Soil pollution of abandoned tailings in one zinc antimony mine and heavy metal accumulation characteristics of dominant plants

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Abstract. This paper analyzes heavy metal content in the soil of abandoned tailings and dominant plants, and absorption and bioconcentration capability as well as cumulative characteristics of the four kinds of dominant plants such as Phragmites australis, Typha angustifolia, Miscanthus sinensis, Equisetum fluviatile for heavy metals Pb, Zn, Sb, Cu, Cr, Cd, As and Mn through investigating samples of the zinc antimony ore abandoned tailings. The results manifest that investigated eight heavy metals contents in the abandoned tailings all exceed soil background values of both Guangxi and the whole nation. Abandoned tailings soil is polluted most seriously by Mn, Sb and Cd, followed by As, zinc and Pb.

Introduction

The heavy metal pollution caused by mining has been increasingly prominent, which gives rise to serious harm to human health and ecological environment. The serious environment pollution results from high content of the heavy metal, poor soil structuredness, and the lack of vegetation of the abandoned tailings in mining area. There are a lot of researches on the heavy metal pollution around the metal mining area such as copper, zinc, lead, etc., abandoned soil, and plants at home and abroad [1]. Antimony, as a kind of toxicity and carcinogenicity for human and animal, can also lead to liver, skin, respiratory system and cardiovascular system diseases, and has the typical sulphophile affinity and oxytropism. With the wide use of the antimony ore, antimony ore mining has caused serious environment pollution[2]. It is also worth noticing the heavy metal pollution of antimony abandoned tailings.

This paper takes an example of a zinc antimony ore in Guangxi to study the soil pollution of the abandoned tailings and heavy metal accumulation characteristics of dominant plants, which can master the soil pollution of the abandoned tailings and screen dominant plants, and provide scientific basis for using plant repair technology to govern the soil heavy metal pollution of the abandoned tailings. Hence, that has a practical significance for the management of heavy metal pollution in mining area.

Materials and methods

Samples collection. We investigate and take samples for the abandoned tailings soil and plants by on- the-spot investigation for the abandoned tailings of the Hechi Jia Zheng zinc and antimony ore-dressing plant. The soil samples of seven tailings and the red and yellow soil samples of surrounding mountains region are obtained by the plum blossom stationing method and the serpentine stationing method, respectively. (Mix five soil samples into one sample, the collection depth of 0~20cm). We collect 4~8 dominant plants which are vigorous , representative and more, and gather 4 kinds of the dominant plants that are Phragmites australis, Typha angustifolia, Miscanthus sinensis and Equisetum fluviatile, respectively. All the samples are taken back to the lab after encapsulated with polyethylene plastic bags.

Samples processing and analysis.The soil sample is dried by air, and then is screened by 100 mesh nylon screen after pulverized. The microwave digestion is carried out by HNO_3-H_2O_2-HF system with a ratio of 4:4:2. Plant samples are divided into four parts of root, stem and leaf and fruit, or two parts of root system and overground part. After washed by ultrapure water, firstly, the sample is treated by high temperature desiccation under 105℃ for 30 minutes, then is dried at 65 ℃ to constant weight, smashed and weighed out 0.2g. The microwave digestion is carried out by the mixed solution with 8ml HNO_3 and 2ml H_2O_2. The heavy metal elements in the soil and plant samples are determined by the inductively coupled plasma emission spectrometer PE-Optima7000DV, their PH value is measured by the water extraction method, and the organic matter is determined by the calcination method.

Data processing and analysis. The bioconcentration factor (BCF) is the ratio of the overground mass concentration of heavy metal and average quality concentration of soil heavy metal. The translocation factor (TF) is the ratio of the overground mass concentration of heavy metal and the root mass concen-tration of heavy metal.The experimental data is processed by adopting Excel and SPSS for analysis of variance, Duncan's method for difference significance test, and origin for drawing analysis.

Results and discussion

The soil background. The average content of heavy metals in tailing sand of abandoned tailings are shown in Table 1 .

Table 1 Heavy metal contents of the study area soil / $mg \cdot kg^{-1}$.

sample	abandoned tailing sand	Soil background values in guangxi	the national soil background value	the Class-Ⅱ standard of soil environment quality	the Class-Ⅱ standad of soil environment quality
Pb	1811.47±455.80	24.0	26.0	250	500
Zn	3358.51±877.64	75.6	74.2	200	500
Sb	1473.91±229.19	NA	1.21	NA	NA
Cu	95.26±9.80	27.8	22.6	150	400
Cr	121.09±3.93	82.1	61	150	300
Cd	146.87±20.81	0.267	0.097	0.3	1.0
As	964.12±91.96	20.5	11.2	40	40
Mn	41716.33±10538.78	176	583	NA	NA

Note: NA is not specified.

It can be seen from Table 1 that heavy metal elements contents in the waste tailings soil all exceed soil background values, there into the contents of Pb, Zn, Sb, Cd, As and Mn are very high, and they are 75, 44, 1218, 550, 47 and 237 times higher than the background value of soil in Guangxi, respectively. According to the Class-III soil environmental quality of national standards GB 15618-1995, the contents of Pb, Zn, Cd and As far exceed the national standard critical value, and Cu and Cr haven't exceeded the Class-Ⅱ standard limit value of soil environment quality. Crommentuijn, etc.[3] thought that allowable maxim-um concentration of Sb in soil is 3.50mg / kg, but Sb concentration in the abandoned tailings far exceeds this value. According to Wangjing Guo, Mn moderate standard of mass fraction in soil is $0.17 \times 10^{-3} \sim 1.2 \times 10^{-3}$. Thus, tailing sand in abandoned tailings are severely polluted by Pb, Zn, Sb, Cd, As and Mn.

Heavy metal contents of dominant plants. There are four kinds of dominant plants which are lush growth, large quantity and great coverage in abandoned tailings. Through research and study, Table 2 shows the average content of heavy metals in different parts of the four plants. As can be seen that the four kinds of plants absorb metals elements differently, and the absorption amount of Mn and Zn are the highest, followed by Pb, As, and Sb, which is relevant to the heavy metal content in soil and plant uptake characteristics. Mn content of Typha angustifolia in aboveground portion exceeds that of the roots as well as Cr content of Miscanthus sinensis and Phragmites australis. By contrast, heavy metals contents of roots in the other plants are remarkably more than aboveground portions and Part of the heavy metals doesn’t exceed the critical value. (The content of Cd is 100 mg/kg, the content of Pb, Cu, As and Cr is 1000mg/kg，the content of Zn and Mn is10000mg/kg, the critical content of Sb is not yet known).

Compared with the content of heavy metals in general plants, heavy metals contents in roots of four dominant plants are in excess of the normal range, aboveground portions contents in some plants are within the normal range, and the rest exceed the normal range.Most of heavy metals contents in various plants exceed the normal range, which is likely related to the higher heavy metals contents in soil samples.

Table 2 Heavy metal contents and those of the normal range of four dominant plants in study area / $mg \cdot kg^{-1}$

sample		Pb	Zn	Sb	Cu	Cr	Cd	As	Mn
normal range		0.1~41.7	1~160	0.02~2.2	0.4~45.8	0~8.4	0.2~0.8	＜1	1~700
Equisetum fluviatile	root	866.88	4937.50	454.38	197.50	74.88	64.75	1245.63	2563.75
	Stem &leaf	22.88	182.38	3.63	12.63	26.13	NA	15.50	557.38
Miscanthus sinensis	root	463.00	1605.00	180.38	181.25	45.38	51.88	891.75	4795.00
	stem	12.88	122.38	8.75	6.63	20.00	NA	12.00	375.88
	leaf	18.00	55.25	2.88	7.50	17.00	NA	1.88	238.50
	seed	42.75	106.50	21.25	10.38	11.75	NA	14.25	268.88
Phragmites australis	root	570.88	640.75	743.50	67.13	15.75	23.88	807.75	1693.75
	stem	17.13	53.63	12.63	7.00	10.13	NA	11.63	95.00
	leaf	42.63	90.88	17.25	10.63	9.63	NA	4.38	247.50
Typha angustifolia	root	728.38	899.88	478.50	74.13	62.50	16.50	303.88	1726.25
	stem	5.13	337.00	1.25	5.50	6.88	NA	2.05	856.13
	leaf	35.88	193.25	18.75	7.63	6.13	NA	6.38	1856.25
	seed	49.50	147.63	47.00	25.00	7.13	NA	30.50	1301.25

Bioconcentration translocation characteristics of heavy metals in plants. The BCF is usually used to indicate the bioconcentration degree of plants for heavy metals in soil and reflect bioconcentration ability of plants. The greater the BCF is, the stronger the absorption ability of plants to heavy metals is. At the same time, the TF reflects plants translocation capability for heavy metals from roots to the aboveground parts. BCF and TF of four kind of dominant plants in abandoned tailings are shown in Figures 1 and 2. From Figures 1, the BCF of four kinds of dominant plants for eight kinds of heavy metals are mostly less than 1. Simultaneously, four kinds of dominant plants bioconcentration ability for Cu is stronger than that for the other seven kinds of heavy metals.

The BCF of Miscanthus sinensis and Typha angustifolia for Cu exceed 1, however, the BCF of Phragmites australis for Cu is higher than those of the other heavy metals. The BCF of Equisetum fluviatile for Zn, Cu and As all exceed 1. Especially, the Miscanthus sinensis and Equisetum fluviatile for Cu is in excess of 2, which demonstrates the superstrong bioconcentration ability. The bioconcentration ability of four kinds of dominant plants for Pb, Sb, Cd and Mn is weaker. The bioconcentration ability of Miscanthus sinensis ,Typha angustifolia and Phragmites australis for Zn is far weaker than that of Equisetum fluviatile, and their BCF is 0.15~0.37 times as large as that of Equisetum fluviatile. The bioconcentration ability of Miscanthus sinensis, Equisetum fluviatile and Typha angustifolia for Cr is stronger than that of Phragmites australis, but their BCF is all less than 1. In addition to Equisetum fluviatile, the BDF of the other three plants is less than 1, moreover, that of Typha angustifolia is the lowest. From Figure 2, the TF of Phragmites australis and Miscanthus sinensis for Cr is more than 1 as well as the TF of Typha angustifolia for Mn, and the translocation ability of Typha angustifolia for Mn is stronger, its TF reaches 2.33. In addition, four dominant plants for heavy metals accumulation is mainly in the roots with less upward transport, and their TF is all less than 1.

Overall, heavy metals contents of the aboveground parts in the investigated four dominant plants don't exceed the threshold, but heavy metal contents in some plants are above the normal range. The local major dominant plants are able to adapt the environment with high content heavy metal of Pb, Zn, Sb, Mn and As in soil, moreover, grow luxuriantly, have a large biomass, and can form small community. These suggest that they have some tolerance for the heavy metals in the mining area soil. Although the heavy metal content in the aboveground portions is not high, Equisetum fluviatile has stronger bioconcentration capability for Zn, Cu and As, and can limit and absorb heavy metals in the roots, hence, it can be used to fix plants of contaminated soil (Tordoff, etc., 2000)[4]. Furhtermore, the BCF of Miscanthus sinensis and Typha angustifolia for Cu is greater than 1, Typha angustifolia has stronger ability to transfer Mn, the TF of Miscanthus sinensis and Phragmites australis for Cr is also greater than 1, and the investigated eight heavy metals contenta in Miscanthus sinensis, Typha angustifolia and Phragmites australis are far beyond those of the normal range. The Miscanthus sinensis, Typha angustifolia and Phragmites australis grow in the abandoned tailings everywhere, which indicates that they are adaptable to contaminated soil by heavy metal and can be used for mining pioneer plants for repair of heavy metal pollution. In short, the four dominant plants play fixation and bioconcentration roles in the contaminated soil by heavy metal, especially they have potential applications in governing waste tailings.

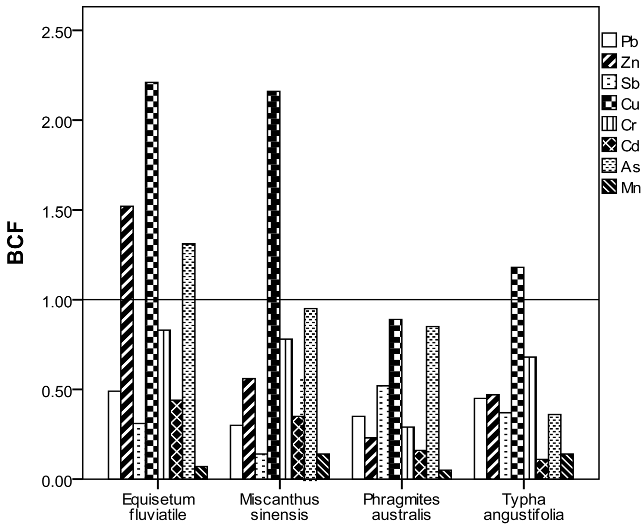

Figure 1 Heavy metal BCF of dominant plants

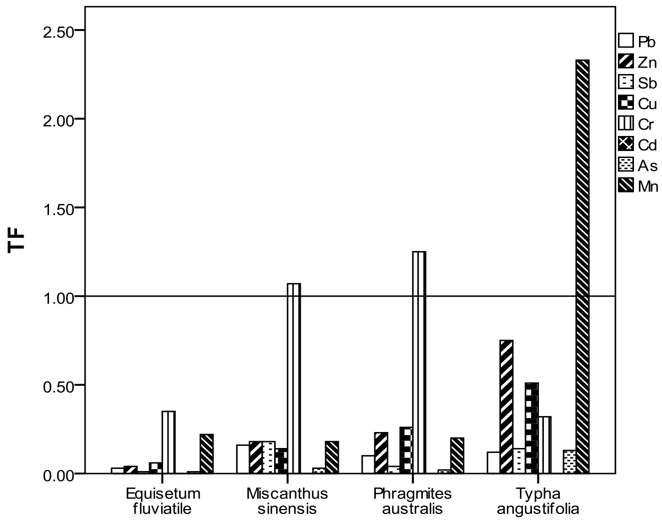

Figure 2 Heavy metal TF of dominant plants

Summary

The contents of Pb, Zn, Sb, Cu, Cr, Cd, As and Mn in the soil of Hechi zinc antimony ore abandoned tailings all exceed soil background values of both Guangxi and the whole nation, thereinto, the contents of Pb, Zn, Cd and As exceed far beyond Class Ⅲ standard values of soil environment quality. The abandoned tailings soil is polluted by various kinds of the heavy metals, of which the pollution of the Mn, Sb and Cd is the most serious, followed by that of As, Zn and Pb.

Heavy metals contents of the investigated four dominant plants in the abandoned tailings don't exceed the threshold, but heavy metal contents in all plants are mostly above the normal range. Moreover, the bioconcentration ability of Equisetum fluviatile for Zn, Cu and As is stronger so that it can limitedly absorb the heavy metals in the root. Therefore, Equisetum fluviatile can be used to fix the plants of the polluted soil, which plays a role in conserving water and soil. The BCF of Typha angustifolia and Miscanthus sinensis for Cu is greater than 1, Typha angustifolia has stronger ability to transfer Mn, and the TF of Miscanthus sinensis and Phragmites australis for Cr is also greater than 1, which suggests that they have the enormous potential to repair the species of the soil pollution in the mining area, can be the repair plants in the mining area of heavy metals pollution, and are worth further study.

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