Characteristics of heavy metal accumulation in five wild plants in Huize Lead-Zinc mining area

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Abstract: In order to screen out the plants used to repair heavy metal pollution in the soil, five plants and surface soil were collected in the Huize lead-zinc mine area, centered on the hyperaccumulator plant *Arabis alpina L. var. parviflora* Franch, measured the heavy metal content of in shoot and root of plant and surface soil, and analyzed the characteristics of heavy metal accumulation in plants. The results showed that the soil Cd pollution in the Huize lead-zinc mining area was the most serious; among the five plants, the Cd bioconcentration factor(BCF) and translocation factor(TF) of *A. alpina* were more than 1, and the TF of Pb was more than 1; the TF of *Anaphalis margaritacea*, *Cyananthus inflatus* and *Arenaria orbiculata* to Cu and Zn were more than 1, the TF of *Juncus effusus* to Cd and Zn were more than 1. These five plants had good tolerance to heavy metals and were of great significance to the remediation and restoration of heavy metal contaminated soil in lead-zinc mining areas.

1 Introduction

Lead-zinc mine is an important strategic mineral resource in China [1]. Long-term mining and smelting activities of mineral resources have produced a large number of slag piles and abandoned land, resulted in serious heavy metal pollution in the mining area [2]. Heavy metal pollution of soil in mining areas will lead to soil degradation in farmland and crop yield reduction, thereby threatening the quality and safety of soil in mining areas [3]. Yunnan is rich in mineral resources, with lead-zinc deposits ranking first in the country and second in Asia [4]. The Huize lead-zinc mine in Yunnan is one of the representatives of large-scale lead-zinc deposits in my country. There were old slag piles and waste land generated during mining and smelting in the mining area, which made the surrounding farmlands seriously polluted by heavy metals [5]. Heavy metals enter the human body through soil and crops, and accumulate in the human body, seriously endangering human health.

There are many ways to deal with heavy metal pollution in the soil, among which the greenest and most effective is phytoremediation. This article discussesd *Arabis alpina L. var. parviflora* Franch(*A. alpina*), *Anaphalis margaritacea*(*A. margaritacea*), *Cyananthus inflatus*(*C. inflatus*), *Arenaria orbiculata*(*A. orbiculata*) and *Juncus effusus*(*J. effusus*) plants and their rhizosphere surface soil in the Huize lead-zinc mining area were sampled and investigated, and their heavy metal enrichment characteristics were studied and analyzed to provide a theoretical basis for remediation of heavy metal soil pollution in the mining area.

2 Materials and methods

2.1. Overview of the study area

The Huize lead-zinc mining area is located in the northeastern part of Yunnan, in Huize County, Qujing City, Yunnan Province. The terrain is high in the southwest and low in the northeast. It is mainly mountainous, with an average elevation of 2183 m. It has a subtropical monsoon climate. The annual average temperature is 12.6 ℃. The sampling points were Chihong site(CHS), Xiaomaping site(XMP) and Sanduoduo site(SDD)(Figure 1).

2.2. Sample collection and processing

The area where the *A. alpina* southern mustard grows in the mining area was selected, and five plants and surface soil were collected in the area, such as *A. alpina*, *A. margaritacea*, *C. inflatus, A. orbiculata* and *J. effusus*, which grew naturally and distributed more frequently. Sealsd all samples with polyethylene plastic bags and took them back to the laboratory.

Firstly, the plant samples were rinsed with tap water to clean the soil attached to the surface of the plants, and then the plants were rinsed with deionized water three times, and the plants were divided into shoot and root. Secondly, place the plants in an oven at 105 ℃ for 30 min, and dry them at 75℃ to a constant weight. Finally, they were crushed with a stainless steel grinder. The soil sample is naturally air-dried and passed through a 0.149 mm nylon sieve.

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2.3. Measurement method

Concentrated HNO_3-$HClO_4$ and concentrated HNO_3-H_2O_2 digestion methods were used to determine the content of Pb, Cd, Cu and Zn in soil and plants, and then measured with flame atomic absorption spectrophotometer.

2.4. Data processing and statistical analyses

Bioconcentration factor (BCF)=heavy metal content in shoot of plant (mg kg^{-1})/heavy metal content in soil (mg kg^{-1})

Translocation factor (TF)=heavy metal content in shoot of plant (mg kg^{-1})/heavy metal content in root of plant (mg kg^{-1})

The data were collected and analyzed by Microsoft Excel. One-way analysis of variance (one-way ANOVA) and significance test(P=0.05) were done by IBM SPSS Statistics 22.

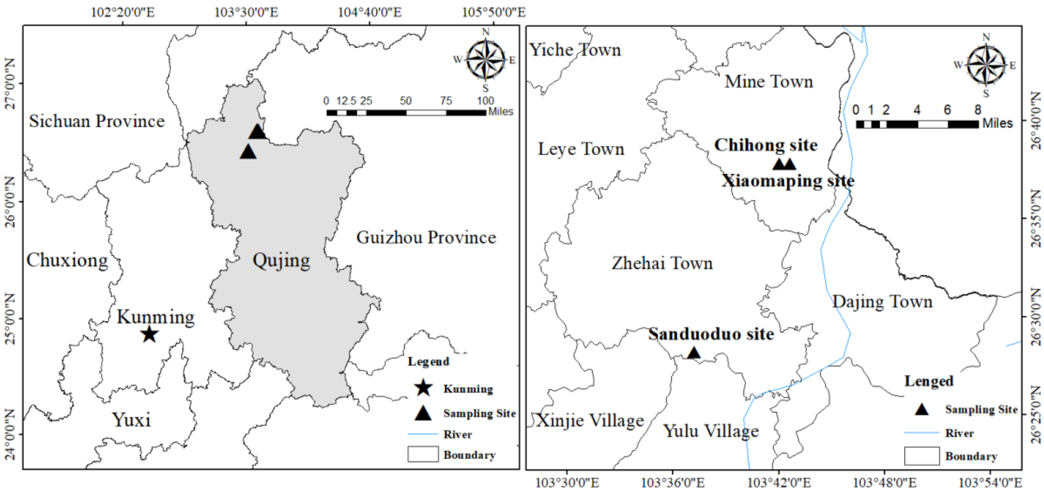

Figure 1. Sampling point location

3 Results

3.1. Soil heavy metal content in mining area

Compared with the national soil environmental quality standard, the average content of Pb, Cd, Cu and Zn in the soil was 15.9 times, 38.4 times, 2.7 times and 35.4 times of the standard. Compared with the soil environmental background value in Yunnan Province, the average content of Pb, Cd, Cu and Zn in the soil was 157.1 times, 262.1 times, 2.9 times and 78.9 times of the standard (Table 1). It can be seen that all four types of heavy metals pollute the soil in the mining area, of which Cd pollution is the most serious.

3.2. Characteristics of heavy metal content in plants in mining area

The contents of Pb, Cd, Cu and Zn in the five planted objects in the mining area were quite different (Table 2).

Table1. Statistics of heavy metal content in plant root soil in mining area (Unit: mg kg^{-1})

Site	Pb	Cd	Cu	Zn
CHS	6654.57±1071.08a	47.57±23.20b	74.10±17.63b	6193.91±1185.78b
XMP	5593.67±1897.81a	55.98±28.69ab	197.25±40.17a	7002.20±1019.88b
SDD	7777.80±1038.48a	97.03±22.81a	149.15±40.97a	10281.25±1661.04a
Average value	6675.34	66.86	140.16	7825.78
National soil environmental quality standard [6]	400.00	1.50	50.00	200.00
Yunnan Province soil environmental background value [7]	40.60	0.22	46.30	89.70

Note: Different lowercase letters in the same column indicate a significant difference (P <0.05), the same below.

The content range of each heavy metal in the shoot of the plant was: Pb 151.88~648.34 mg kg^{-1}; Cd 5.78~39.25 mg kg^{-1}; Cu 15.98~40.23 mg kg^{-1}; Zn 1149.27~1840.13 mg kg^{-1}, and the content range of each heavy metal in the root of the plant was: Pb 164.73~1382.81 mg kg^{-1}; Cd 7.99~50.21 mg kg^{-1}; Cu 10.63~334.93 mg kg^{-1}; Zn 1040.63~1740.86 mg kg^{-1}. The absorption capacity of *A. alpina* to Pb, Cd, Cu and Zn was greater than that of the other four plants.

3.3. Characteristics of plants' accumulation of heavy metals in mining areas

The BCF of Pb, Cu and Zn in five plants were all <1, and the BCF of Cd in *A. alpina* was >1. Except for the *A. alpina*, the Pb TF of the other four plants were all <1; except for *A. alpina* and *J. effusus*, the Cd TF of the other three plants were all <1; except for the *J. effusus*, the Cu TF of the other four plants were all >1; the Zn TF of the five plants were all >1(Table 3).

Table 2. Heavy metal content in plants in mining area (Unit: mg kg-1)

Site	Plant	Pb content		Cd content		Cu content		Zn content	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
CHS	*A. alpina*	648.34±76.00a	1382.81±244.64a	39.25±2.32a	50.21±6.63a	15.98±2.42c	10.63±5.98c	1765.67±63.76a	1463.30±107.23b
	A. margaritacea	472.70±86.04b	1186.20±204.17a	7.11±3.33c	12.09±3.03bc	27.50±5.58ab	24.58±5.69ab	1149.27±169.12c	1094.87±153.63c
	C. inflatus	210.82±126.67c	1130.41±264.94a	15.60±9.00c	20.44±6.00b	18.12±4.96bc	19.38±6.37bc	1228.77±184.31bc	1080.56±121.79c
	A. orbiculata	235.55±94.11c	535.05±188.62b	12.03±4.21c	17.10±5.28bc	17.95±9.51abc	20.41±2.24b	1375.60±127.08bc	1281.94±130.34bc
XMP	*A. alpina*	314.76±84.81bc	287.91±126.78bc	27.80±7.86bc	37.02±10.72ab	16.52±6.38bc	12.59±4.88c	1501.42±164.92b	1478.83±188.70abc
	A. margaritacea	265.74±132.17bc	356.59±165.02bc	5.78±4.97c	8.97±4.92bc	40.23±15.00a	34.93±6.47a	1221.97±112.71c	1040.63±195.25c
	C. inflatus	143.28±60.19c	254.10±92.52bc	13.45±4.48c	20.54±4.57b	24.54±2.69ab	25.51±5.17ab	1162.07±162.52c	1040.47±180.08c
SDD	*A. alpina*	202.69±50.49c	232.28±78.51c	32.03±4.28b	24.98±11.74b	28.79±2.36ab	16.08±1.09c	1840.13±53.07a	1740.86±115.11a
	A. orbiculata	151.88±58.12c	164.73±81.91c	12.37±1.64c	18.67±0.92b	21.28±11.48abc	15.40±4.22bc	1590.13±143.57ab	1636.00±131.33ab
	J. effusus	201.03±106.95c	315.84±167.69bc	9.07±2.01c	7.99±4.43c	26.98±8.69abc	28.11±2.28a	1361.49±185.49bc	1193.41±126.78c

Table 3. Heavy metal BCF and TF of the plants in mining area

Site	Plant	Pb		Cd		Cu		Zn	
		BCF	TF	BCF	TF	BCF	TF	BCF	TF
CHS	*A. alpina*	0.26	0.55	1.91	0.79	0.32	1.91	0.48	1.21
	A. margaritacea	0.32	0.69	0.46	0.65	0.76	1.17	0.66	1.13
	C. inflatus	0.27	0.21	0.82	0.88	0.58	1.16	0.76	1.19
	A. orbiculata	0.16	0.48	0.73	0.80	0.53	0.89	0.92	1.13
XMP	*A. alpina*	0.08	1.23	0.70	0.83	0.20	1.67	0.40	1.02
	A. margaritacea	0.12	0.69	0.44	0.55	0.41	1.28	0.39	1.23
	C. inflatus	0.08	0.60	0.77	0.64	0.26	1.00	0.38	1.18
SDD	*A. alpina*	0.06	0.89	0.51	1.32	0.30	1.79	0.33	1.03
	A. orbiculata	0.04	0.93	0.31	0.66	0.24	1.34	0.30	0.97
	J. effusus	0.08	0.67	0.15	1.37	0.35	0.94	0.25	1.00

It can be seen that the TF of four heavy metals in *A. alpina* are all>1, and it had a strong transport capacity.

4 Discussion

In order to adapt to the severe living environment in places with severe heavy metal pollution, plants have evolved certain defense mechanisms through long-term natural selection [8]. Studies have shown that dominant plants growing in mining areas have a certain tolerance to heavy metals, but each plant has different adaptability and resistance to different heavy metals. Wan et al. investigated the plants in four mines in Hunan and found that *Viola principis* had a strong ability to accumulate Cd, Pb and As [9]. Li Siliang et al. studied the heavy metal accumulation characteristics of dominant plants naturally grown in four lead-zinc mines in Zhejiang Province and found that *Elsholtzia argyi* and *Sedum plumbizincicola* had the ability to accumulate Cd [10].

In this study, Pb, Cd, Cu and Zn in the surface soil collected from the Huize lead-zinc mining area all exceeded the standard. Among them, Cd was the most polluted, which caused heavy metal pollution in the surrounding farmland soil and was not conducive to crop growth. Among the 5 plants selected in the mining area, the absorption capacity of Pb was shown as *A. alpina*>*A. margaritacea*>*C. inflatus*>*J. effusus*>*A. orbiculata*; the absorption capacity of Cd was shown as *A. alpina*>*C. inflatus*>*A. orbiculata*>*J. effusus*>*A. margaritacea*; the absorption capacity of Cu was shown as *A. margaritacea*>*A. alpina*>*C. inflatus*>*J. effusus*>*A. orbiculata*; the absorption capacity of Zn was shown as *A. alpina*>*A. orbiculata*>*J. effusus*>*A. margaritacea*>*C. inflatus*. In the same ecological environment, different plants have different capacities to absorb heavy metals. The content of heavy metals in plants was related to the content of heavy metals in the soil where the plants grow, and the ability of plants to transport and absorb heavy metals [6]. *A. alpina* had a strong ability to accumulate Cd, its BCF and TF were 1.91 and 1.32, and had good transport capacity for Pb, Cu and Zn; the TF of *A. margaritacea*, *C. inflatus* and *A. orbiculata* to Cu and Zn>1, it can be used as Cu and Zn tolerant plants; the TF of *J. effusus* to Cd and Zn> 1, it can be used as a tolerant plant for Cd and Zn. Therefore, studying the plants that grow naturally in mining areas and screening out plant varieties with heavy metal accumulation and tolerance are of great significance for soil restoration and ecological restoration in mining areas.

5 Conclusion

The most serious soil heavy metal pollution in Huize lead-zinc mining area was Cd, followed by Pb, Zn and Cu. Among the five plants, *A. alpina* had a strong ability to accumulate Cd and a good transport ability to Pb, Cu and Zn. *A. margaritacea*, *C. inflatus* and *A. orbiculata* had good transport ability to Cu and Zn. *J. effusus* had good transport ability to Cd and Zn.

Acknowledgments

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