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Screening of hyperaccumulator plants tolerant to drought and salinity and its medicinal value evaluation for ecological reconstruction of copper silver tailings in Northwest China

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ABSTRACT: The heavy metal pollution in soil caused by mining area development is a global problem. In order to screen the ecological restoration plants of copper silver tailings in arid and high saline alkali areas, and evaluate their economic value, nine kinds of plants naturally growing in the northwest copper silver tailings pond were selected, the enrichment and transfer characteristics of eight heavy metals by this plants was analyzed, and potential health risks for humans of plants were focused. The results showed that the heavy metals such as Cd, As, Cu, Hg and Ag are all from the open-air accumulation of tailings slag. Translocation factors of Cu, Ni and Cr by C. tragacanthoides are 2.1205, 53.1548 and 13.7622, bioconcentration factor of Cu, Ni and Cr by C. tragacanthoides are 1.8888, 7.1979, 7.4653, C. tragacanthoides is the hyperaccumulator for Cu, Ni and Cr. Hazard index in roots of S. collina, C. virgata and A. splendens to adults is more than 1, it has a potential non-cancer effects for more than half of adults, and for over 86.23% of children. Ag, Cr and As contribute the best to HI, and the cumulative contribution rate of the three elements can reach 85.59% to 96.39%. It is necessary to improve the treatment of tail slag to reduce environmental pollution, C. tragacanthoides can be considered as heavy metal remediation plants in arid and high saline copper tailing areas, but there is no medicinal value for these plants as ecological reconstruction in tailings area.

Keywords: Heavy metal, Hazard index, Tolerant plant, Health risks, Arid area.

INTRODUCTION

With the acceleration of industrialization and urbanization, the pollution of toxic heavy metals in soil has gradually become a worldwide problem (Wan et al., 2020). Smelting and mining and activities are the primary sources of toxic metal pollution in China (Wu et al., 2018). Moreover, outdated equipment, unawareness of environment protection and backward technology for Chinese enterprise aggravate the heavy metal contamination in ecological environment (Jin et al., 2017). The non-degradable nature of heavy metals and subsequently their bioaccumulation may be considered as a quotidian perilous risk

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(Eghbal et al., 2019). At present, the main methods to control heavy metal pollution include physical remediation, chemical remediation, biological remediation and joint remediation (Song et al., 2017). Phytoremediation is a green and relatively new technology, which is considered to be an economic, environmental protection and high public awareness technology. It has the advantages of low cost, convenient application, small environmental disturbance and large-scale use (Płociniczak et al., 2019; Salam et al., 2016; Tauqeer et al., 2016). In recent years, researchers found a variety of plants with good tolerance to heavy metals (Sultana et al., 2020), and have screened out a variety of heavy metal hyperaccumulators. For example, the plants of Glochidion cf. Sericeum have the ability to accumulate Ni, while the plants of Jingtian have the ability to accumulate Cd (Van et al., 2018; Wu et al., 2013), Pteris vittata can enrich As (Lampis et al., 2015). However, at present, the hyperconcentration plants are affected by the biological factors such as temperature, radiation, water, species structure, and falling products in the growing area, greatly affected the remediation efficiency. Because of the special ecological environment in the arid area of Northwest China, it is difficult to survive the heavy metal restoration plants in the past; it is the basis of Phytoremediation in this area to select the enrichment plants from the native plant species that are resistant to drought and high salinity.

In the past, the effect evaluation of phytoremediation of heavy metal contaminated soil was only limited to the effectiveness and timeliness of remediation, but did not consider the economic benefits. Most drought tolerant and salt tolerant plants in arid areas of Northwest China can be used as feed for livestock and even as Chinese herbal medicine, the collection of traditional Chinese medicine has not been regulated. The adsorption and accumulation of heavy metals in soil by medicinal plants will pose a potential threat to human health through the action of food chain (Gan et al., 2019; Wan et al., 2020; Singh et al., 2016; Afton et al., 2009; Gan et al., 2019; Wang et al., 2010), if heavy metals such as Cd, Ni, As, Ag, Hg enter the human body through the food chain to form excessive accumulation, it will cause non-carcinogenic health risks (Hu et al., 2017; Liang et al., 2017). At the same time of the selection of restoration plants, it is necessary to evaluate the human health risk assessment of the accumulation of heavy metals in the edible parts of medicinal plants, so as to judge the human health risk caused by restoration plants and evaluated the medicinal value of restoration plants. The purpose of this study includes: (1) to analyze the characteristics of heavy metals accumulation of drought and salt tolerant plants growing naturally on the copper silver tailings pond in Northwest China, and to screen the heavy metals remediation plants suitable for the saline alkali land in the arid areas; (2) to evaluate the health risks based on the characteristics of heavy metals accumulation in the edible parts of common plants in the northwest arid areas, determine the medicinal value of restoration plants. The purpose of this study is to provide technical reference for heavy metal remediation of tailings in this area in the future, and to provide scientific basis for the evaluation of medicinal value of restoration plants.

MATERIALS & METHODS

The study area is located in the YaoXianZi copper and silver mine in the south of Zhongwei City, Ningxia Hui Autonomous Region, Northwest China, less than 10km away from Zhongwei City, with geographic coordinates of N37°23′39.45″, E105°10′32.8″. The average annual precipitation in this area is 170mm, the rainfall is concentrated in July August, occasional rainstorm; the soil belongs to coarse bone light gray calcium soil, aeolian sand soil, the soil layer is loose and easy to peel off; the terrain belongs to the Helan Mountain vein, with strong wind erosion at the pass. The vegetation is mainly small shrubs and herbaceous vegetation, and common plants include Artemisia scoparia, Caragana roborovskyi, Stipa capillata, Salsola collina, Chloris virgata, Convolvulus tragacanthoides, Reaumuria soongorica, Salsola passerina, Achnatherum splendens. Artemisia scoparia has high nutritional value, can extract aromatic oil, and can be used as traditional Chinese medicine (Anik et al., 2020); Salsola collina, Chloris virgata, Reaumuria soongorica, Salsola passerina and Achnatherum splendens can be used as traditional Chinese medicine (Zhao et al., 2020); Caragana roborovskyi, Stipa capillata, Convolvulus tragacanthoides have low medicinal value.

After tailings accumulation, Artemisia scoparia, Caragana roborovskyi, Stipa capillata, Salsola collina, Chloris virgata, Convolvulus tragacanthoides, Reaumuria soongorica, Salsola passerina and Achnatherum splendens were selected from three soil slopes (Fig.1), all selected plants grow naturally in the tailings pond. The geographical coordinates of the three slopes are 37.39476389 N, 105.1751222 E, 37.39476389 N, 105.1757083 E and 37.39458667 N, 105.1762167 E. The three tailings accumulation slopes are all accumulated at the same time, so all plants grow on the tailings at the same time. Nine species of plants were sampled from three slopes, and one plant was taken from each slope. There were three replicates for each plant. The whole plant was sampled and taken back to the laboratory to decompose into the aboveground and underground parts of the plant, and the rhizosphere soil was sampled. The basic physical and chemical properties of slope soil were measured (Tab.1).

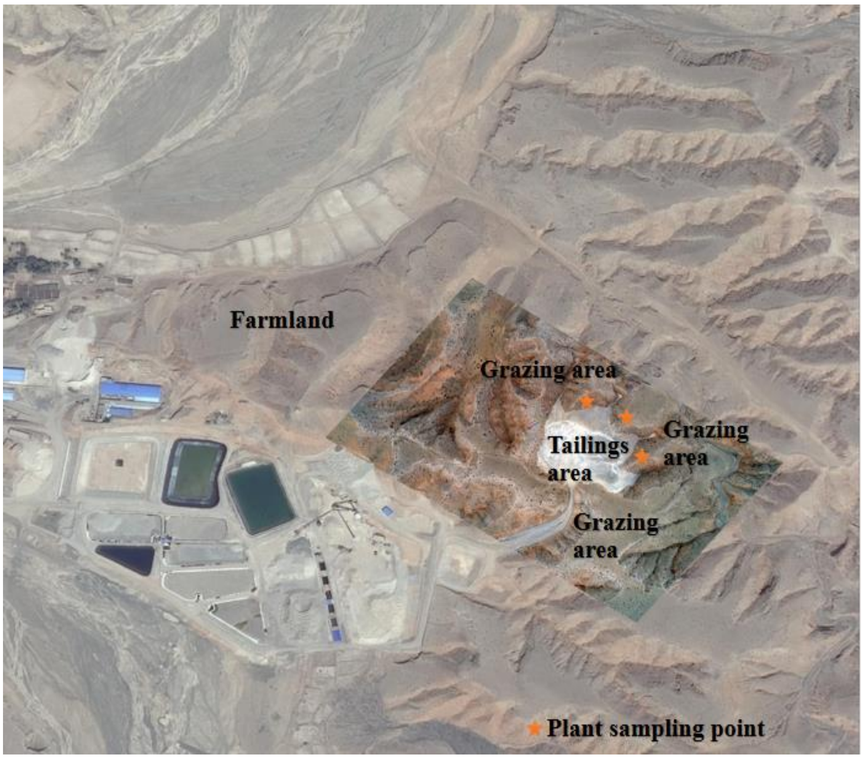

Fig. 1. Schematic diagram of study area (farmland, grazing area and tailings area) and sampling point

Table 1. The basic physical and chemical properties of slope soil

Total phosphorus (g/kg)	Available phosphorus (mg/kg)	Hydrolyzable nitrogen (mg/kg)	Available potassium (mg/kg)	pH
0.07±0.02	12.35±0.91	11.97±1.67	25.47±2.57	8.41±0.05

Wash the plant samples with tap water, remove the soil and dirt adhering to the plant samples, wash them with deionized water, and then dry them in a drying oven at 60 °C to constant weight and grind them for standby. After air drying and grinding, the soil samples were screened for 100 mesh, then digested by HNO3-HClO4 method, and digested by aqua regia perchloric acid method. Determination of Cd, As, Cu, Cr, Ni, Pb, Hg, Ag in digested soil and plant samples by ICP-MS.

The translocation factor (TF) and bioconcentration factor (BCF) are used to evaluate the capacity of tolerate and accumulate heavy metals by different plants (Rafati et al., 2011).

The translocation factor (TF) of the heavy metals in plant was calculated using Eq. (1):

$$TF = \frac{C_{\text{above}}}{C_{undergroud}} \quad (1)$$

where Cabove is concentration of heavy metals in plant aboveground part (mg/kg) while Cunderground refers to the concentration of heavy metals in plant root samples (mg/kg).

The bioconcentration factor (BCF) of the heavy metals in plant was calculated using Eq. (2):

$$BCF = \frac{C_{\text{underground}}}{C_{soil}} \quad (2)$$

where Csoil is concentration of heavy metals in rhizosphere soil (mg/kg).

Source analysis of heavy metals in rhizosphere soil by principal component analysis. Human health risk assessment (HHRA) consists of four steps: risk identification, exposure assessment, dose / response assessment and risk characterization (National Research, 1983). HHRA is considered to characterize the potential adverse health effects of people due to exposure to contaminated environmental matrices (USEPA, 1997). The formulas used to obtain human health risk are as follows:

$$EXP = \frac{CW * IR * EF * ED}{BW * AT} \quad (3)$$

where EXP is daily exposure while Cw refers to the concentration of heavy metals in plant samples (mg/kg). IR refers to the ingestion rate, there is no fixed standard for the dosage of traditional Chinese medicine corresponding to each disease, so it is assumed that the IR of all plants is 0.005 Kg/day. ED is Exposure Duration of traditional Chinese medicine, since ESPA has no this parameter, this study assumes that ED = 1 year. The description and values for other parameters are provided in Table 2.

The non-carcinogenic risk was estimated using the Eq. (4) (Papadakis et al., 2015).

$$THQ = \frac{EXP}{RfD} \quad (4)$$

where THQ is Hazard quotient while RfD is the reference dose for metals, which is based on, USA Risk-based concentration table (USEPA, 1992, 2011).It is defined as a numerical estimate of daily exposure to the human population, that is not likely to cause harmful effects during a lifetime. THQ estimates values above > 1 means that there is a potential for non-carcinogenic risk (Can et al., 2020), while THQ estimates < 1 shows that no potential for non-carcinogenic risk (Kavcar et al., 2009a; Al-Saleh and Abduljabbar, 2017).

Comprehensive evaluation of the health risk of various heavy metals to human body by Eq. (5).

$$HI = \sum THQ = THQ_1 + THQ_2 + \cdots + THQ_n \quad (5)$$

where HI refers to Hazard index.

Monte Carlo simulation was used to assess the risk of different plant intake in children and adults.

Table 2. Parameters (RfD of different heavy metals, Exposure Duration, Average Life Span, Body Weight and Exposure Frequency) used for the estimation of risk for heavy metals

Parameters	Unit	Distribution	Mean	RfD(mg·kg-1·d-1)	References
Cd		Fixed		0.001	USEPA(2011)
As		Fixed		0.0003	
Cu		Fixed		0.04	
Cr		Fixed		0.005	
Ni		Fixed		0.02	
Pb		Fixed		0.0035	
Hg		Fixed		0.0003	
Ag		Fixed		0.005	
Exposure Duration (ED)	Yr.	Log	1		USDoE(2011)
Average Life Span (AT) a	D	Log	8760		
Average Life Span (AT) c	D	Fixed	2190		
Body Weight (BW) a	Kg	Log	76.71		Binkowitz and Wartenberg (2001)
Body Weight (BW) c	Kg	Tri	6.5		
Exposure Frequency (EF)	d/yr.	Tri	180		USEPA(1992)

One-way analysis of variance(ANOVA) and Fisher's protected least significant difference (LSD) tests were used to evaluate significance using SPSS 22.0 software, at the p = 0.05 level of confidence. All data are the means ± SD.

Quality control and quality assurance are included in the analysis to verify the accuracy of the data (Kabir et al., 2017). In the whole determination process, the reagent blank, standard addition recovery and parallel sample determination are controlled to ensure the accuracy and reliability of sample determination. The order of determination is: blank (deionized water, sample probe and graphite tube for contamination), standard curve determination, reagent blank (test whether the reagent and container used are contaminated, make parallel samples), standard addition recovery rate, blank and actual sample analysis. Average percent recoveries ranged between 80% and 105% for all the heavy metals.

RESULTS AND DISCUSSION

The content of heavy metals in different parts and plants were showed in Fig.2. Compared with different plants and different parts, there was no significant difference in Cd and Hg contents. For this plants in different part, the As contents were in the order of soils > roots > aerial part, and for different plants, the As contents were all showed the following order: Achnatherum splendens > Stipa capillat > Salsola passerina > other plants. Compared with different plants and different parts, the Cu contents were in the order of soils>roots > aerial part, and Cu content in Stipa capillat is significantly higher than other plants. Cr and Ni contents in different plants were showed the following order: Stipa capillat > Chloris virgata > Artemisia scoparia > Salsola collina > other plants, and showed that roots > aerial part > soils. For different plants, the Pb contents were all showed the following order: Caragana roborovskyi > Achnatherum splendens > Stipa capillata > other plants, for different parts, the Pb contents were in the order of soils > roots > aerial part in Artemisia scoparia, Stipa capillata, Salsola collina, Salsola passerina and Achnatherum splendens, but it shows soils > aerial part > roots in Caragana roborovskyi, Chloris virgata, Convolvulus tragacanthoide and Reaumuria soongorica. Compared with different parts, the Ag contents were in the order of soils>roots > aerial part, only in Stipa capillata, shows that roots > soils, for different plants, the Ag contents were in order of Achnatherum splendens > Stipa capillata > Chloris virgata > other plants. Compared with other heavy metals, the concentration of Ni and Cr in plants in arid area is higher.

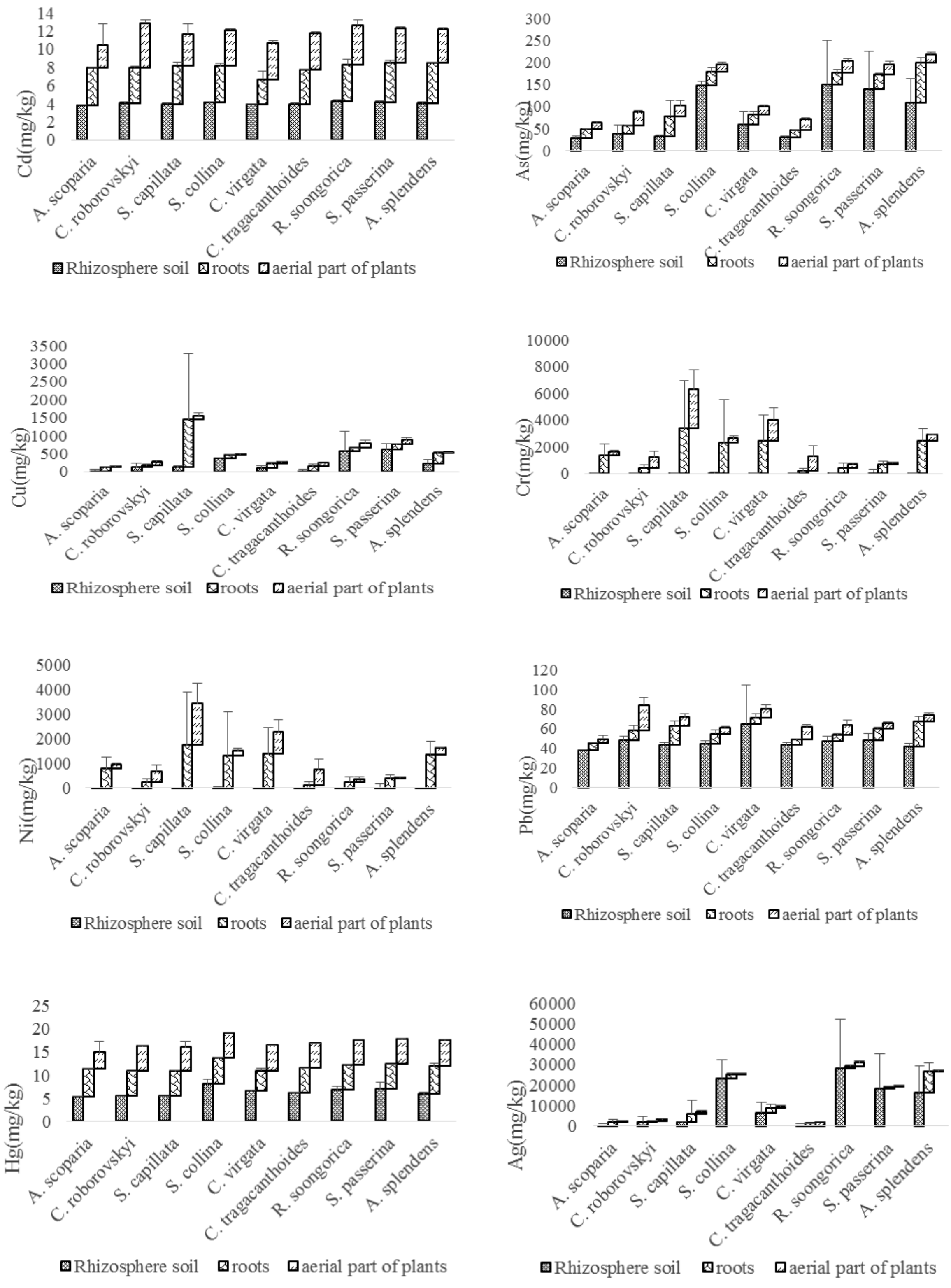

Fig. 2. Enrichment characteristics of heavy metals (Cd, As, Cu, Cr, Ni, Pb, Hg, Ag) in different parts (root, aerial part and rhizosphere soil) of all plants (Artemisia scoparia, Caragana roborovskyi, Stipa capillata, Salsola collina, Chloris virgata, Convolvulus tragacanthoides, Reaumuria soongorica, Salsola passerina, Achnatherum splendens)

Translocation factors (TF) refers to the amount of heavy metal in the aboveground part of plant to the amount of heavy metal in the underground part (root) of plant, which can be used to reflect the ability of heavy metals in plants to transfer from underground part (root) to aboveground parts (Jiang et al., 2019; Liu et al., 2015). The larger the TF, the stronger the tolerance of plants to the heavy metal (Stoltz et al., 2002). Bioconcentration factor (BCF) reflects the adsorption capacity of plants for heavy metals. Generally, the larger the BCF is, the stronger the adsorption capacity and the higher the heavy metal concentration of plants would be (Xineg et al., 2008; Sun et al., 2005; Wang et al., 2011). TF＞1 and BCF＞1 were considered as two critical standards for the selection of hyper-accumulators (Liu et al., 2011). The TF and BCF of heavy metals in plants-soils system were showed in Tab.3, which indicated that the C. tragacanthoides is the hyperaccumulator for Cu, Ni and Cr, C. roborovskyi, S. capillata, C. virgata and R. soongorica were the hyperaccumulators for Cr and Ni. Meanwhile, C. roborovskyi, C. virgata, C. tragacanthoides and R. soongorica had higher (＞1) TFs for Cd, As, Pb, Hg, and Ag, but had lower (＜1) BCFs, which indicated that the adsorption capacity of these plants to the above heavy metals is weak, but the migration capacity is strong. A. Scoparia and S. capillata had higher(＞1) BCFs for Cd, As, Cu, Hg and Ag, but had lower (＜1) BCFs, which indicated that the ability of these plants to transport heavy metals is weak, but the ability of their roots to absorb these heavy metals is strong.

Table 3. Bioconcentration and translocation factors of heavy metals between the different plants (Artemisia scoparia, Salsola collina, Chloris virgata, Reaumuria soongorica, Salsola passerina, Achnatherum splendens)

		Cd	As	Cu	Cr	Ni	Pb	Hg	Ag
TFs	A. scoparia	0.6116±0.5574	0.7695±0.1274	0.4031±0.2219	0.3171±0.1631	0.302±0.1556	0.5535±0.3936	0.6269±0.3422	0.2756±0.2064
	C. roborovskyi	1.2453±0.0605	1.6003±0.132	1.9638±0.9742	2.5276±1.4573	7.7305±9.3828	2.8624±0.7229	1.0299±0.0106	3.3783±0.7719
	S. capillata	0.8300±0.1813	0.6801±0.2843	0.2974±0.236	1.389±1.4937	16.5241±27.6868	0.4868±0.1135	0.9451±0.1307	0.5195±0.4425
	S. collina	0.9859±0.0275	0.6266±0.2578	0.3933±0.105	0.3512±0.2257	0.3646±0.2298	0.6559±0.2338	0.9482±0.0223	0.2883±0.2391
	C. virgata	1.5835±0.4627	1.1395±0.3337	0.7719±0.2452	3.8031±5.6583	3.7792±5.6154	1.8699±0.6307	1.2654±0.143	0.6525±0.3788
	C. tragacanthoides	1.0817±0.0023	1.6871±0.2067	2.1205±2.0174	13.7622±17.4096	53.1548±73.088	2.3358±0.5705	1.0107±0.0192	5.1645±2.0725
	R. soongorica	1.0046±0.1973	1.5274±0.9911	2.7346±2.4464	10.9019±11.9863	12.4598±14.2695	2.4309±0.2061	0.9649±0.0852	3.1269±3.3558
	S. passerina	0.9395±0.0177	0.7658±0.2384	0.9384±0.0887	0.0893±0.0224	0.0343±0.0193	0.6296±0.0559	0.9863±0.0319	0.8502±0.661
	A. splendens	0.8726±0.0389	0.2553±0.0689	0.2500±0.1212	0.612±0.5258	0.6198±0.5218	0.3109±0.0589	0.9422±0.121	0.1073±0.0583
BCFs	A. scoparia	1.0671±0.0053	0.7099±0.0936	1.7215±0.5151	30.455±24.0344	32.5467±23.7624	0.185±0.0193	1.1039±0.0639	1.348±1.0993
	C. roborovskyi	0.9621±0.0667	0.5218±0.1904	0.7707±0.2863	7.9926±5.594	8.1551±7.2435	0.2067±0.1028	0.9965±0.0166	0.2636±0.199
	S. capillata	1.05±0.0732	1.2958±0.9359	14.1868±19.8883	62.1589±73.7483	59.573±79.108	0.4336±0.1142	1.0046±0.0415	2.4467±3.4405
	S. collina	0.9745±0.0757	0.2051±0.0464	0.2877±0.0316	87.7402±136.1606	95.0939±148.0505	0.2228±0.0911	0.7333±0.1143	0.0783±0.0137
	C. virgata	0.6844±0.2119	0.4323±0.2282	1.0902±0.3375	104.4719±84.0235	117.355±95.8235	0.0935±0.0051	0.6957±0.0761	0.5083±0.285
	C. tragacanthoides	0.9496±0.028	0.4978±0.0389	1.8888±2.0149	7.4653±7.19	7.1979±9.2241	0.1263±0.0052	0.8701±0.0179	0.1657±0.055
	R. soongorica	0.9760±0.0771	0.4457±0.4973	0.6241±0.519	16.6064±16.3027	17.6389±18.4983	0.1255±0.0103	0.8141±0.1104	0.4756±0.6258
	S. passerina	1.0376±0.0644	0.3714±0.0501	0.2447±0.0794	17.9286±8.6347	20.563±8.9621	0.2602±0.0545	0.91±0.0041	0.112±0.0194
	A. splendens	1.1097±0.0409	0.9449±0.3418	1.3036±0.4271	50.7436±28.7897	55.7319±35.385	0.6269±0.1593	1.0654±0.0419	0.7369±0.2682

In addition, it can be found that TF and BCF of Pb and Ag adsorbed by S. collina, S. passerina and A. splendens are all less than 1. It can be seen that although these plants have certain tolerance to heavy metals, they will not absorb and accumulate heavy metal ions in large quantities. Therefore, they belong to low accumulation plants. Using low accumulation plants for ecological reconstruction in areas with heavy metal exceeding the standard can reduce the probability of heavy metals entering the food chain, but can not effectively adsorb them Heavy metals in soil.

Principal component analysis of normalized data was used to explain the correlation of heavy metal concentration in plants. This multivariate test has been used in several studies to determine the sources of metals in ecosystems (Faisal et al., 2014; Li et al., 2009; Varol, 2011). Two components with eigenvalue > 1 are extracted and 73.875% of the total variance of the data is obtained. The first principal component (pc1), representing 56.221% of the total variables was dominated by negative loadings for Cd, As, Cu, Hg and Ag , suggesting a close association of these metals indicating a common and strong anthropogenic source (Fig.3), this is consistent with previous studies (Tayebi and Sobhanardakani, 2020), which also believes that some harmful heavy metals come from industrial and mining activities.

The second principal component (PC2), represented by 17.654% of the total variance was characterised by loadings for Cr and Ni, which indicate that the concentrations of these metals observed from multiple sources (Fig.3).

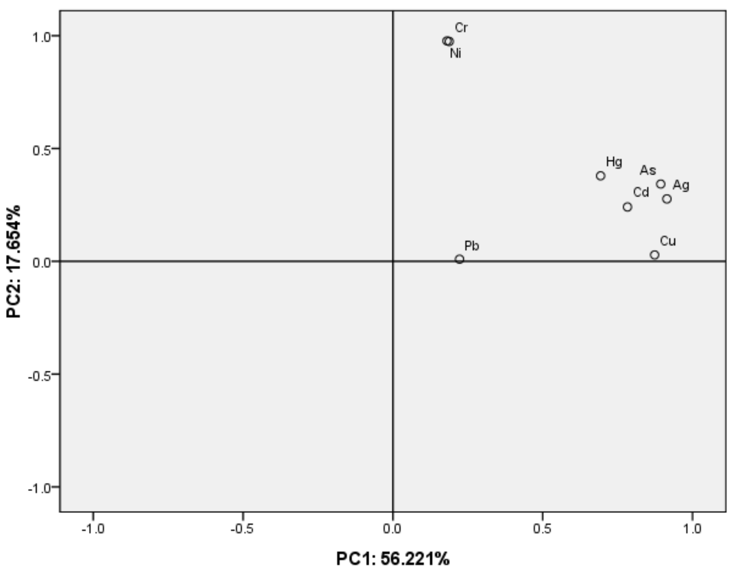

Fig. 3. Principal Components Analysis of heavy metals in soil

Note: PC1=0.783Cd+0.894As+0.8774Cu+0.188 Cr+0.181Ni+0.222Pb+0.693Hg+0.915Ag

PC2=0.241Cd+0.343As+0.029Cu+0.97 4Cr+0.977Ni+0.009Pb+0.379Hg+0.277Ag

Selected medicinal plants, including Artemisia scoparia, Salsola collina, Chloris virgata, Reaumuria soongorica, Salsola passerina and Achnatherum splendens, to evaluate the human health risks caused by heavy metal adsorption and analyze its medicinal value. Hazard index (HI) and contribution rate of heavy metals in different parts of plants to adults and children were showed in Table 4. HI in roots of S. collina, C. virgata and A. splendens to adults is more than 1, which means that eating the roots of these three plants has a potential non-cancer effects for more than half of adults (Figure 4). At the same time, eating the roots and stems of all plants will cause non carcinogenic health risks for over 86.23% of children (Figure 5). In addition, it can also be found that the non-carcinogenic health risks in children is significantly higher than that in adults with the risk values of these eight heavy metals all one order of magnitude higher than those of adults, this is consistent with previous studies (Shao et al., 2018). Ag, Cr and As contribute the best to HI, and the cumulative contribution rate of the three elements can reach 85.59% to 96.39%.

Table 4. Hazard index (HI) and contribution rate of heavy metals in different parts (root and aerial part) of six plants (Artemisia scoparia, Salsola collina, Chloris virgata, Reaumuria soongorica, Salsola passerina, Achnatherum splendens) to adults and children

			HI	Contribution rate of each element (%)							
				Cd	As	Cu	Cr	Ni	Pb	Hg	Ag
Adult	A. scoparia	Root	0.85	0.65	10.59	0.29	41.46	5.95	0.32	3.1	37.64
		Aerial part	0.26	1.29	26.25	0.4	26.71	3.77	0.61	6.46	34.5
	S. collina	Root	1.37	0.4	10.04	0.25	44.44	6.22	0.28	1.89	36.48
		Aerial part	0.32	1.67	25.07	0.43	26.43	3.96	0.73	7.64	34.09
	C. virgata	Root	1.58	0.23	6.35	0.23	41.2	5.78	0.15	1.27	44.79
		Aerial part	0.77	0.7	10.83	0.24	54.21	7.65	0.46	3.2	22.71
	R. soongorica	Root	0.63	0.87	18.17	0.53	17	2.32	0.36	3.94	56.82
		Aerial part	0.63	0.92	19.21	0.7	9.28	1.3	0.63	3.83	64.12
	S. passerina	Root	0.61	0.95	24.9	0.81	24.4	3.39	0.74	4.04	40.77
		Aerial part	0.32	1.62	30.89	1.27	7.75	0.79	0.67	7.51	49.51
	A. splendens	Root	3.88	0.15	10.54	0.23	16.36	2.25	0.26	0.71	69.49
		Aerial part	0.37	1.36	22.07	0.31	34.42	4.91	0.68	6.8	29.46
Children	A. scoparia	Root	40.1	0.65	10.59	0.29	41.46	5.95	0.32	3.1	37.64
		Aerial part	12.44	1.29	26.25	0.4	26.71	3.77	0.61	6.46	34.5
	S. collina	Root	64.49	0.4	10.04	0.25	44.44	6.22	0.28	1.89	36.48
		Aerial part	15.08	1.67	25.07	0.43	26.43	3.96	0.73	7.64	34.09
	C. virgata	Root	74.8	0.23	6.35	0.23	41.2	5.78	0.15	1.27	44.79
		Aerial part	36.31	0.7	10.83	0.24	54.21	7.65	0.46	3.2	22.71
	R. soongorica	Root	29.77	0.87	18.17	0.53	17	2.32	0.36	3.94	56.82
		Aerial part	29.71	0.92	19.21	0.7	9.28	1.3	0.63	3.83	64.12
	S. passerina	Root	28.65	0.95	24.9	0.81	24.4	3.39	0.74	4.04	40.77
		Aerial part	15.12	1.62	30.89	1.27	7.75	0.79	0.67	7.51	49.51
	A. splendens	Root	183.01	0.15	10.54	0.23	16.36	2.25	0.26	0.71	69.49
		Aerial part	17.49	1.36	22.07	0.31	34.42	4.91	0.68	6.8	29.46

It can be seen that although C. virgata and R. soongorica can be used for ecological reconstruction of copper silver tailings in Northwest China, but its high heavy metal adsorption limits its medicinal value.

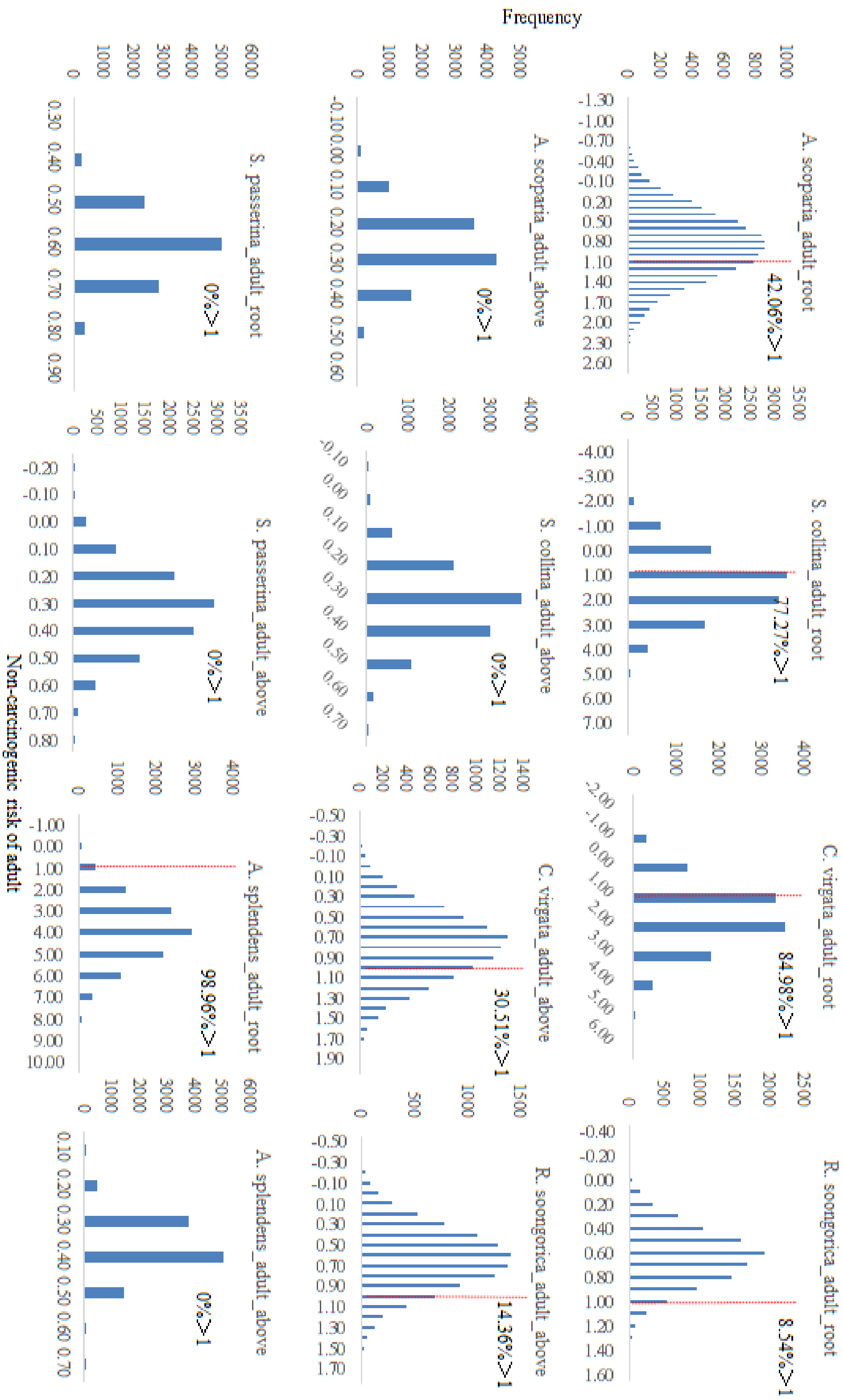

Fig. 4. Non-carcinogenic risk of different parts (root and aerial part) of six plants (*Artemisia scoparia*, *Salsola collina*, *Chloris virgata*, *Reaumuria soongorica*, *Salsola passerina*, *Achnatherum splendens*) to adults

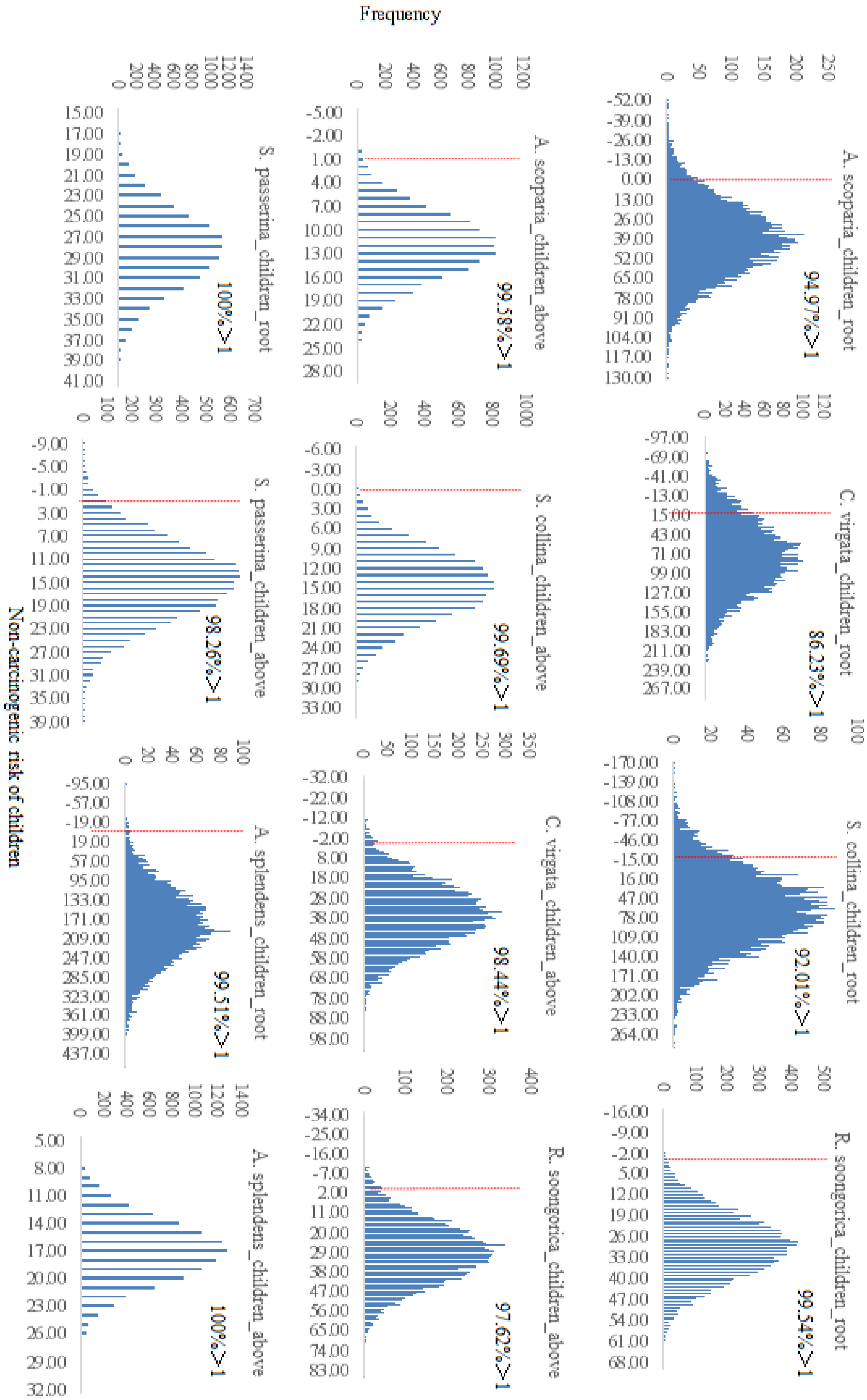

Fig. 5. Non-carcinogenic risk of different parts (root and aerial part) of six plants (*Artemisia scoparia*, *Salsola collina*, *Chloris virgata*, *Reaumuria soongorica*, *Salsola passerina*, *Achnatherum splendens*) to children

CONCLUSIONS

In summary, the results of this study indicates heavy metals in soil such as Cd, As, Cu, Hg and Ag are all from the open-air accumulation of tailings slag. A variety of plants can survive in the copper silver tailings pond with drought and high salinity, and have certain adsorption capacity for different heavy metals. Among them, C. tragacanthoides is the hyperaccumulator for Cu, Ni and Cr, C. roborovskyi, S. capillata, C. virgata and R. soongorica were the hyperaccumulators for Cr and Ni. C. tragacanthoides, C. roborovskyi, S. capillata, C. virgata and R. soongorica can be considered as heavy metal remediation plants in arid and high saline areas to improve the treatment of tail slag to reduce environmental pollution, but these restoration plants do not have medicinal value and can not bring economic benefits, because their high adsorption of heavy metals will bring health risks to the human body, especially for children.

GRANT SUPPORT DETAILS

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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