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Bioaccessibility and Health Risk Assessment of Heavy Metals in Dust of the Urban Areas of Guiyang, Guizhou, China

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ABSTRACT

To investigate what health risks the heavy metals in dust will bring to the human body after they enter humans through different exposure pathways- breathing inhalation and hand-to-mouth ingestion, this study took the old urban area of Guiyang as the study area to grasp the heavy metal concentrations of surface dust, in recreative squares main streets, hospitals, residential areas, and schools in the urban area, and the bioaccessibility in the simulated lung and simulated gastrointestinal. The results showed that the concentrations of Cu, Pb, Zn, Cd, Ni, and Cr in the dust were higher than the background values. Particularly, the Zn concentration exceeded the background value by 9.71 times. The bioaccessibility results indicated that the most soluble heavy metals in the simulated lung, simulated stomach, and simulated intestine were Zn, Ni, and Cu, respectively, and the bioaccessibility of most heavy metals was significantly higher in the gastric phase than that in the intestinal phase, and only the bioaccessibility of Cu was higher in the intestinal phase than that in the gastric phase. The linear results fit showed that the total amount of heavy metals alone could not be used for predicting the human intake of heavy metals in the dust. Human health risk assessment based on bioaccessibility showed that children had higher non-carcinogenic and carcinogenic risks than adults in terms of both hand-to-mouth ingestion and respiratory inhalation exposure pathways, but none of these figures exceeded the limit values.

INTRODUCTION

Cities are now where people spend the majority of their time, and their rapid development has led to numerous environmental health problems (Li et al. 2019a). As an inorganic pollutant, heavy metals are featured by bioconcentration and difficult degradation and can cause a variety of hazards after entering the human body through different exposure pathways (Tang et al. 2017). Dust is an important carrier for the attachment of heavy metals and various pollutants. Since dust is at a different environmental interface and can bring important source-sink effects (Renata et al. 2021). Therefore, many scholars have studied the sources and spatial distribution of heavy metals in dust, and most of the findings show that the sources of heavy metals in dust are mainly related to vehicle exhaust emissions, wear and tear of the vehicles, and aging of pavement materials, while the spatial distribution is related to the source of pollution (Han et al. 2020, Yu et al. 2021, Jose et al. 2021).

Bioaccessibility refers to the ratio of the amount of contaminants released in the gastrointestinal fluid to the total amount after the contaminants in the soil and food enter the human digestive system. Compared with the traditional assessment methods, bioaccessibility can more accurately reflect the heavy metals in the human body scientifically and reasonably. There has been a lot of research on bioaccessibility at home and abroad, but the researches mainly focus on soil heavy metals and metal mining areas, etc. (Du et al. 2020, Sultana et al. 2020). Although the bioaccessibility of heavy metals in dust has been reported, the simulated digestion phase is only limited to the gastrointestinal phase, and there are few studies on the bioaccessibility of the simulated respiratory system in vitro. Therefore, this study used in vitro simulated human digestive system and respiratory system to conduct the bioaccessibility study, and it is significant to carry out a health risk assessment on the urban populations based on bioaccessible concentration.

With the rapid development of the economy and the continuous expansion of urban transportation, Guiyang's ecological and environmental problems have become increasingly prominent. The main objective of this study was to evaluate the total heavy metal concentrations in Guiyang city. In vitro simulation method was used to simulate the leaching of heavy metals from dust in human lungs and gastrointestinal tract respectively, to explore the bioaccessibility of heavy metals. Finally, according to the bioaccessibility of heavy metals in different stages, these data could be used to conduct non-carcinogenic and carcinogenic health risk assessment studies for adults and children in the city.

MATERIALS AND METHODS

Study Area

Guiyang city (106°07′-107°17′N, 26°11′-27°22′E), as it is known in Fig. 1, is located in the central part of the Guizhou province. The old urban areas of Guiyang City were selected for this research: Yunyan District and Nanming District. These old urban areas have been developed for a long period, and there have been historical residues of heavy metals in the dust on the surface of old urban areas due to the expansion of traffic and the construction of a large number of high-rise buildings in its long history course. Therefore, urban residents living in the old city are facing potential health risks from dust and heavy metal exposure.

Sampling and Sample Preparation

A total of 71 dust sampling points were shown in Fig. 1. The sampling sites covered recreative squares, main streets, hospitals, residential areas, schools, and other areas where most people locate. The dust samples are collected from April to May 2021, and it was ensured that the humidity in the city was not high and the weather was clear during the sampling period. All dust samples were packed in individually labeled polyethylene sealed plastic bags and were transported back to the laboratory for processing afterward. Before the experiment, extra materials, such as hairs, sand, grit, and plant residues, were removed from samples through a 1mm nylon screen. Finally, samples were sieved through a 200 µm mesh nylon screen, labeled, and prepared to be tested.

Gamble Analysis

In vitro simulated respiratory system mainly uses the Gamble analysis method (Zoitos et al. 1997). The simulated lung fluid was added to each reactor with a solid-liquid ratio of 1:1000, and the temperature was kept at 37°C, the normal temperature of the human body. The solution oscillated at 100 r·min^{-1} for 24 h in a constant-temperature oscillator, centrifuged at 5,000 r·min^{-1} for 10min, and filtered through a 0.45 µm filter membrane. Finally, the contents of Cu, Pb, Zn, Cd, Ni, and Cr in the filtrate were measured by inductively coupled plasma mass spectrometry (ICP-MS, PerkinElmer NexION 2000).

Physiologically-Based Extraction Test (PBET) Analysis

The PBET method has become the most typical in vitro method for simulating the digestive system (Ruby et al. 1993). The method was based on the physiological characteristics of the human body to simulate the digestion stage of the stomach and the absorption stage of the small intestine. The simulated gastric liquid was added to each reactor at a 1: 100 solid-to-liquid ratio and was oscillated in a constant-temperature oscillator at 100 r·min^{-1} for 1 h. In the intestinal phase, saturated $NaHCO_3$ solution was added until the pH of the solution reached 8.0, and then 0.14 g of bile salt and 0.04 g trypsin were added into the constant, and the mixture oscillated under the same conditions as the simulated stomach for 4 h. Then the supernatant was collected, centrifuged, and filtered.

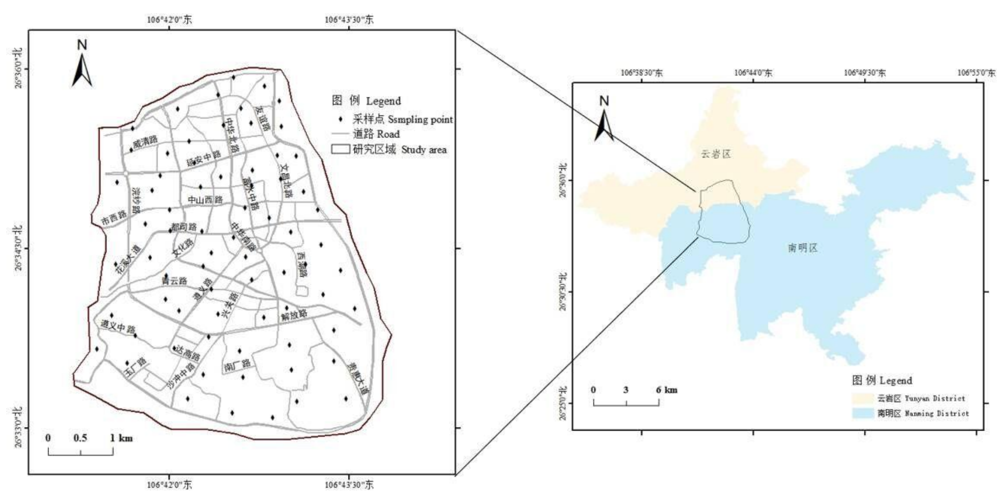

Fig. 1: Sampling points and map of the study area.

Bioaccessibility in the gastric or intestinal stages could be calculated based on the following equation:

$$BAC(\%)=\frac{C_{IV}\times V_{IV}}{T_S\times M_S}\times 100\% \quad \ldots(1)$$

Where *BAC* is the bioaccessibility for heavy metals; C_{IV} means the concentration of heavy metals in the soluble state in the lung dissolution, gastric digestion, and intestinal absorption phases for the simulated experiment (mg.L^{-1}); V_{IV} refers to the volume for the reaction solution in each reactor (L); T_S is the total amount for heavy metals in the sample (mg.kg^{-1}); M_S is the mass for the sample in the reactor (kg).

Human Health Risk Assessment

Considering that human exposure to heavy metals in the dust is mainly through two exposure routes respiratory inhalation and hand-to-mouth ingestion, this study was mainly based on the bioaccessibility of simulated lungs and simulated gastrointestinal tracts to calculate the average daily exposure and the corresponding non-carcinogenic and carcinogenic risks for adults and children under these two routes. the average daily exposure (ADD) and risk values were mainly calculated in the following form:

Table 1: Parameter values in average daily intake calculation models of heavy metals.

Parameter	Physical meaning	Unit	Child	Adult
C_{dust}	The concentration of heavy metals in dust	mg·kg^{-1}	—	—
IngR	Daily intake rate	mg·kg^{-1}	100	200
InhR	Inhalation rate	m^3·d^{-1}	5.6	16.5
EF	Exposure frequency	day·year	180	180
ED	Exposure time	year	6	24
PEF	Dust emission factor	m^3·kg^{-1}	1.36×10^{9}m^3·kg^{-1}	
CF	Conversion factor	/	1×10^{-6}	
BW	Average weight	kg	14.9	58.6
ABS	Skin absorption factor	/	0.001	
SA	Exposed skin surface area	cm^2	4350	1600
AF	Average exposure time	/	0.2	0.2
AT (non-carcinogens)	Average exposure time	day	365×6	365×24
AT (carcinogens)	Average exposure time	day	365×70	365×70

$$ADD_{inh}=\frac{C_{dust}\times InhR\times EF\times ED}{PEF\times BW\times AT} \quad \ldots (2)$$

$$ADD_{ing}=\frac{C_{dust}\times IngR\times EF\times ED\times CF}{BW\times AT} \quad \ldots (3)$$

The physical meaning and values of the specific formula parameters are listed in Table 1.

Heavy metals accumulate in the human body under different exposure pathways and cause chronic non-carcinogenic risks. Cd, Ni, and Cr mainly cause cancer in people. The human health risks caused by respiratory inhalation, hand-oral ingestion, and dermal exposure in this study are expressed as HI and CR, respectively (USEPA 2007).

$$HQ=\frac{ADD}{RfD} \quad \ldots (4)$$

$$HI=\sum HQ_i \quad \ldots (5)$$

$$CR=\sum ADD_i\times SF_i \quad \ldots (6)$$

where HQ (Hazard Quotient) is the single non-carcinogenic risk; *RfD* means the reference dose at different pathways (mg·kg^{-1}·d^{-1}). HI represents the total non-carcinogenic risk due to all heavy metals; CR (Cancer Risk) represents the total carcinogenic risk due to all heavy metals; SF refers to the slope for carcinogenicity (mg·kg^{-1}·d^{-1}).

The Environmental Protection Agency (EPA) believes the risk is low when HQ or HI < 1 and some non-carcinogenic risk is produced when HQ or HI >1; the carcinogenic risk is negligible when CR is below 10^{-6}, within the acceptable range, that is, between 10^{-6} and 10^{-4}, and above 10^{-4}, the carcinogenic risk can be regarded as a serious one. The physical meaning and values of the specific formula parameters are listed in Table 2.

Data Analysis

The data were compiled by Excel 2016, and the spatial

Table 2: Reference doses for non-cancer metals and slope factors for carcinogenic metals.

Elements	RfD_{ing}	RfD_{inh}	SF_{ing}	SF_{inh}
Cu	4.00E-02	4.00E-02	-	-
Pb	3.50E-03	3.50E-03	-	-
Zn	0.3	0.3	-	-
Cd	1.00E-03	1.00E-03	6.1	6.30
Ni	2.00E-02	2.06E-02	-	0.84
Cr	3.00E-03	2.86E-05	-	42.0

distribution for sampling points was performed by ArcGis 10.2. The visualization of the data was plotted by OrginPro 8.0. The fitting relationship between the total amount of heavy metals in dust and the bioaccessibility in different simulation stages was performed by SPSS 16.0. The degree of fit could reflect the correlation between the total amount and the bioaccessible amount.

RESULTS AND DISCUSSION

Total Metal Concentration

The concentrations of Cu, Pb, Zn, Cd, Ni, and Cr in 71 dust samples in this study were shown in Fig. 2 and Table 3. From Table 3, all heavy metal concentrations of dust were significantly above the background values, which were 5.16, 1.82, 9.71, 2.92, 3.41, 4.99, and 1.72 times the background values, respectively. The concentrations were ranked as follows: Zn > Cu > Cr > Ni > Pb > Cd. Although the concentration of Pb in this study exceeded the background value, it was significantly reduced compared with previous studies on heavy metals in urban road dust. It could be speculated that the Pb concentration in this study was less than limited levels probably because of the widespread use of unleaded gasoline. However, the reason why it was higher than the background value might be due to the relatively long development history of the old city, some of the Pb was deposited in the dust or might be related to the wear of automobile materials (Zheng et al. 2020). Among the investigated heavy metals, Zn content significantly exceeded the standard of other heavy metals. According to our analysis, the main sampling sites in this study were located near the main roads and parking lots of residential areas. Some studies suggested that the high concentration of Zn was related to the wear and tear of car parts and tires (Goix et al. 2016). According to the statistical principle, the larger the coefficient of variation (C.V), the greater the degree of dispersion of the pollutant, and the greater the influence of external factors. From Table 3, it could be seen that the coefficient of variation was ranked from high to low as Pb > Cd > Zn > Cr > Cu > Ni so it could be seen that Pb, Cd, and Zn showed a higher level of variation, indicating that these three heavy metals were uniformly distributed spatially compared with each other and were more influenced by external factors. At the same time, the conclusion in this study is consistent with the conclusion drawn by Fan et al. (2020).

In Vitro Stimulation of the Respiratory System

The bioaccessibility of Cu, Pb, Zn, Cd, Ni, and Cr in the simulated lung was shown in Fig. 3 and Table 4. Among the six elements involved in this study, Cr had the lowest

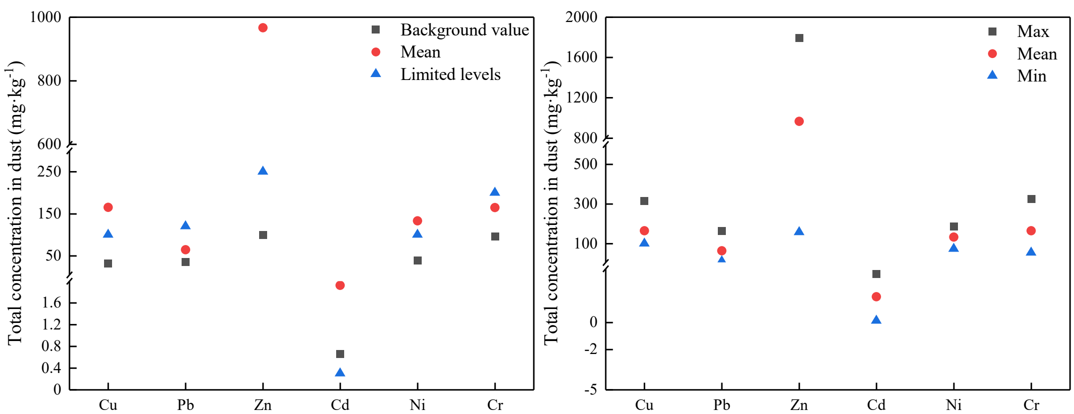

Fig. 2: Total heavy metals in dust in this study.

Table 3: Concentrations of heavy metals (mg.kg^{-1}) in surface dust.

Element	Minimum	Maximum	Median	Mean ± SD	C.V. [%]	Background value
Cu	100.67	315.72	156.98	165.41 ± 47.37	28.64	32.0
Pb	11.24	163.34	45.82	64.41 ± 44.28	68.76	35.2
Zn	157.44	1793.91	996.21	966.61 ± 373.19	38.61	99.5
Cd	0.13	3.62	1.99	1.924 ± 0.89	46.41	0.659
Ni	73.72	187.52	127.82	133.26 ± 26.39	19.81	39.1
Cr	54.91	325.86	162.64	164.86 ± 53.69	32.57	95.9

bioaccessibility (3.81%) and Zn had the highest bioaccessibility (38.97%). The high dissolution of Zn in simulated lungs might be related to the special characteristic of Zn. Studies had shown that car tire wear is an important source of ZnO in dust, and the low bioaccessibility of Cr might also be related to the occurrence of ZnO (Adachi & Tainoshu 2004). Some researchers extracted different forms of Cr using Tessier sequential extraction method and found that Cr was mainly in the insoluble residual fraction and the soluble fraction was relatively low. Therefore, the bioaccessibility of Cr in simulated lung fluid was the smallest. In this study, the bioaccessibility of Cd in simulated lung fluid was similar to that of Cr and was at a lower level (Li et al. 2019b). However, some studies had shown that the bioaccessibility of Cd in simulated lungs was at a higher level. The reason for the difference may be related to the components in the simulated lung fluid, pH, extraction time, and the source of Cd (Zhang et al. 2019). The bioaccessibility percentages of the other three heavy metals Cu, Pb, and Ni in the simulated lung were 12.99%, 15.51%, and 10.54%, respectively.

In Vitro Stimulation of the Digestive System

In this study, the bioaccessibility of heavy metals in dust in the simulated stomach and intestine stage was shown in Fig. 3 and Table 4. It could be seen that the bioaccessibility of Cu, Pb, Zn, Cd, Ni, and Cr in the stomach and intestine of 71 samples. Table 4 summarized the range, average concentration, and median of the bioaccessibility of heavy metals in dust samples. The heavy metals with high bioaccessibility in the gastric phase were Cu, Zn, Cd, and Ni, which all were more than 40%. Cr had the lowest dissolution rate of 4.19%. In the intestinal phase, the average of heavy metals bioaccessibilities was as follows: Cu>Zn>Ni>Cd>Pb>Cr. Compared with the bioaccessibility of the gastric phase, the bioaccessibility in the intestinal phase was significantly reduced, Pb bioaccessibility decreased from 23.89% to 13.26%, Zn

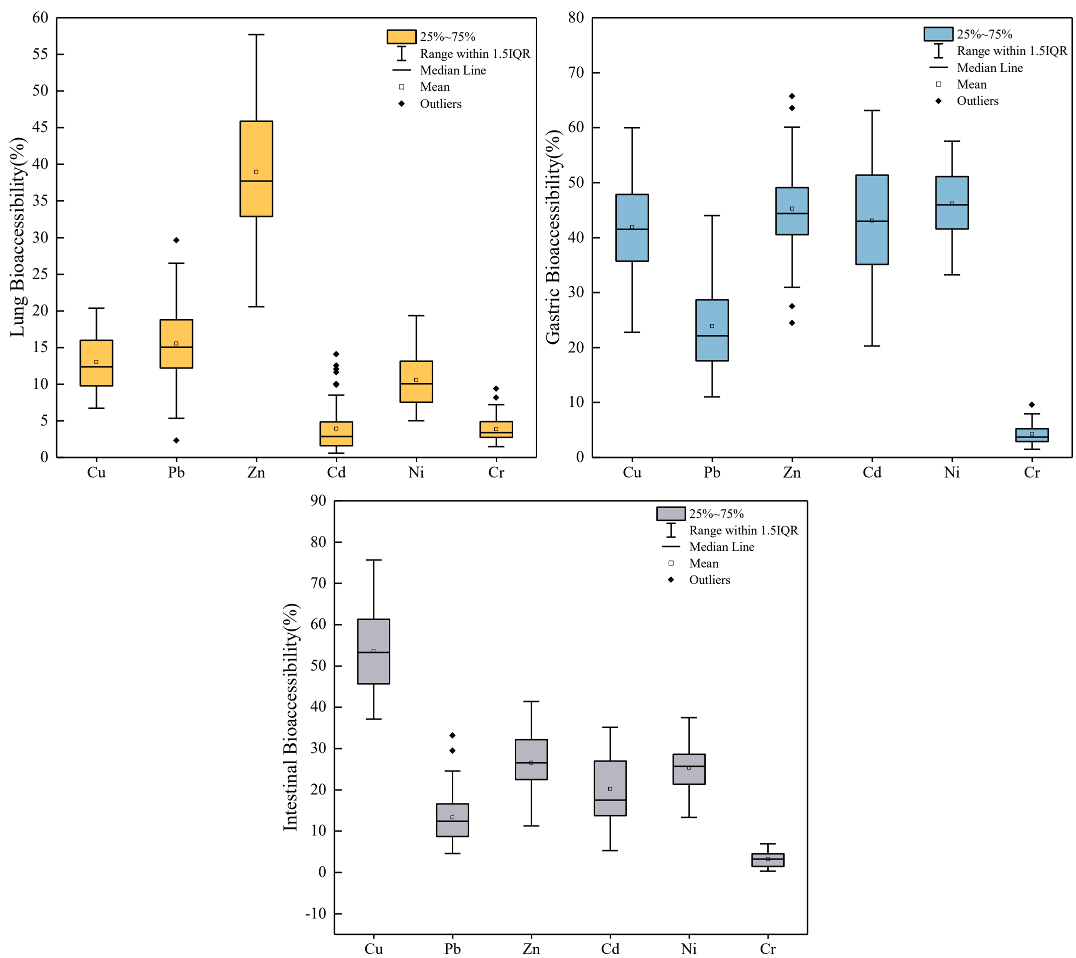

Fig. 3: The percentage for bioaccessibility of each heavy metal at different simulation stages.

Table 4:Bioaccessibility of heavy metals in the lung phase, gastric phase, and intestinal phase of dust.

Heavy metals	Lung [%]			Gastric [%]			Intestinal [%]		
	Range	Median	Mean	Range	Median	Mean	Range	Median	Mean
Cu	6.68-20.36	12.36	12.99	22.77-59.98	41.46	41.85	37.13-75.66	53.26	53.62
Pb	2.26-29.61	15.01	15.51	10.98-43.96	22.11	23.89	4.57-33.14	12.37	13.26
Zn	20.54-57.69	37.67	38.97	24.43-65.69	44.35	45.22	11.25-41.36	26.51	26.49
Cd	0.57-14.03	2.82	3.88	20.26-63.10	42.96	43.07	5.29-35.14	17.46	20.17
Ni	4.99-19.34	10.04	10.54	33.22-57.51	45.91	46.16	13.27-37.46	25.64	25.32
Cr	1.47-9.33	3.39	3.81	1.47-9.51	3.68	4.19	0.27-6.87	3.21	3.09

bioaccessibility from 45.22% to 26.49%, Cd bioaccessibility from 43.07% to 20.17%, and Ni from 46.16% to 25.32%. The bioaccessibility of Cr from the stomach stage to the intestine stage changed little, while Cu increased from 41.85% in the stomach stage to 53.62% in the intestine stage. In general, the bioaccessibility of most heavy metals was significantly higher in the gastric stage than in the intestinal stage. Some research showed that heavy metals, such as Pb, Zn, Cd, and Ni, were more active and easily soluble and digested under acidic conditions in the stomach (Soltani et al. 2021, Zhao et al. 2020). After the heavy metals dissolved in the gastric stage (acidic) enter the intestinal stage (alkaline), the adsorption and precipitation reaction occurred and the solubility of heavy metals decreased. The small degree of change in Cr might be mainly because Cr was mainly in the form of residues and the dissolution rate was not high in simulated human gastrointestinal fluid (Li et al. 2019b). The reason for the increased Cu bioaccessibility was that Cu could be complex with trypsin and bile salts, thus showing a higher solubility effect in the intestinal absorption phase (Xu et al. 2018).

Relationships Between the Bioaccessibility and the Total Concentrations

The linear relationships between the total amount of Cu, Pb, Zn, Cd, Ni, and Cr in dust and bioaccessibility in the simulated lung phase, gastric phase, intestinal phase were presented in Fig. 3, Fig. 4, Fig. 5. Linear coefficients (R^2) of the total

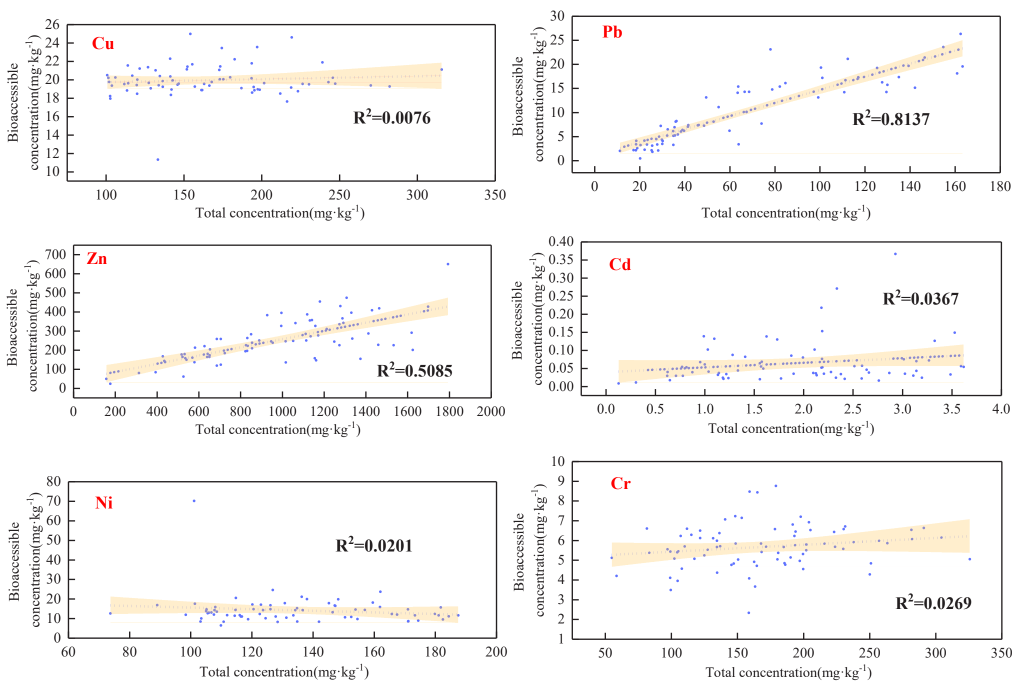

Fig. 4: Linear fit of the lung phase.

amount of each heavy metal in the dust and bioaccessibility in the simulated lung phase were 0.0076, 0.8137, 0.8044, 0.0367, 0.0201, and 0.0269, respectively. Only the total amount of Pb (R^2=0.8137) and Zn (R^2=0.8044) showed a significant correlation with the concentration of the lung fluid extract, while other heavy metals had no significant linear relationship with the total concentration. The linear coefficients (R^2) of each heavy metal in the gastric phase were 0.6057, 0.8003, 0.8074, 0.6868, 0.7151, and 0.1168, respectively. The concentration of Pb, Zn, and Ni in the gastric fluid extract stage showed good correlations with the total amount in dust, Cu and Cd showed moderately positive correlation, and there was no significant correlation for Cr. The linear coefficients (R^2) of each heavy metal in the simulated intestinal phase were 0.6279, 0.6276, 0.5085, 0.4501, 0.4135, and 0.1244, respectively, and the total amount of heavy metals showed a moderately positive correlation with the concentration of the intestinal extract stage except for Cr. It could be seen from the linear fit relationships in different phases that the total amount of Pb and Zn could only be used to simply estimate the digestive dissolution in the human lung and stomach, but most of the total heavy metals could not greatly affect the bioaccessibility. Since human mainly intakes heavy metals through the intestine, therefore, the previous health risk using the total amount of heavy metals had some errors and could not accurately reflect the absorption of heavy metals in the human body or carcinogenic and non-carcinogenic risk values (Sun et al. 2018).

Health Risk Assessment of Heavy Metals Based on Bioaccessibility

According to Table 5, the average daily non-carcinogenic exposure for children was higher than that for adults in both pathways, and the daily average non-carcinogenic was also higher than that for adults. The daily average exposure of non-carcinogenic heavy metals for hand-to-mouth intake was shown as follows: Zn>Cu>Ni>Pb>Cr>Cd. Zn could reach 8.29E-04, and Cd was the smallest among all these heavy metals, reaching 1.21E-06. Thus, in comparison, the number of heavy metals absorbed in the intestine was higher, and the non-carcinogenic risk by hand-oral intake was also much higher than that through respiratory inhalation (Shahab et al. 2018). However, the non-carcinogenic risks for Cu, Pb, Zn, Cd, Ni, and Cr in both exposure pathways did not exceed 1, which was below the standard values, indicating that no non-carcinogenic risks were caused. Although both children and adults had the highest daily average exposure to Zn by these two pathways among all these metals, Pb was the non-carcinogenic element with the greatest risky value in the non-carcinogenic risk assessment results. According to Table 3, children had the highest average daily exposure of Ni for children reached 4.99E-10 under the respiratory inhalation pathway, the total carcinogenic risk for children was 6.38E-07 under the two pathways, and the total carcinogenic risk value for adults was 8.71E-10. Furthermore, the carcinogenic risk values of Cd, Ni, and Cr for children were

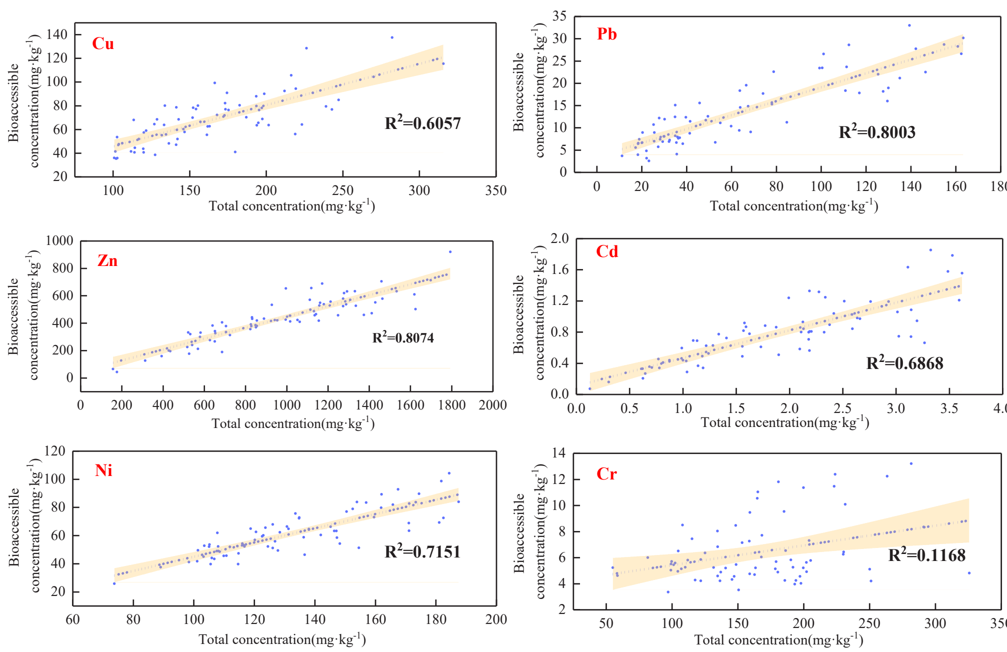

Fig. 5: Linear fit of the gastric phase.

Table 5: Health risk assessment on heavy metals based on bioaccessibility in dust for adults and children.

Heavy metals	Children					Adults				
	ADD_{ing}	HQ_{ing}	ADD_{inh}	HQ_{inh}	HI	ADD_{ing}	HQ_{ing}	ADD_{inh}	HQ_{inh}	HI
Hazard quotient(HQ) /mg·kg^{-1}·d^{-1}										
Cu	1.48E-04	3.69E-03	2.72E-09	6.80E-08	3.69E-03	7.51E-05	1.88E-03	2.04E-09	5.09E-08	1.88E-03
Pb	2.51E-05	7.15E-03	1.34E-09	3.84E-07	7.15E-03	1.27E-05	3.64E-03	1.01E-09	2.88E-07	3.64E-03
Zn	8.29E-04	2.76E-03	5.29E-08	1.76E-07	2.76E-03	4.22E-04	1.41E-03	3.96E-08	1.32E-07	1.41E-03
Cd	1.21E-06	1.22E-03	8.77E-12	8.77E-09	1.22E-03	6.17E-07	6.18E-04	6.57E-12	6.57E-09	6.18E-04
Ni	1.12E-04	5.58E-03	1.94E-09	9.43E-08	5.58E-03	5.67E-05	2.84E-03	1.46E-09	7.07E-08	2.84E-03
Cr	1.62E-05	5.41E-03	7.68E-10	2.68E-05	5.44E-03	8.25E-06	2.75E-03	5.75E-10	2.01E-05	2.77E-03
Total	1.13E-03	2.58E-02	5.97E-08	2.75E-05	2.58E-02	5.75E-04	1.31E-02	4.47E-08	2.06E-05	1.32E-02
Cancer risk(CR)/ mg·kg^{-1}·d^{-1}										
Cd	1.04E-07	6.35E-07	7.52E-13	4.74E-12	6.35E-07	6.01E-14	3.67E-13	2.25E-12	1.42E-11	1.46E-11
Ni	—	—	1.67E-10	1.40E-10	1.40E-10	—	—	4.99E-10	4.19E-10	4.19E-10
Cr	—	—	6.58E-11	2.76E-09	2.76E-09	—	—	1.97E-10	8.28E-09	8.28E-09
Total	1.04E-07	6.35E-07	2.34E-10	2.90E-09	6.38E-07	6.01E-14	3.67E-13	6.98E-10	8.71E-09	8.71E-09

6.35E-07, 1.40E-10, and 2.76E-09, respectively. According to the calculation results, the carcinogenic risk of children could also be ignored. The carcinogenic risk values of Cd, Ni, and Cr in adults reached 1.46E-11, 4.19E-10, and 8.28E-09 respectively, which the risk of cancer in adults was negligible based on the calculation results. Based on the evaluation results, although the non-carcinogenic and carcinogenic risks did not reach the risk values, the exposure to heavy metals was highest under the hand-to-mouth pathway of ingestion, so people who need to travel should take protective measures, such as wearing a mask and washing hands regularly.

CONCLUSIONS

In this study, the total amount of Cu, Pb, Zn, Cd, Ni, and Cr in surface dust in the old urban area of Guiyang city was

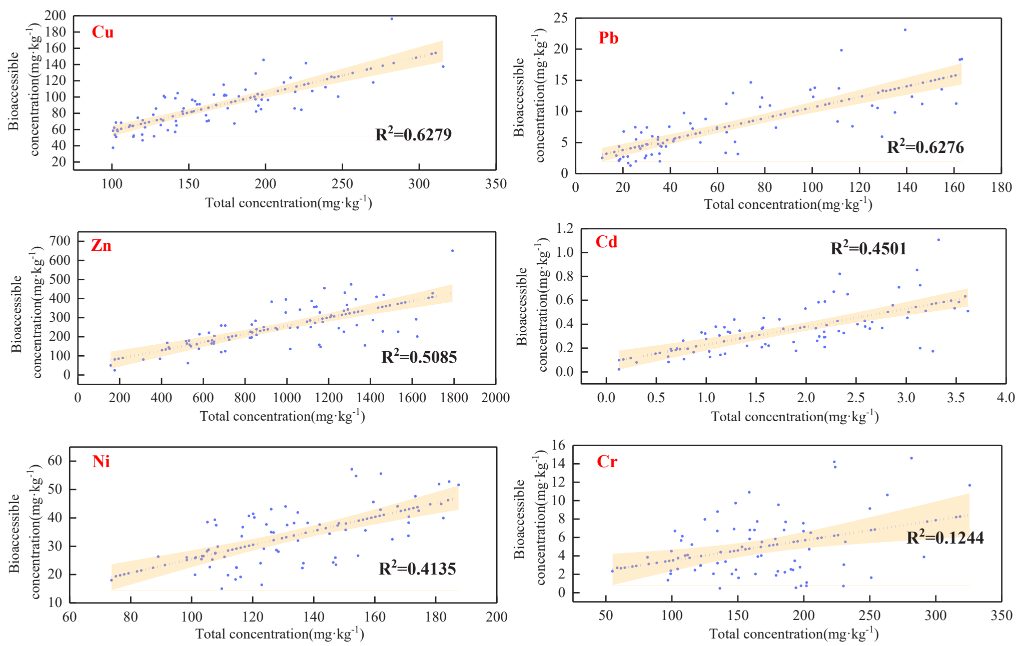

Fig. 6: Linear fit of the intestinal phase.

investigated. The study aimed to study the bioaccessibility and health risk assessment of the two exposure routes of inhalation and hand-to-mouth ingestion were studied. The results indicated that (1) The total amounts of Cu, Pb, Zn, Cd, Ni, and Cr in surface dust in the old urban area of Guiyang exceeded the background values of Guizhou Province, showing different degrees of pollution. Especially, the extent of Zn exceeded the standard greatly, 9.71 times the background value. The coefficient of variation indicated that Pb, Zn, and Cd were mainly disturbed by human activities and external factors. (2) Subsequently, bioaccessibility experiments on heavy metals in dust were conducted in the simulated lung, stomach, and intestine. According to the results, among the heavy metals with the highest dissolution in the simulated lung stage, Zn (38.97%) had the highest bioaccessibility and Cr (3.81%) had the lowest dissolution. In the gastric phase, the highest bioaccessibility was Ni (46.16%) and the lowest dissolution was Cr (4.19%). In the intestinal phase, Cu (53.62%) had the highest bioaccessibility while Cr (3.09%) had the lowest dissolution. (3) Thirdly, a linear fit was shown between the total amount of heavy metals in dust and the bioaccessible amount of Pb and Zn in different simulation stages, which proved that only the bioaccessibility of Pb and Zn had a better correlation with the total amount in the simulated lung and gastric phases. In the simulated intestine stage, the heavy metals had no significant correlation with the total amount in this study, showing that the total amount of heavy metals alone could not help predict the human intake of heavy metals in the dust. (4) The results of health risk assessment based on bioaccessibility showed that the non-carcinogenic and carcinogenic risks for children were higher than those of adults under both hand-to-mouth intake and respiratory inhalation exposure pathways, and the non-carcinogenic and carcinogenic risk values for Cu, Pb, Zn, Cd, Ni, and Cr did not exceed the limits, indicating that the health risks of children and adults in this region were within acceptable limits. However, the non-carcinogenic and carcinogenic risks did not reach risk values, the risk under the hand-to-mouth pathway was higher than those under the respiratory inhalation pathway so people living in this urban area need to take certain protective measures.

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