The Enrichment and Transfer of Heavy Metals for Two Ferns in Pb-Zn Tailing

Jiajie Mai [a], Qihe Yang [b], Yingfei Zhang[c], Xianlu Zeng [d], Yanmei Zhong [e] and Deliang Liu [f]

School of Life Science, Jiaying University, Meizhou 514015, China
[a]neusee@163.com, [b*]yangqh@jyu.edu.cn, [c]fei314@foxmial.com, [d]xyz@jyu.edu.cn, [e]zym@jyu.edu.cn, [f]ldl@jyu.edu.cn

Abstract. The enrichment and transfer of 8 heavy metals of *Equisetum ramosissimum* and *Pteris vittata* growing naturally close to edge of the sewage pool in Bencun Pb-Zn Tailing, Eastern Guangdong were investigated. The results indicated that the pollution of Cd, Pb, Hg, Zn was very severe in this tailing, followed by Cu and Mn. The potential ecological risk of heavy metals was assessed to be very strong based on soil background values of Guangdong Province and at high risk according to criteria of the second grade State Soil Environmental Quality Standard, and Cd, Hg, Pb were the main factors leading to potential ecological risk. The content of 8 heavy metals in the two ferns did not reach critical content of hyperaccumulator, so neither of them was typical hyperaccumulator, but both had a certain tolerance to these heavy metal pollution. Underground parts of *Pteris vittata* had an enrichment coefficient above 1 and that of *Equisetum ramosissimum* had a value near 1, therefore the two ferns could be utilized as potential enrichment plants. The two ferns have strong adaptability to the tailing habitat and can be used as pioneers in ecological restoration of Pb-Zn tailings.
Keywords. *Equisetum ramosissimum*, *Pteris vittata*, heavy metal phytoremediation

1 Introduction

The enrichment and transfer of 8 heavy metals of *Equisetum ramosissimum* and *Pteris vittata* growing naturally close to edge of the sewage pool in Bencun Pb-Zn Tailing, Eastern Guangdong were investigated. The results indicated that the pollution of Cd, Pb, Hg, Zn was very severe in this tailing, followed by Cu and Mn. The potential ecological risk of heavy metals was assessed to be very strong based on soil background values of Guangdong Province and at high risk according to criteria of the second grade State Soil Environmental Quality Standard [1], and Cd, Hg, Pb were the main factors leading to potential ecological risk. The content of 8 heavy metals in the two ferns did not reach critical content of hyperaccumulator, so neither of them was typical hyperaccumulator, but both had a certain tolerance to these heavy metal pollution. Underground parts of *Pteris vittata* had an enrichment coefficient above 1 and that of *Equisetum ramosissimum* had a value near 1, therefore the two ferns could be utilized as potential enrichment plants. The two ferns have strong adaptability to the tailing habitat and can be used as pioneers in ecological restoration of Pb-Zn tailings.Soil resource is one of the main sources of livelihood and the basis of terrestrial ecosystem and agricultural development. It has important significance to maintain the species diversity and determine the yield and quality of agriculture. The heavy metal pollution in soil is a kind of irreversible pollution process and also a severe threat to human, which directly leads to crop production and brings serious damage to human health through a negative feedback effect. In mine tailings, such as Pb-Zn tailings, their components and residual flotation reagent bring about serious contamination to ecological environment. The acidic water produced by sulfide in tailings caused the leaching of heavy metals to contaminate the soil and water environment in tailing area.

Bencun Pb-Zn Mine Tailing (24o22'54"E, 116o13'12"N), with a slope of 15o ~20o (Figure 1) , is one of mine tailings with the most largest volume of industrial solid waste in Meizhou City, East Guangdong, South China. The mine started operation in 1970 and abandoned in 1980. The mineral waste residue had been directly discharged and piled up in top of this slope without any purification measures till over a decade ago, the contaminants from waste residue leached by rainwater which flows into pools and farmlands down along this slope and then resulted in severe ecological degradation [2]. Meizhou city enjoys a warm and humid subtropical monsoon climate with abundant sunshine, plenty and concentrated rainfall; the average temperature ranges from 20.6~21.4oC, average annual sunshine hours 1714.6~2010.5 h, average rainy days is about 150 d, average annual rainfall is 1483.4~1798.4 mm, with 75% of which being concentrated in months from April to September, and a frost-free period is 309 d.

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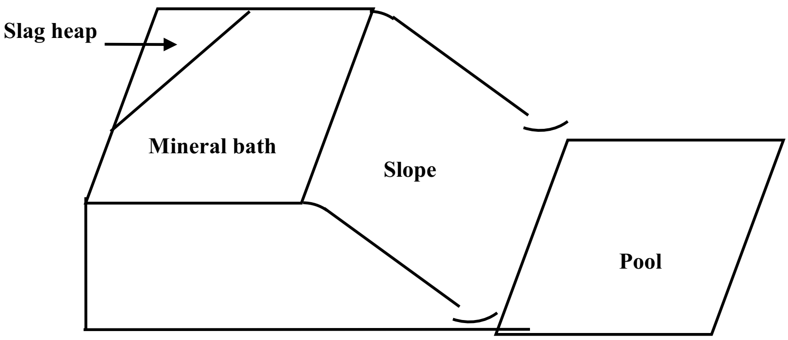

Fig.1. Schematic diagram of Bingcun Pb-Zn tailings area

Leaching of heavy metals flows into the water and farmland in the mine area and results in serious pollution. Due to the complexity of the mechanism of heavy metal toxicity to plants and their stability in the soil, the control and treatment of heavy metal pollution has been a hot research task for decades [3-4]. At present, heavy metal pollution in soil and water can be remediated by one or more of the following technologies: isolation, immobilization, toxicity reduction, physical separation or extraction [4-5]. But physical and chemical methods always require a great amount of engineering and investment, and can only repair small contamination area application. Phytoremediation is an effective polluted soil restoration technology developed since the mid19th century, namely heavy metal hyperaccumulator plants are screened, which grown in the polluted soil to absorb and remove heavy metals when they are harvested from the field [6-7]. It is relatively less cost and applicable for remediation of large area of heavy metal polluted soil especially in economic less-developed areas.

Equisetum ramosissimum and *Pteris* vittata are two dominant plants in Bencun Pb-Zn Tailing. On the edge of slope near the pool, the two ferns can grow strong almost as vigorously as in areas far from tailings, but other plants are rarely distributed (Figure 1). In this study, the characteristics of heavy metal absorption and enrichment of *Equisetum ramosissimum* and *Pteris vittata* growing close to the edge of a sewage pool in the Pb-Zn Mining Tailing were investigated through analysis on heavy metal content in mine soil around the roots, the aboveground and underground parts of the two ferns in order to provide theoretical basis for heavy metal pollution remediation and ecological restoration in Pb-Zn tailing area.

2 Materials and methods

2.1 Collection of soil and plant samples

Samples of the ferns and soil (0-10 cm below soil surface) close to edge of the sewage pool were collected in winter of 2014 at interval points in Bencun Pb-Zn Tailing, sieved (with 2 cm holes) and packed on the spot and taken back laboratory for further procedures of analysis.

2.2 Pretreatment of plant samples

Plant samples were divided into two parts: aboveground parts and underground parts, rinsed 3 times with tap water, and then cleaned with ultrapure water to avoid interference from heavy metal ions in soil. The samples were dried for 5 min at 105^{o}C and at 80^{o}C for 8 h, and broken in an organization crusher, then ground into fine powder in mortar. Powder samples were preserved for 2 h in an oven at 105oC and used in subsequent experiments described below after being sieved with 200 mesh sieve.

2.3 Pretreatment of soil samples

Soil samples were firstly air-dried, from which the stones and animal and plant residues were removed, and milled with agate rods and sieved through 2 mm nylon sieve, then ground into fine power in agate mortar and followed by sieved with 100 mesh nylon sieve (0.149 mm), finally preserved for subsequent experiments as described below.

2.4 Determination of soil pH value

10 g soil samples after pretreatment were taken into a 50 ml beaker, added 25 ml boiled distilled water, stirred vigorously for 1~2 min with a glass rod and let stand for 30 min, then measured by pH meter.

2.5 Digestion of plant and soil samples

Digestion of plant and soil samples was basically carried out as described byYang et al.(2012), but made some subtle changes. Briefly, 0.5 g of plant and soil powder was placed into a 50 ml ptfe high-pressure digestion tanks (KH-100 ml, Shanghai Yingdi Instrument Equipment Co., LTD.), and wet with 4 drops of double distilled water, then transferred to a ventilation cabinet for an overnight cold digestion after slowly adding 5 ml HNO_3 to remove organic matter after soaking for 0.5 h. Followed by addition of 2 ml H_2O_2, the digestion tanks were taken into the supporting steel liners. After being covered inner lids and firmly tightened stainless steel sheathes, the tanks with plant samples were transferred to a constant oven and heated for 3 h after the temperature rose to 120°C, but those with soil samples were transferred to oven and heated for 9 h at 160°C. When all the tanks naturally dropped to room temperature (25~30 °C) in the oven, they were placed on electric heating plates to dispel HNO_3 in the digestion liquid after their lids were carefully opened. Digestion liquid was transferred to 50 ml calibration test tubes for constant volume with 0.5% HNO_3 solution which was then shook, let stand, and used in subsequent tests. For each batch of soil samples, double distilled water was replaced samples in 2 copies of reagent blank test.

2.6 Determination the heavy metals of plant samples and soil samples

Heavy metal (Cr, Mn, Ni, Cu, Zn, Cd, Hg and Pb) contents in digested solution of plant and soil samples were determined in parallel using X Series 2 inductively coupled plasma mass spectrometry (ICP-MS, Thermo Fisher).

2.7 Assessment of heavy metal enrichment capability of ferns and soil heavy metal pollution

Heavy metal enrichment capability of plants was evaluated by indicators of TF (transfer factor) and EC (enrichment coefficient). TF of heavy metals for plant is the ratio of metal content in above-ground parts to that in underground parts. EC of heavy metals for plant is the ratio of metal content in organs or parts of plant to that in the soil where the plant grows, which reflects the plants' capability to enrich heave metals from its soil or water environment. The larger the enrichment coefficient of a metal is, the easier the element will be enriched. Single factor pollution index and Nemerow pollution index were applied to assess heavy metal pollution, and potential ecological risk index was calculated according to the method proposed by Hakanson [8]. The potential ecological risk level was assessed according to criteria of the second or third grade Environmental Quality Standard in China for Soils (GB 15618-1995) based on soil background values of Guangdong Province [9-11].

The calculation formula of single factor pollution index is $P_i=C_i/S_i$. P_i refers to the single factor pollution index of pollutants in soil; C_i refers to the measured content of pollutants in soil; S_i to the evaluation standard of pollutant. The formula of Nemerow synthetic pollution index is $P=\{[(C_i/S_i)^2_{max}+(C_i/S_i)^2_{ave}]/2\}^{1/2}$. $(C_i/S_i)_{Max}$ refers to the maximum of pollution index in soil; $(C_i/S_i)_{Ave}$ to the average pollution index in soil.

The formula of potential ecological risk index is: $E_r^i= T_r^i \times C_f^i = T_r^i \times C_i/S_i$; $RI=\sum E_r^i$. E_r^i refers to the single heavy metal potential ecological risk index; T^i_r refers to heavy metal toxicity coefficient, RI to the potential ecological risk index of a variety of various metals. The heavy pollution level and potential ecological risk of heavy metal pollution were determined according to the classification standard of heavy metal pollution level [12-13].

2.8 Data analysis

All data were proceeded and analyzed with Excel2003 and SPSS17, and multiple comparison of means was carried out by Duncan's（$P<0.05$）multiple range tests.

3 Results

3.1 Soil pH

The pH value of soil was 7.78, which revealed a weak alkaline. When evaluating the pollution level of heavy metal in soil, the numerical criteria should refer to the range of pH value above 7.5 in the second grade SSEQS (State Soil Environmental Quality Standard) in China or greater than 6.5 in the third grade SSEQS. Guo et al. found that in Guangdong Province, the spatial distribution pattern of soil pH in the Province had less change (mainly acidic), except that in Pearl River Delta and part of Qingyuan and Shaoguan (weak alkaline) City in the past over 30 years and industrialization and mining increased the soil pH in some areas[14].

3.2 Heavy metal content of soil

The data showed that the heavy metal content in soil was in descending order of Pb, Mn, Zn, Cu, Cd, Cr, Ni, Hg. Pb content in soil reached the maximum (13332.94 mg.kg-1), but Hg content was the minimum (only 4.12 mg.kg-1). The contents of Pb, Zn, Cd and Hg were far above the third grade SSEQS, and were 26.67, 10.81, 39.62, and 2.75 times more than the third grade SSEQS, respectively. Cu content was above the second grade SSEQS, but Cr and Ni content did not exceed national standard. In addition to Cr, the content of other heavy metals exceeded the background value in soil of Guangdong Province, that of Cd was even 707.50 times more than the background value, it is reported that the medium standard of Mn content in soil was 170 ~ 1200 mg kg-1, so the Mn content in the region exceeded the medium standard; the Ni content didn't exceed the national standard, but also 1.32 times more than the soil background value in Guangdong province (Table 1).

Table 1. The content of heavy metals in soil.

Heavy metal	Cr	Mn	Ni	Cu	Zn	Cd	Hg	Pb
Content(mg kg^{-1})	20.32	12575.67	19.05	272.92	5404.75	39.62	4.12	13332.94

3.3 Evaluation on the single factor and synthetic pollution index of heavy metals

According to the second grade SSEQS (but Mn content has not been set in the SSEQS), the single factor pollution index of Cr and Ni belonged to the clean degree, other five metals all had reached the pollution level. The decreasing order of single factor pollution index was Cd, Pb, Zn, Hg and Cu, the single factor pollution index of Cd, Pb, Zn, Hg, Mn and Cu reached the heavy level, but that of Ni reached the light degree (Table 2). Both the synthetic pollution index of heavy metals calculated on the basis of the second SSEQS and the soil background value in Guangdong Province reached the heavy pollution level.

Table 2. The index and grade of soil heavy metal pollution.

Heavy metal	P_{Cr}	P_{Mn}	P_{Ni}	P_{Cu}	P_{Zn}	P_{Cd}	P_{Hg}	P_{Pb}	$P_{综}$
S_1	0.08C	NA	0.32C	1.36L	18.02H	66.03H	4.12H	38.09H	48.45H
S_2	0.40C	45.07H	1.32L	16.05H	114.27H	707.50H	52.82H	370.36H	513.46H

Note: S means security, W means alert; C means clean; L means light pollution; M means moderate pollution; H means heavy pollution. S_1 was calculated based on the second grade State Soil Environmental Quality Standard, S_2 was calculated based on the soil background value in Guangdong Province, the second grade State Soil Environmental Quality Standard, NA means the data cannot be calculated because Mn content has not been set in the State Soil Environmental Quality Standard, the same as below.

3.4 Evaluation of potential ecological risk of heavy metals in soil index

Based on the second grade SSEQS, the descending order of ecological risk index was Cd, Pb, Hg, Zn, Cu, Ni, Cr, the potential ecological risk index for Cd was the highest and reached very strong level, those of Pb and Hg both reached strong degree, but those of Zn, Cu, Ni and Cr was lower and reached minor level, and even that of Cr was below 1 and had hardly any hazard. Based on the soil background value in Guangdong Province, the decreasing order was Cd, Hg, Pb, Zn, Cu, Ni and Cr, the potential ecological risk index of Cd, Hg and Pb reached extremely high degree, those of Zn and Cu reached high degree, but those of Ni and Cr was relatively low and reached slight degree (Table 3).

Table 3. The index and grade of potential ecological risks of soil heavy metal pollution.

Heavy metal	E_r^{Cr}	E_r^{Mn}	E_r^{Ni}	E_r^{Cu}	E_r^{Zn}	E_r^{Cd}	E_r^{Hg}	E_r^{Pb}	RI
S_1	0.16A	NA	1.59A	6.82A	18.02A	1981.00E	164.80D	190.47D	2362.86D
S_2	0.80 A	NA	6.61A	80.27C	114.27C	21225.00E	2112.82E	1851.80E	25391.57D

Note: A. Slight; B. Moderate; C. Strong; D. Very strong; E.Strmely strong

3.5 Heavy metal content and transfer coefficients of two ferns

Enrichment pattern of heavy metals including Cr, Mn, Ni, Cu, Zn, Cd, Hg and Pb in *Equisetum ramosissimum* was different from that in *Pteris vittata*. For both the ferns, heavy metal contents of the aboveground parts were below that of underground parts, namely the heavy metals were mainly concentrated in the underground parts. For *Equisetum ramosissimum*, the decreasing order of heavy metal content in aboveground parts was Zn, Mn, Pb, Cu, Ni, Cd, Cr, Hg, and that in underground parts was Zn, Mn, Pb, Cu, Cd, Ni, Cr, Hg. For *Pteris vittata*, the decreasing order of heavy metal content was Zn, Mn, Pb, Cu, Ni, Cr, Cd, Hg in aboveground parts, while that was Zn, Mn, Pb, Cu, Ni, Cd, Cr, Hg in underground parts, i.e, besides that Cd and Cr were in reverse order, the other 6 metals are in the same order.

Except that the transfer coefficient of Hg in *Equisetum ramosissimum* was above 1, all the other transfer coefficients of heavy metals in both *Equisetum ramosissimum* and *Pteris vittata* were below 1. As for the same heavy metal, the transfer coefficients of *Equisetum ramosissimum* were above those of *Pteris vittata* (Table 4).

Table 4. Heavy metal content ($mg\cdot kg^{-1}$)of above and under ground parts and transfer coefficients.

Species	*Equisetum ramosissimum*			*Pteris vittata*		
Part	Above-ground	underground	TF	Above-ground	underground	TF
Cr	1.82	4.63	0.39	1.40	6.10	0.23
Mn	427.16	1487.33	0.29	56.78	1233.80	0.05
Ni	9.81	12.26	0.80	4.06	20.35	0.20
Cu	52.70	110.24	0.48	9.00	92.18	0.10
Zn	819.41	2734.91	0.30	176.55	1460.52	0.12
Cd	6.88	18.12	0.38	0.88	11.76	0.07
Hg	0.17	0.11	1.55	0.11	0.29	0.38
Pb	300.37	697.97	0.43	36.23	783.08	0.05

3.6 Enrichment coefficient of above and underground parts for two ferns

Table 5. Heavy metal enrichment coefficients of above and under round parts for two ferns.

Species	*Equisetum ramosissimum*		*Pteris vittata*	
Part	Above-ground parts	Underground parts	Above-ground parts	Underground parts
Cr	0.09	0.25	0.07	0.30
Mn	0.03	0.13	0.004	0.10
Ni	0.51	0.73	0.21	1.07
Cu	0.19	0.35	0.03	0.34
Zn	0.15	0.33	0.03	0.27
Cd	0.17	0.26	0.02	0.30
Hg	0.04	0.03	0.03	0.07
Pb	0.02	0.05	0.0027	0.06

Except that the enrichment coefficient of Ni in *Pteris vittata* was above 1, the enrichment coefficients of all metals in both ferns were below 1. In *Equisetum ramosissimum*, the descending order of 8 heavy metals in the aboveground parts were Ni, Cu, Cd, Zn, Cr, Hg, Mn, Pb, and that in underground parts were Ni, Cu, Zn, Cd, Cr, Mn, Pb and Hg. In *Pteris vittata*, the order of enrichment coefficients in aboveground parts were Ni>Cr>Cu=Zn>Cr>Pb, and that in underground parts were Ni>Cu>Cr=Cd> Zn>Mn>Hg>Pb. The ECs of both ferns were low, and that in aboveground parts were below in the underground parts (Table 5).

4 Discussion

4.1 Evaluation of heavy metal content and pollution in soil

Soils in most regions of Guangdong Province is acid[10], but the soil in Bencun Pb-Zn Tailing was weak alkaline, which may be due to large volume $CaCO_3$ application during the mine construction and operation in recent years. The soil heavy metal pollution in this tailing is undoubtedly a composite pollution, the content of Pb, Zn, Cu, Cd and Hg in the soil was all above SSEQS and the soil background value in Guangdong Province, the Mn content was 45.07 times above the soil background value in Guangdong Province and also above Mn moderate standard. Liu et al. found the content of Pb, Zn, Cd and Cu in soils on a ladder slope in Bencun Pb-Zn Tailing[6], the results were shown that the content of 4 heavy metals were below that in soils close to edge of the sewage pool in this study, which suggested that the soil pollution of heavy metals close to pool, including Pb, Zn, Cd, Cu, was more serious than other areas in the tailing, because long term rain erosion caused accumulation of heavy metals in pools surrounding the tailing. Based on the analysis of soil heavy metal pollution index and pollution levels, it is not difficult to find that the main factors in the soil heavy metal pollution were Cd, Pb, Zn and Hg which had reached heavy pollution level, so the accumulation of these 4 heavy metals was key causes for the soil pollution. Soil RI of heavy metals is high, indicating the soil has high potential ecological risk of heavy metal pollution. In Bencun Pb-Zn Tailing, Cd, Hg and Pb were the main factors of the potential ecological risk, followed by Cu, Zn, so the soil in this tailing does not meet the requirements for growing crops. These results were consistent with studies made by Chu & Luo [15] that in Qixiashan Pb-Zn Tailing, the main pollution elements were Pb, As, Cd and Zn, as well as a mild Cu pollution in some soils. In Changhua Pb-Zn Tailing, the heavy metal pollution, including Cd, Cu, Pb and Zn, reached very high pollution levels [16]. As described by Li et al. [17], in Shuikoushan Pb-Zn Tailings, Cd pollution was the most serious, and there also was a serious pollution of Cd, Pb, Hg and mild compound pollution of Zn and As. Therefore, in Pb-Zn tailings, there usually exists a serious composite pollution of Cd, Pb, Zn and Cu, which also occurred in the present study. In addition, Hg pollution cannot be ignored in Bencun Pb-Zn Tailing.

4.2 The characteristics of heavy metal absorption and enrichment of two ferns

The definition of heavy metal hyperaccumulator widely used at present is the reference values of heavy metals in plants proposed by Baker and Brooks [18], the critical content of Zn is 10000 $mg.kg^{-1}$, Cd 100 $mg.kg^{-1}$, Hg 10 $mg.kg^{-1}$, Pb, Cu, Ni, Co 1000 $mg.kg^{-1}$, and both EC (enrichment coefficient) and TC (transport coefficient) of these plant should be above 1.

In the present study, Pb or Zn content of underground parts in *Equisetum ramosissimum* and *Pteris vittata* are very high and above the normal content range in plants (0.1~4.17 $mg.kg^{-1}$ for Pb, 1.0~160 $mg.kg^{-1}$ for Zn)[7], but the content of two ferns were far below the critical content standard of hyperaccumulators. When the heavy metal pollution in soil is heavy, the plant growth and crop yield may decrease. It was reported that when the Zn concentration reached 140~310 $mg.kg^{-1}$ in soil [3], it could inhibit the growth and development of barley, rye grass, clover, buckwheat and other plants, but *Equisetum ramosissimum* and *Pteris vittata* could grow in Bencun Pb-Zn Tailing, and the appearance and growth of these individuals distributing in the tailing were almost the same as those distributing in the non-polluted areas. But the heavy metal content and TC were below the critical standards of hyperaccumulator, for example, the Pb content of above ground parts in *Pteris vittata* was only 36.23 $mg.kg^{-1}$, the TC was only 0.05, so the two ferns were not typical hyperaccumulators.

Cd content in plants is usually below 3.00 $mg.kg^{-1}$, but that in those growing in Cd-enriched soil may be above 20.00 $mg.kg^{-1}$, even if growing in Cd-contaminated soils, it is rarely above 100.00 $mg.kg^{-1}$[5]. In this study, the Cd content of *Equisetum ramosissimum* and *Pteris vittata* was above 3.00 $mg.kg^{-1}$, suggesting the two ferns had relatively strong Cd tolerance, even though Cd content did not exceed the threshold for hyperaccumulator.

Mn content in plants is usually in the range of 1.0~700.0 $mg.kg^{-1}$[7], but that of *Equisetum ramosissimum* and *Pteris vittata* in this study was above the normal value range. The EC was too low and below 1. So the two ferns are likely to have strong adaptability to high Mn-enriched soil and can be used as a pioneer in ecological restoration of Pb-Zn tailings.

Cu content of *Equisetum ramosissimum* was above that of general plants whose Cu content is usually 0.4~45.8 $mg.kg^{-1}$[7] and mainly accumulated in underground parts. TC and EC were both below 1, but it has been reported in other researches that EC of *Equisetum ramosissimum* was above 1, indicating *Equisetum ramosissimum* has some Cu enrichment ability and can be regarded as a phytoremediation plant in Cu-polluted soils[19].

The normal Ni content for most plants is 0.05~5.00 $mg.kg^{-1}$. When Ni content in the dry matter of plants reaches 0.01~0.15 $mg.kg^{-1}$, leaves appear on urea toxic symptoms and had tip necrosis [20]. In this study, except in the above ground parts of *Pteris vittata*, Ni content of other parts in two ferns was above 5.00 $mg.kg^{-1}$, so the two ferns can be regarded as ideal Ni pollution tolerant plants.

Hg content of *Equisetum ramosissimum* and *Pteris vittata* was far above that reported in other plants (0.010~0.050 $mg.kg^{-1}$) [21], which confirmed the two ferns were subject to a certain level of Hg pollution, but they were still not typical Hg hyperaccumulators because Hg content of the two ferns was below the critical content value (10 $mg.kg^{-1}$) and EC was below 0.1. Han (2012) carried out a cultivation experiment of *Pteris vittata* in 10 $mg\cdot kg^{-1}$ Hg solution and found its TC and EC were 0.38~0.71 and 0.01~0.06 respectively [22], these results were similar to the results in this study. The Cr content in plants are usually 0~8.4 $mg\cdot kg^{-1}$ [7], that of these two ferns were also within the range.

In conclusion, the soil in Bencun Pb-Zn Tailing was severely polluted by heavy metals, especially Cd, Cu and Mn. The potential ecological risk of heavy metals was assessed to be very strong based on soil background values of Guangdong Province and at high risk according to criteria of the second grade SSEQS, and Cd, Hg, Pb were the main factors leading to potential ecological risk. The content of 8 heavy metals in *Equisetum ramosissimum* and *Pteris vittata* did not reach critical content of hyperaccumulator, so neither of them was typical hyperaccumulator, but both had a certain tolerance to the combined pollution of Pb, Zn, Mn, Cu, Cd, Hg and Ni. The underground parts of two ferns had a relatively strong enrichment, the EC of Ni in underground parts of *Equisetum ramosissimum* was near 1, and that in *Pteris vittata* was over 1, so the two ferns could be utilized as Ni potential enrichment plants. The transfer ability of 8 heavy metals by the two ferns was not strong, except for Hg by *Equisetum ramosissimum*, the TC of other metals by *Equisetum ramosissimum* and that of the 8 heavy metals by *Pteris vittata* were below 1. The heavy metal pollution in ground soil could increase after the ferns withered, but the heavy metals could be fixed in the soil and could not unlimitedly migrate and diffuse, water heavy metal pollution was then reduced. The two ferns can grow vigorously in the tailing indicating they had strong adaptability to the tailing habitat, so they can be used as pioneers in ecological restoration of Pb-Zn tailings.

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