Heavy Metal Contents and Accumulation Characteristic of Dominant Plants in Tin Mining Wasteland of Gejiu city,Yunnan,China

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KEYWORD: Wasteland; Heavy metal; Dominant species

ABSTRACT: Land contaminated by high levels of heavy metals in Tin mining wasteland is urgent to be remediated.To find out the tolerant plants which can adapt to the local climate and the soil conditions is thesystem restoration of the area. Results showed that the average content of soil heavy metals of Mn, Cu, Cd and Zn were 5733.8702mg/kg, 2250.7998mg/kg, 1974.8084mg/kg and 17.0273mg/kg, the soil was alkaline soil in the wasteland. It was found that the 12 wild plants had different abilities of uptake and accumulation of Mn, Cu, Cd and Zn. The bioaccumulation factor (BCF) of all the dominant plants were less than 1, only *Polygonum* capitatum and *Hippochaete* debilis of BCF were relatively large, and the biological transfer factor (BTF) of *Polygonum* capitatum to Mn and Zn were more than 1, the BTF of *Hippoc* premise and foundation of vegetation reconstruction.Analyzed the amount of heavy metals, and the enrichment and transporting features of heavy metals, such as Mn, Cu, Cd and Zn, in the dominant species in the district, and then we select the pioneer plants for eco*haete* debilis *t*o Cd and *Zn* were more than 1. In general, the results indicate that the two plants had strong capability of BCF and BTF to heavy metals. Apart from two plants, other 10 dominant plants had a better tolerance in metal pollution in mining area, and they can be used as pioneer plants of ecological rehabilitation in tin mining wasteland.

INTRODUCTION

With the rapid development of the mining industry, the problem of heavy metal pollution in the wasteland has become one of the hot issues of environmental pollution. This kind of contamination in the soil long residual period, the soil microorganisms can not be broken down, these pollute the groundwater, inhibit the growth and development of plants, more serious is that after the accumulation of edible part in crops passed to humans through the food chain, causing heavy metal poisoning, a direct threat to human health and safety(Yang et al. 2004, Yue2000). According to statistics, China's mining wasteland area has reached 40,000 hectare, and annual at a speed of 200 hectare growth(China Environmental Protection Agency 2000). Mining activities seriously interfere with and over the ecosystem self-recovery tolerance limits, if let the mining wastelands rely on natural succession recovery, it may take 100 to 10,000 years(Bradshaw1997). So the ecological restoration in mining wasteland has become a top priority.

Phytoremediation is the use of plant absorption and fixation of heavy metals in the soil, thereby to repair contaminated soil green engineering technology, which is based on the restoration of heavy metals have a high tolerance, high enrichment of hyperaccumulator plants. Hyperaccumulator as an emerging green technology, has the characteristics of efficient, economic and ecological coordination and becomes a hot area of current research, and it is widely used in the field of remediation of heavy metal pollution for its thoroughness of restoration and environment friendly characteristics. Therefore, it is the premise and foundation of vegetation reconstruction to find out tolerant plants which can adapt to the local climate and the soil conditions.

Gejiu is a super large tin copper polymetallic mining area, the cumulative proven reserves of nonferrous metals 4.76million t, which the tin reserves of 1.72million t, mining resulted in large areas of wasteland in Gejiu(Gan et al. 2008, Zhang et al. 2010). Therefore, the study by sampling wasteland soil and dominant plant from Niubahuang, Kafang and Southern in tin mine of Gejiu, and by analyzing the content of heavy metal in soil and plant, the accumulation and migration of heavy metal in plant, this research will provide scientific evidence for ecological restoration and revegetation in tin mining wasteland in Gejiu.

MATERIALS AND METHODS

Brief introduction of research area

The research site is in Gejiu County city, Honghe prefecture of Yunnan province,southern China, across the east longitude 103°07′28″～103°09′14″, north latitude 23°18′56″～23°21′39″. Gejiu is the production of tin-based and produce lead, zinc, copper and other non-ferrous metals metallurgy industrial city, is world-renowned "tin can".There are big differences between the elevation height, with significant vertical climate vertical distribution, belonging to 5 kinds of climate zones (north tropics, south Asian tropical, subtropical, tropical and north and south temperate). The annual sunshine short, small temperature difference, long frost free period, dry and rainy seasons clear, mild climate, the average annual sunshine 1986.6h, with an average annual temperature of 16.4 degrees, the year rainfall 890mm.

Research methods

Sample Collection

Collection of Soil samples: Field investigation and sample collection were done in 2014 June in three Tin mining wasteland, Niubahuang, Kafang and Southern of Gejiu City. According to the wasteland area and the terrain characteristics, respectively by the methods of "S" distribution and zonal distribution, gathering 0~20cm topsoil, samples of each of plurality of points by mixing soil samples were collected using quartation, whichever weighing about 1kg, into the ziplock, label, back to the lab.

Collection of Plant samples:Selection of high frequency distribution, growth better, a large number of plants were randomly sampled, including natural settled the dominant plants and artificial large area planted of economic crops in the three mining wastelands. The plants of 5 to 10 plants were collected from different parts of the plant, such as root, stem, leaf and fruit, etc, form a composite sample(after preparation, the general, at least 20-50g dry weight of the sample),

aboveground parts and underground parts to be separated, try to maintain the integrity of plants. Put the collection of samples into valve bag, and labeled, indicating the No., collection sites, name of plants collection ,etc.

Pretreatment of samples

Pretreatment of soil samples:Soil samples were placed the dry soil shelf of National plateau Wetlands Research Center of Southwest Forestry University, by flipping, tick miscellaneous,etc, after being air dried soil samples and fully grinding to make it all over 100 mesh nylon sieve. Sieved samples were mixed well by quartation, bagged, indicating the No.,labeled, pended the determination.

Pretreatment of plant samples:Plant samples woody plants by the roots, stems, leaves separated, herbs separated by aboveground parts and underground parts.The plant samples were washed with water and then to clean them three times using deionized water, placed to dry naturally. To chop them by stainless steel knife after dried, in the drying chamber firstly at 105˚C fixing 30min, after at 70˚C in drying to constant and then were milled through a 60 mesh nylon sieve.Sieving samples are mixed evenly, then packed into sealed bags labeled save and set aside.

Table1 The analysis of the characteristics of heavy metal content of wasteland soil

Mining wasteland	pH	Mn mg/kg	Cu mg/kg	Cd mg/kg	Zn mg/kg
Niubahuang	7.82	6091.74±580.72	2836.11±994.66	24.14±12.86	2514.65±601.63
Kafang	7.61	5410.82±1109.63	1572.44±792.01	15.84±9.80	2626.48±1280.78
Southern	7.68	5699.05±1875.75	1485.87±832.11	11.10±7.55	1611.26±180.33
Soil environmental background level in Yunan Province	/	515	28.7	0.083	86.0
National soil environmental quality III standard	/	/	400.00	1.00.00	500.00

Determination of samples

The soil pH were determined in accordance with the "Soil Agrochemical analysis" method, by the method of 1:2.5 for soil and water ratio determination.

Nitric acid, hydrochloric acid -perchloric digestion, atomic spectrophotometer were used for the determination of heavy metal Mn, Cu, Cd, Zn, in soil.

Nitric acid and perchloric acid digestion of preparation to be checked, atomic spectrophotometer were used for the determination of heavy metal Mn, Cu, Cd, Zn, in plant.

RESEARCH RESULTS AND ANALYSIS

Heavy metal content in mining wasteland soil

The results of soil pH determination showed that the soil pH of wastelands soil were more than 7.5(neutral soil when pH was 6.5 to 7.5), for alkaline soil, which showed that the soil no acidification occurs. From table1, it can be seen that the contents of heavy metals in three mining wastelands more significant difference, and the contents of heavy metals Mn, Cu and Cd in Niubahuang wasteland were significantly higher than the Kafang and the Southern, the content of Zn in the Kafang > the Niubahuang > the Southern. On the whole, the contents of heavy metals Mn > Zn > Cu > Cd, and the average contents of 4 kinds of heavy metals were 5733.87mg/kg, 2250.80mg/kg, 1974.81mg/kg and 17.03mg/kg, compared with the soil environment background level of Yunnan province(Liu and Ma2010), the average contents of Cd, Cu, Zn and Mn were higher than 11.13, 26.17, 68.81 and 205.51 in the Tin wastelands of Gejiu, and compared with the national soil environment quality grade three standard(Fan2011), the soil of Zn, Cd and Cu average contents higher than 4.94, 17.03 and 4.50.

An excess of heavy metal ions in soil great harm to plants, and the tolerance of plants is a key factor when remediating heavy metal polluted soil. In general, when the soil Cd content of 3~8mg/kg, Pb content of 100~400mg/kg, Zn content of 70~400mg/kg, Cu content of 150~400mg/kg(total) is considered to produce toxicity to plants(Chen2013).

Composition of plants

Heavy metals in the soil for plants is a stress factors, especially in metal mining area, the shortage of nutrient, poor matrix structure, and high heavy metal content characteristics, the production of on plant growth stress or inhibition. Under normal circumstances, only a few highly tolerant plants on which to settle, the most of these plants have a special mechanism have adapted to their growth environment, special tolerance mechanisms of formation, has stronger resistance and adaptability for the harsh environment. They were usually dominated by herbs, shrubs and arbors occasionally settled, which may be related to herbs were more likely to form heavy metal tolerance.

The tin mining wasteland vegetation of Gejiu is domi nated by herb plants, accord with the characteristics of mine vegetation. This study collected plant spe cies was less, only 12 species, belonging to 8 families, 4 kinds of compositae, polygonaceae and pteridaceae families each 2 kinds, collected plants were mostly with herb plants was given priority to, which may be relevant to the characteristics and herb plants grow quickly, barren resistance, etc. The collection of the dominant plant species was shown in Table 2.

Table2 The plant samples genus name of wastelands

Family	Species
Polygonaceae	*Polygonum hydropiper* L.
	Polygonum capitatum
Pteridaceae	*Hippochaete* debilis
	Pteris wallichiana
Gramineae	*Phragmites* australis
Ranunculaceae	*Thalictrum minus var.*hypoleucum
Solanaceae	*Solanum tuberosum* L.
Composotae	*Eupatorium adenophorum* Spreng
	Galinsoga parviflora
	Erigeron acer
	Artemisia carvifolia Buch.
Coriariaceae	*Coriaria* nepalensis

Table3 The dominant plants of heavy metals content of wasteland

Mining wasteland	The sample name	parts	Mn	Cu	Cd	Zn
			mg/kg	mg/kg	mg/kg	mg/kg
Niuba-huang	*Polygonum hydropiper L.*	Aboveground part	533.62	415.88	6.16	173.85
		root	809.16	377.621	13.05	390.51
	Coriaria nepalensis	Aboveground part	1292.16	70.65	3.93	190.41
		root	1438.90	93.04	6.21	642.36
	Polygonum capitatum	Aboveground part	2883.76	959.60	7.06	651.33
		root	1941.68	1203.31	11.79	537.48
	Hippochaete debilis	Aboveground part	957.28	333.71	10.59	429.50
		root	4445.00	1835.29	8.67	288.39
	Phragmites australis	Aboveground part	515.68	87.17	4.51	326.34
		root	907.03	229.57	5.40	409.83
	Eupatorium adenophorum Spreng(1)	Aboveground part	1022.19	99.13	3.26	166.26
		root	1383.70	174.60	5.27	237.33
Kafang	*Erigeron acer*	Aboveground part	1159.72	98.48	6.74	173.85
		root	2334.06	314.79	12.78	340.14
	Artemisia carvifolia Buch.	Aboveground part	209.32	85.52	4.55	254.58
		root	1023.98	138.05	12.55	278.73
	Eupatorium adenophorum Spreng(2)	Aboveground part	1092.06	90.00	7.39	300.12
		root	2253.56	140.22	12.87	272.52
Southern	*Thalictrum minus var.hypoleucum*	Aboveground part	173.90	93.04	9.22	214.22
		root	2248.96	317.18	21.07	543.00
	Solanum tuberosum L.	Aboveground part	351.46	86.52	9.76	465.03
		root	816.98	84.13	2.72	830.73
	Pteris wallichiana	Aboveground part	350.08	87.83	5.27	445.71
		root	1261.34	254.36	5.18	251.82
	Galinsoga parviflora	Aboveground part	448.06	82.17	7.95	201.45
		root	935.20	425.88	5.54	492.63

The contents of heavy metals in each part of dominant plants

The 12 dominant plants contents of heavy metals in tin mining wastelands in table 3. From table 3, the contents of heavy metals in plants and the contents of heavy metals in soil were basically consistent, reflected the heavy metal enrichment characteristic of plants exist a positive correlation with the contents of heavy metals in soil, the accumulation contents of heavy metals in plant increased with increasing of the content of heavy metals in soil, it consistented with the result of Yang Shengxiang, He Dong, et al. Overall, the absorption and enrichment characteristics of heavy metals in different plants showed a greater difference.

In terms of Mn accumulation in plants, the highest content of *Hippochaete debilis,* 5402.28mg/kg, the lowest content of *Solanum tuberosum* L. Was 1168.44mg/kg, and the accumulation of Cd in plants, the highest content of *Thalictrum minus var.*hypoleucum, 30.83mg/kg, the lowest content of *Eupatorium adenophorum* Spreng (1), 8.53mg/kg. Typically, the normal content of heavy metals in plants: Mn 20~400mg/kg, Cu 0.4~45.8mg/kg, Cd 0.2~3mg/kg, Zn 1~160mg/kg. In this study, in 12 kinds of dominant plants, the Mn content of *Polygonum* capitatum aboveground up to 2883.76mg/kg, more than 7 times the normal content of the highest level of plant. Besides, *Coriaria* nepalensis, *Eupatorium* adenophorum and Spreng, *Erigeron* acer, the three plants aboveground and ground contents of Mn were higher than 1000mg/kg, indicating these four plants of Mn has stronger ability of enrichment.The content of Cu in the range of 70.65~1853.29mg/kg in plants, the highest of which *Hippochaete* debilis, was 40 times the normal level. The content of Cd in plants was 2.72~21.07mg/kg, which is 0.91~7.02 times higher than the normal highest level.The content of Zn in plants was 166.26~830.73mg/kg, which is 1.04~5.19 times higher than the normal highest level.

The transfer and enrichment characteristics of heavy metal in dominant plants

BCF (bioaccumulation factor) was the ratio of the content of heavy metal in plant shoots and the corresponding content of heavy metal in soil, used to measure theplant on the absorption ability and accumulation ability of heavy metals in soil. BCF greater, indicating that its accumulation ability of heavy metal was stronger. From table 4, we can see that the BCF value of 12 kinds of dominant plants were less than 1, only Polygonum capitatum and Equisetum BCF of heavy metals were relatively large, indicating that these plants accumulation ability of heavy metal elements were weak.

BTF (Biological Transfer Factor) was the ratio of the content of heavy metals of aboveground and underground part in plant, used to measure the transfer ability of plant to heavy metals. BTF greater, suggested that the plant will divert heavy metals from the roots to shoots was stronger, that is, the tolerance of plant to heavy metal was stronger. The table 4 shows that in the 12 kinds of dominant plant, only the BTF of Polygonum capitatum to Mn was greater than 1, the BTF of *Polygonum* hydropiper and *Solanum* tuberosum to Cu were 1.10 and 1.03, the BTF of *Hippochaete* debilis, *Solanum* tuberosum and *Galinsoga* parviflora were greater than 1, especially *Solanum* tuberosum, its BTF to Cd was as high as 3.59, the BTF of *Polygonum* capitatum, *Hippochaete* debilis, *Eupatorium*

Table4 The BAF of heavy metals for plants of wasteland

Mining wastel-ands	The sample name	Mn		Cu		Cd		Zn	
		BCF	BTF	BCF	BTF	BCF	BTF	BCF	BTF
Niuba-huang	*Polygonum hydropiper L.*	0.09	0.66	0.15	1.10	0.25	0.47	0.07	0.45
	Coriaria nepalensis	0.21	0.90	0.02	0.76	0.16	0.63	0.08	0.30
	Polygonum capitatum	0.47	1.49	0.34	0.80	0.29	0.60	0.26	1.21
	Hippochaete debilis	0.16	0.22	0.12	0.18	0.44	1.22	0.17	1.49
	Phragmites australis	0.08	0.57	0.03	0.38	0.19	0.84	0.13	0.80
	Eupatorium adenophorum	0.17	0.74	0.03	0.57	0.14	0.62	0.07	0.70
Kafang	*Erigeron acer*	0.19	0.50	0.03	0.31	0.28	0.53	0.07	0.51
	Artemisia carvifolia Buch.	0.03	0.20	0.03	0.62	0.19	0.36	0.10	0.91
	Eupatorium adenophorum	0.18	0.48	0.03	0.64	0.31	0.57	0.12	1.10
	Thalictrum minus	0.03	0.08	0.03	0.29	0.38	0.44	0.09	0.39
Southern	*Solanum tuberosum L.*	0.06	0.43	0.03	1.03	0.40	3.59	0.18	0.56
	Pteris wallichiana	0.06	0.28	0.03	0.35	0.22	1.02	0.17	1.77
	Galinsoga parviflora	0.07	0.48	0.03	0.19	0.33	1.44	0.08	0.41

adenophorum Spreng and *Pteris* wallichiana to Zn were greater than 1. Therefore, the five native plants (*Polygonum* capitatum, *Hippochaete* debilis, *Solanum* tuberosum, *Polygonum* hydropiper an-d*Eupatorium adenophorum* Spreng) can be chosen in the tin mining wasteland as tolerant plant.

DISCUSSION

Mine wasteland is a product of mining industry, with the increase of the number of its, it has become a global problem. Therefore, as soon as possible to the vegetation reconstruction in order to reduce the environment pollution of heavy metal in mining area, was the best strategy for mining area ecological restoration. However, these factors ,such as, poor soil structure, the shortage of nutrient, high heavy metal content, etc., limited the natural settlement of plants in mining wastelands. Nevertheless, there were still some plants (such as super accumulation plant) can complete their life history in the contaminated soil of high concentration of heavy metal, this indicates that the plant itself has a series of physiological and biochemical reaction in the long-tern natural evolution, for absorption and accumulation of heavy metal to form a series mechanism, such as suitable growth, resistance, tolerance and detoxification mechanism, adapted to the environment. Therefore, the 12 kinds of dominant plant can be used as the phytoremediation resources in tin mining wasteland. In addition, in 12 kinds of dominant plant, herbaceous plant accounted for the majority of the all, suggested that herbaceous plant has a strong ability to adapt the harsh environment of the tin mining wasteland.

Hyperaccumulator was a kind of plant, which refered to excessively absorb of heavy metals and constantly transfer its to the aboveground of plant. At present, the definition of hyperaccumulator mainly reference to Baker and Brooks proposed reference value in 1983, there are 3 basic characteristics. (1) the critical characteristics of content, namely, the critical content of accumulation of heavy metals in stems and leaves of plant, respectively, Mn and Zn were 10000 mg/kg, Cu was 1000mg/kg and Cd was 100mg/kg, or 10 to 100 times of the common plant without pollution. (2) transfer characteristics, that was, the content of heavy metal in the aboveground of plant were greater than the content of heavy metal in the root of plant. (3) grow well, no obvious toxic symptom, that was, with a certain ability of tolerance. In the 12 kinds of dominant plant, only the contents of polygonum capitatum and *Hippochaete* debilis reached to the Cu hyperaccumulator critical content standards. At the same time, they also showed a certain tolerance and absorption ability of heavy metals. These plants can adapt to the special environment of the mining area, which have the characteristics of tolerance barren and heavy metal stress. If these plants were planted in early stage of ecology restoration, they could increase vegetation coverage, improving soil surrounding and they could be pioneer plants in ecology restoring of the tin mining wasteland.

CONCLUSION

The results showed that the wasteland soil pH were more than 7.5, for alkaline soil. On the whole, the contents of heavy metals Mn > Zn > Cu > Cd, and the average contents of 4 kinds of heavy metals were 5733.87mg/kg, 2250.80mg/kg, 1974.81mg/kg and 17.03mg/kg.

This study collected plant species was less, only 12 species, belonging to 8 families, 4 kinds of compositae, polygonaceae and pteridaceae families each 2 kinds, most of collected plants were herbaceous plants. The accumulation contents of heavy metals in plant increased with increasing of the content of heavy metals in soil, the contents of heavy metals in most plants were higher than the normal contents of general plants.

The study collected 12 kinds of dominant plant, the BCF of plants were less than 1, only the BCF of polygonum capitatum and *Hippochaete* debilis to heavy metals were relatively large. From the BTF, the BTF of polygonum capitatum and *Hippochaete* debilis respectively to two kinds of heavy metals were greater than 1. Therefore, the two native plants such as, polygonum capitatum and *Hippochaete* debilis can be chosen in the tin mining wasteland as tolerant plants.

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