City. In this special area, the composition in urban dust is not only affected by atmospheric deposition, but also affected by buildings weathering and releasing of products containing heavy metals, These Pb sources may contribute as much Pb to the urban dust as traffic does (Miguel et al., 1997; Turner et al., 2012). We analyzed Pb concentration in paint chips in school area, and the result of 171–2529 mg/kg illustrates the contribution from pain chip to Pb level in dust.

Human-caused accumulation of Cu and Zn mainly comes from tire wear, break abrasion, as well as renovation and demolition of buildings. Meanwhile, the concentration levels of 1198±30.5 mg/kg of Cu and 6278±24 mg/kg of Zn in plastic scrap from school playground also suggest the potential contribution of rubber racetrack abrasion to Cu and Zn levels in dust.

3.4 Risk of heavy metals in dust to children

Children are exposed to urban dust mainly through three ways: ingestion of dust particles, inhalation of dust particles, and dermal contact with dust particles (Ferreira-Baptista et al., 2005), among which unintentional ingestion is the most important pathway.

In this study, the heavy metals of As, Cd, Cu, Ni, Pb and Zn unintentional ingested by children are 0.106, 0.010, 0.905, 0.314, 0.847 and 3.15 ug/kg BW·d, respectively, varied between different metals, with higher Cu and Pb, lower As and Cd. Compared with RfD (Reference Dose, by EPA), the Hazard quotient (HQ) to RfD descreases in the order of As>Pb>Cu>Ni>Zn (Cd). As and Pb in dust ingested through unintentional ingestion by children are 35.3% and 23.7% of RfD per day, respectively. Therefore, there is no obvious risk to children.

Table 5 lists the HQ for children in different cities yielded by the same model and RfD as this study. It is apparent that the risk of heavy metals in dust of Guiyang to children is relatively low.

Table 5 Hazard quotient (HQ) for children of different cities in China

City	HQ (10^{-2})						References
	As	Cd	Cu	Ni	Pb	Zn	
Guiyang	35.30	1.00	2.30	1.60	23.70	1.00	This study
Hefei	/	6.60	2.50	/	55.10	11.40	Li et al., 2011
Kaifeng	/	/	1.30	3.50	93	1.32	Wang et al., 2011
Baoji	47.70	/	2.22	1.87	97	1.84	Chen et al., 2011

Note: /. no data.

4 Conclusions

Levels of As, Cd, Cu, Ni, Pb and Zn in Guiyang dust follow normal distribution, and their Means±SDs (mg/kg) are 16.1±5.50, 1.54±0.786, 138±90.1, 47.7±17.4, 129±67.7 and 479±266, respectively. Compared with the background value of heavy metals in soil of Guizhou Province, Cd, Cu, Pb and Zn are heavily accumulated in dust of living area with the accumulation factors of 4.10, 5.12, 4.12 and 5.51, respectively. Concentrations of metals in dust vary with each function area. City squares possess the highest geometric means of As, Cd, Cu, Pb, and Zn, probably because they mainly sites in the city center and bears large amount of daily foot traffic. Risk for exposure of different heavy metals to children is in an order of As>Pb>Cu>Ni>Zn (Cd). There is not obvious risk to children.

Acknowledgements This research project is supported by National Natural Science Foundation of China (41161079).

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